Logging, Damage and Efficiency: A Study on the Feasibility of Reduced Impact Logging in Cameroon

Final report

W.B.J. Jonkers
(Editor)

Tropenbos-Cameroon Programme

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The Tropenbos-Cameroon Programme, Kribi (Cameroon)
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ABSTRACT

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A study was made of current logging operations in Cameroon to identify improvements, aimed at reducing logging damage and improving efficiency. It is shown that modifications in the planning and execution of felling and skidding lead to damage reduction, but that there is hardly any chance in the costs of the operations.

Key words: Reduced Impact Logging, tropical rain forest, Cameroon

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Preface

About Tropenbos
The Tropenbos Foundation was established in 1988 by the Government of the Netherlands with the objectives to contribute to the conservation and wise use of tropical rain forest by generating knowledge and developing methodologies, and to involve and strengthen local research institutions and capacity in relation to tropical rain forests.

The Tropenbos Programme carries out research on moist tropical forestland at various locations around the world. At present (semi-)permanent research sites are located in Colombia, Guyana, Indonesia, Côte d'Ivoire and Cameroon. At the different locations, research programmes follow an interdisciplinary and common overall approach, which allows to exchange data and to make results mutually comparable.

About the Tropenbos-Cameroon Programme and ITTO project PD 26/92
The present publication has been produced in the framework of ITTO project PD 26/92(F,I), entitled "Development of Methods and Strategies for Sustained Management of Moist tropical Forest in Cameroon", which is an integral part of the Tropenbos-Cameroon Programme (TCP). The research on which this publication is based, was financed by the International Tropical Timber Organisation (ITTO), the Common Fund for Commodities (CfC), the Tropenbos Foundation and the implementing agencies mentioned below.

The Tropenbos-Cameroon Programme was established in 1992 by the Cameroonian Ministry of Environment and Forests (MINEF) and the Tropenbos Foundation. The general objective of the TCP is to develop methods and strategies for natural forest management directed at sustainable production of timber and other forest products and services. These methods have to be ecologically sound, socially acceptable and economically viable. TCP consists of several interrelated projects in the fields of ecology, forestry, economy, social sciences, agronomy and soil science[1]. In 1994, ITTO and CfC decided to co-finance six of these projects, which together form ITTO project PD 26/92. The 'Office National de Développement des Forêts' (ONADEF) is the agency responsible towards ITTO and CfC for the implementation of the Project PD 26/92.

The present document describes the main findings of the logging study of Project PD 26/92, entitled 'Logging, damage and efficiency (F1)'. Part of the information included was published earlier in conference proceedings and in journals.

The implementing agencies involved in the study are Wageningen University (formerly Wageningen Agricultural University) and the 'Institut de la Recherche Agricole pour le Développement' (IRAD). The study was done in a logging concession of Wijma-Douala SARL (GWZ), and GWZ made logging personnel and equipment available for the experiments. The researchers involved are G.J.R. van Leersum, F. Ngibaot and E. Laan. Funding for Mr. Laan's participation was made available by the Royal Netherlands Agricultural Society (KLV).

Acknowledgements
The funding agencies ITTO, CfC, Tropenbos and KLV are thanked for making funds available for this research project and GWZ is thanked for making its personnel and equipment available. Thanks are also due to the personnel of Tropenbos-Cameroon and the many students who participated in the study.

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[1] For further details, see Foahom, B. and Jonkers, W.B.J. (eds.), 1992. A programme for Tropenbos research in Cameroon. Final report Tropenbos-Cameroon Programme (Phase 1). The Tropenbos Foundation, Wageningen, the Netherlands.

W.B.J. Jonkers
Scientific coordinator TCP

Introduction

W.B.J. Jonkers (editor)

This document describes the principal results of a logging study, executed between 1994 and 1998 as part of the Tropenbos-Cameroon Programme (TCP). The general objective of the TCP forestry research, as formulated in 1992, is to develop methods for sustained timber production in the rain forests of Cameroon (Foahom and Jonkers, 1992). The envisaged management system was, and still is, a polycyclic management one, that is, a system whereby the forest contains trees of all ages and sizes, and whereby part of the timber stand is harvested at intervals of 20 - 40 years. One of the presuppositions of such a management system regime is that sufficient commercial trees remain after exploitation to provide a next harvest within a few decades, that is, that logging damage remains within acceptable limits. The evidence available in 1992 suggested that logging damage generally is moderate in African rain forests. It was considered, however, that any degree of logging damage represents a loss of capital in the form of trees, which might otherwise be harvested in the future, and deterioration of the biotic and physical environment. Thus it was concluded that measures to minimize such damage should be seriously considered. Such measures have to be technically feasible and economically acceptable. The chance that logging companies will implement damage-reducing measures is enhanced, if such measures also lead to improvements in efficiency and econmic benefits. It was considered that there might be room for such improvements, as timber-harvesting methods had changed little in the last decades, and systematic efficiency studies in Africa were rare or non-existent.

Similar studies in Suriname (Hendrison, 1989), Australia (Ward and Kanowski, 1985) and Malaysia (Mattson Marn and Jonkers, 1981) had succeeded in achieving the dual purpose of reduced damage and improved efficiency. Conditions in these countries differ considerably from those in Cameroon, however. For example, trees harvested are generally larger in Cameroon, but the number of trees felled per hectare is considerably smaller. It was therefore considered that the Malaysian, Australian and Suriname methods could be used as a starting point, but that a method for Cameroon has to be adapted to local conditions. In recent publications, such methods are referred to as Reduced Impact Logging.

Objective of the study

Foahom and Jonkers (1992) formulated the following principal objective for the TCP logging study: "to develop a logging system for the evergreen rain forests of Cameroon, which is efficient and ecologically sound. This system will be part of an overall polycyclic management system for these forests".
More specifically, the study focused on reductions in logging damage and improvements in efficiency, which can be obtained through improvements in planning and logging methods, while using the same equipment and personnel as in existing logging operations. Examples of potential improvements are:

- pre-harvest inventory and detailed mapping of all timber trees and terrain characteristics;
- planning and constructing logging roads, landings and main skid trails prior to felling;
- applying directional felling to facilitate skidding, and/or to avoid large felling gaps;
- winching of logs from stump to the trail to reduce the area damaged by skidding;
- liana cutting to reduce felling damage.

Long-distance transport from landing to sawmill or harbour is not a forest operation and was therefore not investigated.

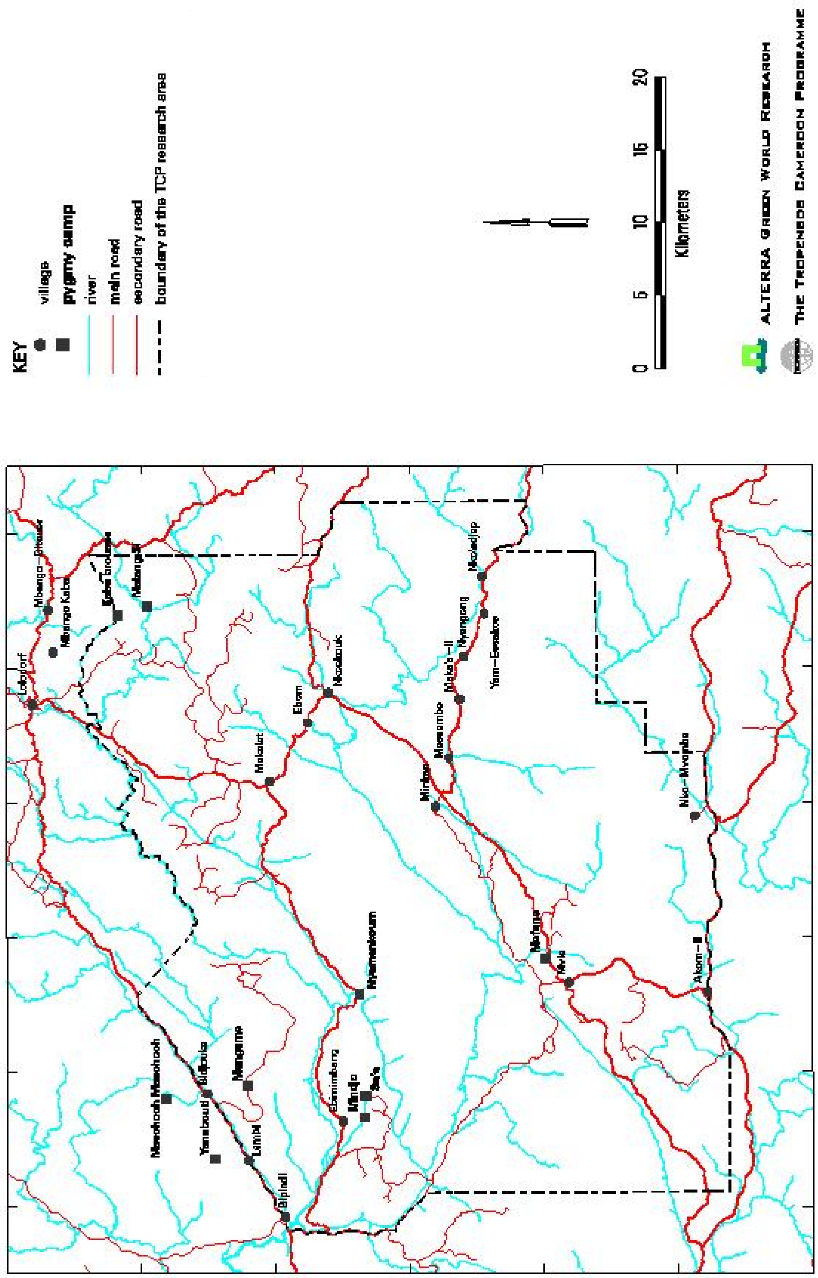
Methodology

The logging research was divided into three phases. The study started with a detailed investigation of the existing logging methods, which are referred to as conventional methods in this document. The purpose is to identify opportunities for improvement of conventional methods. In the second phase, experiments were executed to see if individual improvements identified in the first phase are practically feasible and contribute to efficiency and damage control. The third and final phase consisted of an integral test on a practical scale of the modifications in harvesting operations, proposed after phase two. During this phase, efficiency and damage reduction under the revised harvesting system and under conventional logging were compared.

The study site

The TCP research area is situated in south-west Cameroon at approximately 80 km East of Kribi, between 2°47'-3°14' N and 10°24'-10°51' E. The area is delimited by the villages of Bipindi, Akom II and Lolodorf (Fig. 1). Administratively, the TCP research area is part of the South Province of the Republic of Cameroon and is divided over the Departments Océan and Ntem. The TCP area covers about 1700 km^2 and coincides to a large extent with former concessions of the Dutch logging company of Wijma-Douala S.A.R.L. (GWZ).
The landscape varies considerably. The altitudes range from just 40 m above sea level in the northwestern part to more than 1000 m in the southeast. The low-lying parts in the west are fairly flat and easily accessible, but elsewhere the terrain is predominantly hilly or mountainous, with slopes of more than 10% (see van Gemerden and Hazeu, 1999). The climate of the humid equatorial type, with average temperatures of about 25 °C and a mean annual precipitation of 2000 – 2500 mm/year. The original vegetation consists of dense humid evergreen forests. Many forests have been affected by shifting cultivation and logging activities.
The population consists of approximately 15,000 people, meaning that the population density is about 9 people/ha (Lescuyer and Essiane Mendoula, 1999). Five ethnic groups are represented in the area, four Bantu groups and the Bagyeli or Bakola pygmies, who form a small minority.
Agriculture is the main means of subsistence of the Bantu population. The traditional shifting cultivation system involves the clearing and burning of primary and old secondary forest just before the rainy season and the planting of cucumber, maize, cassava, coco-yam and plantain. With decreasing soil fertility, the tending and harvesting of a field gradually stops and the land is left fallow. The agricultural fields are then colonized by forest vegetation. The total surface of this rotational fallow system is less than ten hectares per farmer (Nounamo and Yemefack, 1999).
Non-timber forest products (NTFPs) are a major source of food, construction materials, agricultural and household utensils, medicines and cash for the local population. The gathering of NTFPs is for the Bantu population supplementary to agriculture. For Bagyeli it is the mainstay. In addition to subsistence agriculture, cacao is cultivated for cash revenues by mainly Bantu farmers and small cacao plantations are found throughout the area. Recently, more large-scale oil palm, pineapple and banana plantations have been created in the TCP area.

Fig. 1. Map of the Tropenbos-Cameroon research site



Until recently, timber exploitation was a main economic activity in the area. Most of the forest within the TCP research area has been selectively logged at least twice by national and international companies, among them the Dutch GWZ. GWZ left the area in 1998, shortly after the fieldwork for the present study had been completed. The average logging intensity was 0.7 trees per hectare, which is low compared with regions like Malaysia, where on average 15 trees per hectare are removed.

Implementation of the study

The research activities were executed as part of a commercial logging operation, with personnel and equipment of the concessionaire, Wijma-Douala SARL. The advantage of this approach is that the findings were obtained in a "real life situation". However, major disadvantages were that the researchers were not free in choosing the time and place for their fieldwork and had limited control over the implementation. Research activities often had to be rescheduled or even cancelled, or could not be executed in full due to reasons beyond the control of the researchers. There were several cases where the management of the logging company terminated its activities at a research location before the research was completed, or where logging at such a location was postponed for many months. Such management decisions were usually taken for good reasons, but were detrimental for the quality of the study.

About this document

This document includes all articles published so far on the TCP logging study and a report on the final test, in which conventional GWZ logging and the method designed by the project were compared. The articles reflect the state of knowledge at the time of writing and some of the reservations made regarding the feasibility of Reduced Impact Logging were not confirmed by the more recent findings discussed in the last part of this document, which provides the final results obtained.

References

Foahom, B. and Jonkers, W.B.J. (eds.), 1992. *A programme for Tropenbos research in Cameroon*. Final report Tropenbos-Cameroon Programme (Phase 1). The Tropenbos Foundation, Wageningen, the Netherlands.

van Gemerden, B.S. and Hazeu, G.W. (1999). *Landscape ecological survey (1:100,000) of the Bipindi – Akom II – Lolodorf region, southwest Cameroon*. Tropenbos-Cameroon Documents 1. The Tropenbos-Cameroon Programme, Kribi, Cameroon.

Hendrison, J. (1990). *Damage-controlled logging in managed tropical rain forest in Suriname*. Ecology and Management of Tropical Rain Forest in Suriname 4. Agricultural University, Wageningen, the Netherlands.

Lescuyer, G. and Essiane Mendoula, E. (1999). *La variable humaine dans la gestion de la forêt tropicale : Intérêt et résultat des enquêtes socio-économiques pour l'aménagement de la zone de recherche Tropenbos*. Paper presented at the Tropenbos-Cameroon international workshop on Sustainable Forest Management of African Rain Forests: Planning and analysis for forest management with special emphasis on lesser-known species. November 8-13, 1999, Kribi, Cameroon.

Mattson Marn, H. and Jonkers, W.B.J. (1981). Logging damage in tropical high forest. In: P.B.L. Srivastava *et al*. (eds.). *Tropical forests: source of energy through optimisation and diversification*. Penerbit Universiti Pertanian Malaysia, Serdang, Malaysia.

Nounamo, L. and Yemefack, M. (1999). *Shifting cultivation practices and sustainable forest land use in the evergreen forest of Cameroon*. Paper presented at Tropenbos-Cameroon International Symposium on Sustainable Forest Management of African Rain Forests: Results of the Tropenbos-Cameroon Programme and their Applicability. November 15-16, 1999, Kribi, Cameroon.

Ward, J.P. and Kanowski, P.J. (1985). Implementing control of harvesting operations in north Queensland rainforests. In: K. Shepherd and H.V. Richter (eds.). *Managing the tropical forest*. Australian National University, Canberra, Australia.

REDUCED IMPACT LOGGING: A GLOBAL PANACEA? COMPARISON OF TWO LOGGING STUDIES[2]

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The Tropenbos-Guyana and Tropenbos-Cameroon programme

INTRODUCTION

In recent years, several major events have drawn the attention of the public to the importance of forestry and the global environment. Perhaps the most important of these was the United Nations Conference on Environment and Development, which was held in Rio de Janeiro in June 1992. One of the main outcomes of this Conference was the explicit recognition by policy-makers that forests are essential for sustainable economic development and also for the cultural and physical well-being of current and future generations. To ensure that forests are sustained for future generations and to improve the economic and social contributions of forestry, environmentally sound harvesting techniques that will improve standards of utilisation and reduce environmental impacts should be developed and promoted. Given the current state of knowledge, however, it is not clear whether specific practices will actually achieve the desired outcome: i.e. that the standards of sustainable forest management be met.

Publications on reduced-impact logging or the improvement of codes of practice for sustainable management are on the increase. After Mattson Mårn and Jonkers (1981) in Sabah, Ward and Kanowksi (1985) in Australia, and Hendrison (1990) in Suriname, a whole new generation of researchers have taken up the topic, and all describe its advantages: Crome *et al.* (1992) in Australia; Blate (1997) and Johns *et al.* (1996) in Brazil; Webb (1997) in Costa Rica; van der Hout (1996) in Guyana; Bertault and Sist (1995) in Kalimantan; Pinard and Putz (1996) and Cedergren *et al.* (1994) in Sabah. Some describe the methods and the results obtained more precisely than others do (i.e. quantitatively), but the general message is: reduced-impact logging is less destructive than conventional practices and increases utilisation standards. These conclusions suggest that there should be no hesitation among logging companies to start employing this practice or for governments to enforce its implementation. On the contrary, the adoption of the techniques remains an elusive goal. In the Brazilian Amazon, for example, only a few forestry operations have implemented low-impact-logging techniques, despite the legal requirements to do so (Uhl *et al.*, 1996). The question arises: what withholds the implementation of these techniques (see also ter Steege, this seminar).

Two projects concerning the impact of selective logging have more or less been completed at the same time in two different Tropenbos programmes: one in Guyana, the other in Cameroon. While writing their reports, the authors discussed their respective results, explained what they had learned from complementary experiences, and sought support for their impressions and conclusions. For the purpose of this seminar, they have placed their tentative results in the framework of reduced-impact logging for sustainable management. The difference in set-up, and in the scientific and natural environment between the two projects became clear. In this paper, we will focus on the impact of selective logging on the vegetation and how this was attenuated by introducing reduced-impact-logging systems. The impact of these systems on the cost/benefit aspects will not be considered here.

DEFINITIONS

What are ‘conventional practice’ and ‘reduced-impact logging’? Some expressions may need further clarification before we continue. Both logging practices refer to selective logging of commercially viable

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[2] Published earlier in Tropenbos (1998). Research in tropical rain forests: its challenges for the future. Seminar proceedings. The Tropenbos Foundation, Wageningen, the Netherlands.

stems, meaning a limited number of individuals (of a minimum size and stem quality) out of a restricted number of tree species.

Reduced-impact logging (RIL), in our view, comprises new techniques and new concepts of organising and planning timber harvesting, with the primordial objective of damage reduction, and with a proximate goal of improving the efficiency of the operation. 'New' in this context means new to the environment and to the society in which these concepts are to be introduced. They are consequently experimental, and hence a topic of research and validation. The adjective 'reduced' hints at a comparison with another logging method, obviously the current, conventional practice. So RIL is about new, not yet commercially validated logging techniques that lead to less damage than the conventional methods of logging.

Now, *conventional practice* covers a broad range of methods, varying from '*savage*' forest exploitation (timber mining with hardly any degree of planning at all) to '*close-to-best practice*[3]'. Which extreme to chose? Comparing the RIL concept with savage-logging practices does not really put new technological and conceptual developments in their right perspective. The commonly presented RIL package includes many concepts and techniques already present in the close-to-best practices. This means that many of these concepts and techniques have already been validated on a practical scale and have been incorporated in a company's production strategy.

We consider this clarification and demystification of RIL important when looking at the aspects of disseminating research results. Taking enterprises practising savage logging to the level of close-to-best practice can best be done by demonstrating or imposing techniques that have already been commercially validated by the forestry sector itself. Taking the *avant-garde* enterprises a step further to RIL level can best be done through a comparison between their current standard of practice and the experimental one. To really demonstrate the added value of new concepts and techniques, a comparison of the RIL concept with close-to-best practices would therefore seem a far more useful exercise.

BACKGROUND OF THE TWO PROJECTS

The two Tropenbos programmes differ considerably in set-up. The Guyana programme hooked on to an existing programme of the University of Utrecht. It formally commenced in 1989 and initially involved the Departments of Plant Ecology and Evolutionary Biology, and Physical Geography, the former being represented by the sections Vegetation Ecology, Ecophysiology, and Herbarium. Its focus has been on trees and their environment, with special attention to individual tree species, population dynamics, environmental stress, plant-animal interactions, and biodiversity offset by human-induced disturbances, specially artificial canopy gaps. In its current second phase, this scope has been broadened, notably with ethnobotany and non-timber forest products. The forestry component was inserted in 1992, with a study to assess the impact of logging intensity on logging damage and subsequent growth and yield rates. Reduced-impact logging, following the system developed by Hendrison (1990) in the neighbouring country of Suriname, was treated as an extrinsic variable in the research (i.e. it was included in the experiment as a complete package approach to be compared with conventional practice). The core of the programme was basically ecological in nature, and forestry was dealt with within one project only.

In Cameroon, the Department of Forestry of the Agricultural University of Wageningen started a multi-disciplinary research programme from scratch in 1994. Best represented from the onset were Land-Use Planning, Economy, Social Science, and Logging research. Logging research was rather a separate project in a range of complementary forestry studies. The study focussed largely on the logging itself and aimed at the modification of current logging practices towards reduced- impact logging. No ecological or silvicultural studies had been undertaken at the start of the research. Social science and land-use studies did make tentative results available and could thus be taken into account.

3 Best practice means that inputs are used with the highest technical efficiency according to available knowledge and techniques (de Koning *et al*., 1995). Since this is a rather theoretical concept the next best would be 'close to best'(or next best) practice.

In Guyana, the above factors led to an intrinsic link between logging, silviculture, and ecology, whereas in Cameroon the study tended towards a scrutiny of logging operations and their relationship with the rest of the production chain and the local forest population.

The environmental setting of the two programmes also differed, specially concerning the forest composition and the presence of forest dwellers (Table 1). Forests in Guyana are relatively poor in terms of species (*cf.* Ek, 1997) and log dimensions. Traditionally, logging has targeted mono-dominant patches of exploitable species in the forest, the most important being Greenheart (*Chlorocardium rodiei*, Lauraceae), a timber species. Recently, the set of targeted species has been broadened by an increased demand for peeler species, which is related to an increased interest of mainly South-East Asian timber companies. Logging activities in the study area, although also influenced by an increased marketability of lesser-used species, still aim at Greenheart. Because of the clumping of this species, selective logging in Guyana is disturbing the landscape in a very patchy fashion, and exploitation can reach a level of 20 stems per hectare or $60m^3$/ha (Clarke, 1956; Zagt, 1997). Tree diameters are relatively small, most logs being smaller than 70 cm. The canopy height of Greenheart reaches 30-40 m. Some sought-after species are emergents and attain large diameters, but these usually comprise only a small proportion of the harvest.

In Cameroon, the forests are richer in species; no similar-sized clusters occur, and large individuals are broadly dispersed. Logs are considerably bigger on the average. The concessionaire focuses mainly on Azobé (*Lophira alata*, Ochnaceae) for its sawn timber. Adult individuals of Azobé and most other marketable species are emergent, and therefore cause considerably more damage upon felling than trees belonging to the canopy.

Another important difference in setting is that the concession area in Guyana is virtually uninhabited, whereas sedentary as well as shifting-cultivation dwellers are present in Cameroon. Cameroon is also a prominent tropical timber exporting country while this is not the case for Guyana. The reasons for this difference can be found in the extremely low population density in Guyana, its relatively poor forests, and its geographical position. Because of the latter, Guyana is not located along a major trade route, which increases the transportation cost and results in smaller export profit margins.

The two projects coincide in the choice of their partners: both conduct their research in 'close-to-best practice' concessions, owned by foreign companies. The terrain of the two projects also correspond, both being flat to gently rolling.

Table 1 Characterisation of the environmental setting of the two Tropenbos research sites

	Guyana	**Cameroon**
Species diversity	moderate	rich
Exploitable species	in patches	dispersed
Topography (slopes)	<20%	<20%
Diameter range	under 120 cm	sometimes > 200 cm
Average diameter	60 cm	120 cm
Exploitation level (100 ha)	2 trees = 6 m^3/ha	0.5 tree = 6 m^3/ha
Concessionaire	Close-to-best practice	close-to-best practice
Forest dwellers	uninhabited	6 per km^2

HARVESTING PHASES

Four components can be identified in environmentally-sound harvesting practices (Dykstra, 1996):

1) Harvest planning;
2) Implementation and control of harvesting operations;
3) Assessment and communication of results between planners and operators;

4) A competent and properly motivated workforce.

Harvest planning should be a part of overall forest-management planning. The strategic harvest plan describes non-harvest areas, annual operating areas (coupes), the working methods, the main transportation and extraction system, and annual labour requirements. The tactical harvest plan provides the details of operations within the annual coupe. The following aspects are usually recommended for tactical harvest plans:

- Preparation of topographic maps;
- Identification of individual cutting units (blocks);
- Inventory of the trees per cutting block;
- Layout of a detailed transportation and extraction system;
- Scheduling of operations to accommodate the timing of, for example, the rainy season (Dykstra, 1996).

The comparison of the two logging studies focuses on these aspects and on the logging method. We will tackle these aspects not from a tactical viewpoint but from a strategic viewpoint. We will focus on the four harvesting phases most cited in literature: a) inventory, b) pre-felling logging activities, c) felling, and d) skidding.

INVENTORY

In temperate forests, forest inventory for harvesting through sampling is usually sufficient (see e.g. de Vries, 1986), as the volume to be harvested from each hectare is high and it is not necessary to know the location of each individual tree. In mixed tropical forests, the volume harvested per hectare is usually low, and it is now generally considered essential to make a complete inventory of all trees that might be harvestable (100% enumeration) to reduce harvesting and infrastructure cost.

The traditional way of making an inventory in both countries (close-to-best practice situation) is that a cutting block is delimited by cut lines, usually 1 km apart. Between these cut lines, the forest is divided into strips, which are systematically browsed to locate harvestable stems. The position, size, and species are marked on a map, together with topographic details such as slope direction, gullies, and streams (see e.g. Hendrison, 1990). It is also common practice to project this information on a blown-up version of a standard topographic map, scale 1:50,000 (Guyana) or 1: 200,000 (Cameroon). The map that is used for felling and skidding has a scale of 1:2,500 in Guyana and 1: 5,000 in Cameroon.

The tree-stock map assembled in this way may look neat, but contains a high degree of false accuracy. Firstly, the blown-up grid of contour lines is too coarse and does not take into account very local steep slopes and ridges. Secondly, the combination of primitive field equipment (compass and surveyor's rope), dense vegetation, and the strip system lead to considerable deviations from the reality in the forest. A compass misreading of only one degree will lead to an error of more than 17 m on a strip length of 1 km. Larger deviations are not uncommon when working under dense forest conditions. Moreover, the tree's position is represented by a circle, in which species code, tree size, and tag number are pictured, which easily takes up 1 cm on the map = 50 m. Consequently, mapped tree locations and distances between trees show great aberrations.

Surprisingly, the low accuracy of the map generally appeared to pose no problem with the low density of the trees to be felled and skidded in Cameroon. The prospector still had time to locate trees while the feller was busy bucking the previously felled tree, and the logging clerk could lead the way to the next tree when the skidder was on its way to and from the landing. In Guyana, the density of the trees to be felled is often high. In this case, a low accuracy can influence the efficiency of the operation, because trees are being omitted or felled in the wrong sequence.

But what demands does Reduced Impact Logging (RIL) impose on the quality of the current inventory work? One of the major credits ascribed to RIL is the reduction of damage to the residual forest -

especially to sub-adult trees of commercial species - by designating skid trails and by directional felling. For this purpose, it is important to know the number and condition of these potential crop trees (PCT), as well as seed trees, and to know where they are. Hence it is often suggested that they should be included in the pre-felling inventory. But it should be realised that the number of trees to be mapped doubles when trees only 10 cm below the cutting limit are taken, and triples when trees 20 cm below the cutting limit are taken. In the case of Guyana, where tree densities can already reach 20 trees per ha, there would be physically no space left on a map with a scale of 1:2,500. In Cameroon, larger map scales were experimented with, but did not improve accuracy. There are also practical reproaches; the daily coupe should be on one manageable map.

It is also suggested that the direction of fall of each tree to be harvested should be marked on the map. Indicating the expected and proposed direction of fall of a tree would require space to such an extent that the map would be fully filled and hence not workable.

Conclusion

To accommodate the demands that RIL imposes on forest inventory for harvesting (e.g. inclusion of potential crop trees, mapping of proper alignment of the designated extraction system, and indicating the direction of fall) requires more accurate topographic and tree position information and a better presentation of the inventory data. Within the current inventory technology, the current inaccuracies can only be partially tackled by increasing the scale of the maps and working with smaller inventory blocks. A switch to a completely new technology, GPS/GIS, for instance, may be inevitable.

Table 2 Pre-felling logging activities in two countries

Frequently mentioned activities	Location	Cameroon	Guyana
Planning	in camp	some	some
Climber cutting	in forest	no	no
Marking PCT	in forest	no	no
Marking Seed trees	in forest	no	no
Skid trail alignment	in forest	some	no

PRE-FELLING LOGGING ACTIVITIES

In the current discussions on Reduced Impact Logging, there is a lot of attention for activities that should take place before one proceeds with the actual felling of the trees that were enumerated during the inventory. A whole array of activities is mentioned in literature. It is usually advised to perform them during the inventory, or to base them upon the results of the inventory. The actual state of affairs in Cameroon and Guyana is that none of these activities are employed (Table 2). Their applicability was studied explicitly in Cameroon. In Guyana, three activities were incorporated in the RIL experiment: 1) planning; 2) climber cutting, and 3) pre-felling skid-trail alignment.

Table 3 Constituting elements of harvest plan preparation

Activity	'Current practice'	Reduced Impact Logging
Manpower-machine input	present	frequently mentioned
Designation cutting blocks	present	frequently mentioned
Roads and landings	present	frequently mentioned
Designation buffer zones	absent/present	frequently mentioned
Skid rail alignment	absent	frequently mentioned
Tree selection system	absent	rarely mentioned
Seed trees	absent	rarely mentioned

Social trees*	absent/present	rarely mentioned
Exploitation level*	absent	rarely mentioned
Felling patterns*	absent	not mentioned

* = added by the authors

Planning

The preparation of the harvest plan requires a confrontation of the working-method outline - as described in the strategic plan - with the actual results of the inventory. Planning commonly comprises the planning of the monthly production, the machine and personnel input, and the planning of cutting blocks, truck roads, and landings. Some of the above elements are included in a ‘close-to-best practice’ situation, although usually in a crude form. The planning is mostly executed at forest-camp level and is pretty much a straightforward calculation of the machines and personnel needed, based on the commercial composition of the forest (number and volume of tree to be cut per species). Table 3 shows what is expected to take place under the RIL scenario, according to various publications and completed with impressions obtained at the two sites.

Most of the frequently-mentioned features of the RIL method are already in place at a considerable level at the two research sites. Under the present circumstances, however, the designation of ‘buffer zones’ is based on the abundance of commercial stems. Poorly stocked or hilly areas are left untouched because the cost/benefit ratio of exploiting those areas is too high. No consideration is given to uniqueness or richness of flora or fauna.

Silvicultural aspects, grouped in the ‘tree-selection system’, are rarely, or not at all, mentioned in current publications on RIL. For forests in Fiji, de Vletter (1993) mentions aspects like maximum attainable diameter per species, (10%) reduction for over-maturity, grouping of species, and diameter limits per group. Burgess (1989) also sums up silvicultural considerations: 70% of the trees in the 15-65 cm class are to be retained as growing stock for future harvests, and 40% of the trees in the 65-75 cm class. But hardly touched upon are the number of seed trees to be left standing during harvesting in relation to the distribution of mature individuals per hectare, or the regeneration strategy per species. Yet, when harvesting for sustainable forest management, these aspects must be taken into account.

Figure 1 Logging intensity in Guyana: number of trees felled per hectare

A striking feature is that, under RIL, the setting of limits to the (absolute) logging intensity is hardly mentioned. It would seem that one might harvest as much as one likes, as long as one does so correctly. This is of course erroneous, as one may still end up with no forest at all. The study in Guyana revealed that by far the most important damage factor was not the logging method, but the exploitation level (Figure 1). Data from Cameroon confirm that, when one is talking about felling damage, intensity is a more decisive factor than the logging method.

Felling patterns (i.e. the distribution of felling gaps over the area) receive very little attention. Should clustered felling, creating multiple tree gaps, be promoted or rather discouraged? Data from the experiment in Guyana show that, if the felling intensity exceeds 8 trees/ha, the accumulated gap area is less in a conventional Greenheart operation (clustered felling) than in the experimental operation (trees to be felled evenly distributed). RIL compensates for this negative effect, however, by a smaller mean gap size. Apparently, we are being confronted with a trade-off. Is there a maximum or minimum gap size before we start talking about damage? Does it depend on the sort of forest we want to end up with? Again, not much has been published in this regard.

Loss of canopy cover as a percentage of total area (black and hatched parts of bars) and ground area affected by skidding (white and hatched parts of bars) as a percentage of total area in a conventional and an RIL operation in Pibiri, Central Guyana. With an intensity of 8 trees/ha, canopy loss is the same with either method, but, with an intensity of 16 trees/ha, it is higher with RIL. On the other hand, skidding damage is markedly more extensive with conventional logging. Also, skidding damage in canopy gaps (hatched parts of bars) is negligible with RIL and extensive with conventional logging. Ground disturbance in gaps will undoubtedly lead to the development of undesirable vegetation.

The interaction with the local population also remains largely beyond the scope of the publications on RIL. Accommodating the usufruct rights of local gatherers by the concessionaires (e.g. by sparing 'social trees' or crop fields) seldom receives attention, and yet the impact of harvesting on the life of the forest dwellers may be considerable. Small adaptations after consultation may well improve the situation at virtually no expense to the concessionaire. In Cameroon, the logging company decides not to cut certain trees, only upon request of the local population and only if the logger thinks the reasons are valid, with a strong inclination towards materialistic reasons rather than customary beliefs.

Climber cutting

Climber cutting is one of the most frequently mentioned tools to reduce felling damage. By cutting climbers some time prior to exploitation, it may be expected that they will have died and that the physical connections binding one crown with another will have weakened considerably. Falling trees may then be less liable to carry down with them their smaller neighbours. Similarly, while felling, fewer trees will be hung up when severed at the base. Studies on the effect of climber cutting on felling damage by Appanah and Putz (1984) and by Fox (1968) showed a substantial reduction of felling damage after climber cutting. Putz (1984) found that climber-infested trees carried down more trees in natural tree falls than did climber-free trees. To ensure that the vine stems have weakened sufficiently, it is recommended that they be cut about one year prior to logging (Pinard,1994), or even two years (Sarre *et al.*, 1996). Cedergren *et al.* (1994) report that pre-felling climber cutting has been found useful when opening skid trails with tractors. They also warn that climber cutting is ecologically questionable, climbers being an important source of food for the fauna. More user- friendly and efficient tools for climber cutting are needed; promising equipment is already available on the market.

In the Pibiri experiment in Guyana, lianas were cut about six months before felling. A comparison of canopy opening due to felling between conventional and experimental logging did not show any clear difference in canopy opening due to liana cutting. Single tree-fall gaps did not differ in area; gaps containing two trees were slightly smaller with experimental felling, whereas multiple tree gaps were larger. The latter two differences were related rather to the felling pattern than to a climber-removal effect. One may argue that the period of six months was too short. Indeed, field observations during felling confirmed that in some cases the climber stems had not weakened sufficiently. Otherwise, there may have been differences in the density of lianas (unconfirmed). Besides climber cutting, there were other differences between the conventional and experimental logging method, specially the felling pattern, which may have concealed an effect of climber cutting. A definite answer to this question would thus require a specific study into the effect of climber cutting.

In Cameroon, a large-scale climber-cutting experiment was set up to test its effects on felling and skidding damage. In the experiment, with 3 treatments and 7-11 repetitions on 1 hectare plots, climbers were cut 9 and 4.5 months before tree felling. Tentative results show that gap size does not decrease with pre-felling climber cutting. Nor was it demonstrated that the level of damage to individual trees had decreased (Parren, 1998). Canopy openness after skid-trail construction with and without climber cutting did not show any great differences either. Again, one may argue that the time that had elapsed after cutting had been too short, but field observations did not confirm this in Cameroon.

Marking of potential crop trees (PCTs) and seed trees

The marking of potential crop trees (PCTs), in combination with directional felling, is frequently cited as an important tool in reducing damage to the (commercially interesting part of the) residual stand. This aspect was only studied in Cameroon and results are not yet available. Questions in this study are: the phase in which tree marking should take place (during or after inventory, during felling) and the visibility of marked PCTs during felling.

In the Guyana experiment, marking of PCTs was deliberately omitted. In this respect, we have to distinguish between preserving PCTs during felling and during skid-trail construction. During felling, attention was given to the retention of PCTs, but this was secondary to achieving the desired felling pattern. The motive behind this was that a trade-off was expected between choosing for a particular felling pattern (herringbone system) and the retention of PCTs. It was argued that any deviation from the felling pattern would increase the extent of ground disturbance, and also that, during log extraction, it would increase the probability of killing trees that were spared during felling. It was found, however, that strict adherence to the felling directions was not absolutely necessary to achieve the desired pattern (van der Hout, 1996; van Leersum, 1984). With regard to safeguarding trees during skid trail construction, this would require important changes in the procedure for skid-trail alignment. The alignment of the skid trails was marked on the ground prior to felling, on the basis of topography and on a fixed distance between trails. Clearly, it is hardly an option to adjust the alignment in order to safeguard a single PCT, for this would result in undesirable winding of the planned trails, while small diversions would probably not even guarantee that marked trees would be spared.

In summary, felling directions can be adjusted to accommodate the safeguarding of PCTs because of the flexibility when extracting logs. Under Guyanese forest conditions, these adjustments can easily take place at the moment of felling (but probably not under Cameroon's forest conditions). To avoid unnecessary killing of PCTs during skid-trail construction, it would be necessary to map PCTs and adjust alignments on a map, because *ad hoc* adjustments would lead to sudden diversions. The pros and cons of including PCTs during the inventory have been discussed above. Whether such an activity is necessary will depend strongly on the abundance of PCTs.

Conclusion

Newly-proposed activities in selective logging in mixed tropical forest are extended planning and subsequent pre-felling forest operations. These, by far, require the most labourious adaptations. If they are to be executed in their most extended form, as suggested now in the various publications on RIL, the implications for current practices will be strong - stronger than in the other harvesting stages. They would require:

- Staff capable of obtaining silvicultural, ecological, and sociological data and including these data in harvesting planning;
- Adequate instruments to elaborate the inventory results and communicate harvest prescriptions;
- Intensive communication between office and forest camp;
- Intensive communication between forest operations.

These implications should be seen against an environment which, at present, possesses far from a proper administration and communication structure.

FELLING

As for felling, many publications deal with what could be called the improvement of conventional felling practices. Making proper felling notches, avoiding undermining of the notch, improved cross-cutting, and so on, are all directives to improve safety and to benefit cut-wood utilisation, which came with the introduction of the chainsaw in tropical forestry in the thirties. Nevertheless, only rudimentary elements of what was once controlled felling are being practised nowadays, because of the poor education system of on-the-job apprenticeship in the forest. The necessity to renew the controlled felling concepts amongst fellers in the tropics is becoming more and more apparent.

The really new concept in the discussion on felling may be directional felling. To master this technique, some knowledge of mechanics and of the tree properties is required. Directional felling is quoted by many authors (Mattsson-Mårn and Jonkers, 1981; Hendrison, 1990; Malmer and Grip, 1990; Gullison and Hardner, 1993; Pinard *et al.*, 1995; Pinard and Putz, 1996; Johns *et al.*, 1996; Cedergren *et al.*, 1994; Whitman *et al.*, 1997) as a new concept for the purposes listed in Table 4.

Table 4 Justification for directional felling under RIL and its validity at two research sites

Purpose	Cameroon	Guyana
Reduction of damage to potential crop trees	Questionable	Questionable
Facilitation of skidding	No	Yes
Reduction of damage to the felled trunk	No	Yes
Creation of multiple tree gaps	Questionable	Yes

By steering the tree to be felled in a certain direction, the destruction of the surrounding young potential crop trees can supposedly be avoided. Instead of tearing off valuable tree crowns, cut trees may hit commercially less-interesting species instead, or may be directed towards natural gaps in the vegetation.

In both countries, it was proved that directional felling is technically possible. In Cameroon, the large diameters and large buttresses do not hinder a successful execution. Wedges are not needed to make the emergent trees gain momentum for the fall. In the experiment in Guyana, a direction of the lie favourable to skidding was the primary objective. Where possible, trees were felled at obtuse angles (30-45°) to the skid trails for ease of skidding. In the field, the felling direction could be adjusted for the sake of safety to the feller, for the avoidance of damage to the harvested tree and potential crop trees, and for the avoidance of hang-ups. It appeared to be hard to predict how far the impact of a falling tree will reach from the epicentre of its fall, especially when domino effects take place. To be safe, it would probably have been necessary to divert more than 45 degrees from the designated felling direction. Diversions to such an extent would have fouled up the felling pattern and were generally not allowed, but felling in the opposite direction was practised frequently. Despite these efforts, PCTs suffered in the same proportions as non-commercial trees, which means there must have been other reasons for this equality, one of which may be the abundance and dispersion of the PCTs. In Cameroon, simulation with inventory results did not indicate any need to deviate from the natural direction of fall in order to avoid potential destruction of potential crop trees: in whichever direction a tree would be felled, a potential crop tree would be destroyed. In summary, the results from both Guyana and Cameroon indicate that employing directional felling to avoid damage to PCTs is quite equivocal.

Skidding may be facilitated by felling the tree under an angle that makes it easier for a machine to skid or winch the log immediately into the desired direction, instead of having to change the position of the log. The low harvesting levels in Cameroon (Table 1) and the scattered dispersal of the felled trees led to long skidding distances between consecutive logs. These conditions, combined with the impracticability of log winching (see *Skidding* below), are not calling for any scrupulous planning of the direction of fall of a tree. Whatever the angle of the log, the machine could nearly always get to it without deviating too much from the most logical trail pattern.

In Guyana, the extent of skidding damage was reduced tremendously by applying RIL, regardless of logging intensity (Figure 1). This can be mainly contributed to an almost complete reduction of movements around the stump (data not shown). This was achieved by winching the bole to the machine, which in turn was made possible by the favourable position of the logs. As mentioned under *Marking of potential crop trees*, a trade-off between directional felling to safeguard PCTs and directional felling for the ease of skidding is inevitable (although the usefulness of directional felling in retaining PCTs could not be demonstrated by us). This was also pointed out by Cedergren *et al.* (1994), who suggested narrowing down the number of PCTs to be protected through a distinction between PCTs and Next Crop Trees (NCTs). The latter would receive a higher priority for protection. According to their prescriptions, tree crowns should be directed to fall onto skid trails to minimise canopy openings. Such prescriptions would amplify the trade-off, because felling debris on skid trails would have to be chopped up before skid-trail construction.

A reduction in felling damage to the trunk may consist of reducing the loss of wood through breakage when the trunk hits rocky outcrops, felling downhill, suspension of the tree in other crowns, or trees sliding into the bottom of a valley. Under the terrain conditions in the study areas in Guyana and Cameroon, this occurred in less than 1% of the cases.
The creation of multiple tree gaps versus single tree gaps is a question that was highlighted earlier under felling patterns. Directional felling can assist in either of these strategies. Unfortunately, it is not clear which of these strategies should be applied at the two sites.

Results from Guyana showed that the proportion of gaps formed by a single tree, or by two or multiple trees, was influenced both by the logging method and the logging intensity. At an intensity of 8 trees/ha, fewer than most gaps contained less than 3 felled trees with RIL whereas, with conventional logging, 15% of the gaps fell into this class. At an intensity of 16 trees/ha, a quarter of the gaps fell into this class with RIL whereas, with conventional logging, more than half fell in this class. The size of the canopy openings was mainly determined by the number of trees contained in the gap. As mentioned earlier, the total gap area was increased by employing RIL at the highest logging intensity, and apparently we are being confronted with a trade-off. Applying RIL, with its regular felling pattern, is leading to smaller gaps, but also to a higher total gap area when a certain logging intensity is exceeded. Knowing that, in terms of sustainable forestry, large gaps are far less desirable than small gaps (see e.g. ter Steege *et al.*, 1996), one might still opt to employ the experimental logging method. Nonetheless, also from this point of view, it is of paramount importance that an upper limit to the absolute logging intensity is a prerequisite for sustainable forestry.

Conclusion

Felling standards surely need improvement, but most of them deal with reinforcing the concepts of controlled felling. Directional felling may only be rarely applicable in Cameroon, whereas in Guyana its usefulness is clear, but so, too, is the increased complexity of decisions to be made because of the trade-off between the various purposes of directional felling. Also, it has become crystal-clear that a high logging intensity neutralises the beneficial effects of directional felling.

SKIDDING

Concerning skidding, it may again be useful to distinguish between practices that have been common for the last decades, but have somehow eroded, and totally new concepts. When bulldozers and skidders were first introduced into the scene of tropical forestry, the extraction of wood was based on inventory maps and was closely supervised. These costly machines have never entered the forest without even the slightest planning. Over the last decade, however, supervision of skidding activities in the forest has steadily declined, and also many new, less-well-organised entrepreneurs, copying everything but the planning aspects, have entered the scene.

The new concepts of RIL comprise:

- Detailed planning of the skid trails on the map;
- Detailed alignment of the skid trails in the forest;
- Log winching to the skid trails.

Planning the skid trails

Planning the skid trails as proposed by RIL goes further than the conventional planning of skidding, in principle, intends to go. Where a primary skid trail should pass and where secondary tracks should branch off is no longer a mere indication on the map. Under RIL in its most extreme forms, we may want to plan nearly every movement of the machine and plan the order in which logs are to be extracted. This should all translate into a map with self-explanatory information for the alignment crew.

Skidding in the 'close-to-best practice' situation in Cameroon is still portraying some degree of planning, basing itself on maps and some elementary skid trail alignment in the forest by the crew chief just before the machine enters the forest. Post-logging damage patterns also indicate a reasonable amount of planning in the skidding activities. This impression is reinforced through method studies and interviews with crew members. Skidding damage can be reduced (by as much as 30%), not so much through a better planning on the map or in the forest, but through closer supervision during the execution of the skidding and a better transmission of felling results to the skidding crew beforehand.

The results obtained at both sites will be discussed in the sections below.

Alignment of skid trails

Many authors advise signposting or flagging skid trails before actual skidding takes place. Some combine this with marking the trees to be felled or trees to be preserved (de Vletter, 1993). Pinard (1994) proposes that, after the appropriateness of the planned locations has been confirmed in the field, the proposed routes for skid trails and their end-points be marked with paint. In addition, all harvestable trees are painted with a paint slash that indicates the preferred felling direction. Putz (1994) adds the necessity of specifying the construction and use practices. Cedergren *et al.* (1994) aligned their trails at a distance of 60 m, as parallel to one another as nature allowed, following natural borders such as streams and ravines. Sharp curves were avoided and culverts in the trails consisted of hollow logs. The PCTs along the trail were marked. Restricting tractors to ridge tops only would not allow logging at full intensity. There is no reason to believe that skidding would be less efficient on pre-aligned trails - rather the opposite.

While planning primary and secondary skid trails along the contours is already an existing activity in Cameroon (and Suriname), detailed alignment of the skid trail represents an additional harvesting activity. Skid-trail alignment (and construction of the trail) can be done before or after felling. In Cameroon, post-felling alignment of the skid trail was done before the extraction of 165 trees by a Caterpillar (CAT) 528 skidder. The alignment was based on an improved inventory map (scale 1:5000). The marking in the forest was then done in the presence of the skidder operator in order to let him indicate whether or not he could pass certain obstacles or between certain trees. Apparently, the scale of the map (1:5000) was not detailed enough, because this inspection led to important deviations from the planned route. Later, when actually opening up the skid trail, further deviations from the aligned track had to be made because, once the operator was on his machine, the situation proved to be more difficult (i.e. more hilly) than he had originally foreseen. Also, parallel routes had to be created because the carrying capacity of the soil did not permit more than a few passes. Finally, the order in which the logs were extracted changed dramatically because of the inaccessibility of large parts of the terrain after heavy rains. Bulldozers had to be deployed to evacuate most of the wood.

In the Pibiri experiment in Guyana, skid trails were aligned with a 80 m spacing, where topography allowed this. Skid trails were planned on a very detailed map (1:1000), marked in the forest before felling, and constructed after felling by a CAT 528 skidder. The system worked well, but it should be noted that it was intensively supervised. It should also be noted that the scale of the experiment was rather small (cutting blocks of 6 ha only) and that the terrain was rather easy, with sandy soils and few slopes. It is questionable whether such detailed planning and intense supervision is (economically) feasible on a large scale. Surprisingly, the total area of the actual trails was only slightly reduced, compared with a conventional operation. As mentioned under *Felling*, the main beneficial effect of the RIL system was the elimination of movements in the bole zone. Winching is playing a major role in this respect.

Log winching

Log winching (in combination with skid trail planning and alignment) is commonly advocated for its damage-reducing features. It consists of restricting the movements of the extraction machinery to the greatest extent possible. The skid-trail grid is designed in such a way that the machines do not need to deviate from the secondary trails to fetch the logs; these are being winched over distances of up to 30-50 m from the stump to the skid trail. It is strictly prohibited to manoeuvre around the stump to position the log in such a way that the skidding crew can easily attach the cable and proceed; this has been replaced by two crew members pulling the winch cable over a considerable distance. The advantages are twofold: logging damage (around the stump and tertiary trails) is reduced, and machine productivity is considerably increased.

In Guyana, skidding in accordance with the RIL principles proved to be highly effective. Hooking did not present many problems because the majority of the log diameters were below 70 centimetres. Winching distances of up to 30 m were subsequently attained, resulting in a strong decrease in affected ground area (Figure 1). Since winching is playing a decisive role in reducing skidding damage, one might argue that directional felling and skid-trail planning are subordinate and, therefore, could be de-emphasised. Nevertheless, it should be clear that the feasibility of winching depends greatly upon the felling pattern and the skid trail alignment, both being determined by the planned extraction route.

In Cameroon, an experiment with the skidding of 165 trees revealed severe limitations to the applicability of RIL concepts. Hooking, even when a specially designed skidding stick was used to pull the cable underneath the log, proved to be impossible for most of the logs with diameters of over 100 cm and weights of more than 6 tonnes. Winching the log from the stump site frequently yielded the opposite effect, with the machine being pulled to the log instead of the other way round. Most of the supposed beneficial effects in terms of damage reduction therefore proved not to hold true. Table 5 summarises the results obtained at the two sites.

Table 5 Log winching to the skid trail. Tentative results of studies of the two Tropenbos sites

Country	Activities		Effects	
	Hooking	Winching	Reduction tertiary trails	Reduction manoeuvring
Cameroon	negative	negative	negative	positive
Guyana	positive	positive	positive	positive

Conclusion

Especially when the number of trees harvested per hectare is high and log dimensions are small, as in Guyana, the RIL concept is applicable. In Cameroon, where the opposite prevails, the need and possibilities for a switch is less evident. But, a better organisation and closer supervision of the current skidding phase could already reduce damage considerably.

DISCUSSION

Reduced Impact Logging (RIL) has been hailed as an important step towards sustainable forest management. Given the current state of knowledge, however, it is not clear whether specific practices will actually achieve the desired outcome. One of the reasons for this is that criteria with which to assess the environmental acceptability of various harvesting practices are neither yet fully available nor globally applicable (*cf.* Dykstra, 1996). Most recent publications on this subject seem to agree on an array of activities that will reduce the environmental impact of selective logging in mixed tropical forest. The authors of the present paper have screened these activities against their experiences in Cameroon and Guyana, which has resulted in the following comments on the applicability of RIL.

Studies on Reduced Impact Logging (RIL) conducted by Tropenbos in two continents reveal that this concept is not always fully applicable and does (or will) not always lead to less damage than conventional logging practices.

1. Although Reduced Impact Logging is a great step forward, silvicultural, ecological, and sociological considerations need to be added to this technical concept in order to better meet the demands of sustainable forest management, whatever they may be.
2. The set-up and scale of published experiments in which the added value of RIL is being tested are mostly biased and small and not sufficient to convince potential users or legislators.
3. Reduced Impact Logging is an example of developing one of the aspects of 'precision forestry' in the tropics. We can still push for more precision, but improving current conventional practices, taking them to the level of 'the best practice', has a far greater impact on forest conservation. The conditions for this improvement lie in better planning, organisation, and supervision in the forest during operations and more adequate training and remuneration of personnel.
4. A careful study of current harvesting practices reveals strong ties between the forest activities on the one hand and, on the other, the demands within the rest of the production chain of the logging enterprise. Even when the economic and financial feasibility of a complete shift towards RIL is clearly demonstrated to a logging enterprise, pressures from outside the forest (and even outside the company) will continue to dictate the forest protocol.
5. The (partial) applicability of RIL guidelines should be taken into account when timber certification schemes are being devised. Non- compliance with what may be globally proclaimed as the solution may have its good reasons locally and may be totally justifiable.
6. On inventory: because of the necessity of integrating silvicultural, ecological, and sociological considerations in logging practices - in Guyana as well as in Cameroon - current inventory practices may need considerable upgrading. Drastic changes in the scale of maps and level of detail during field work, as well as other maps and map-information management, have become inevitable.
7. On pre-felling logging activities: in Guyana as well as in Cameroon, harvest planning following forest inventory will have to shift from a mere 'rule of thumb' exercise at the landing site to a more silviculturally-oriented office-level planning process. In this process, attention must be given to the exploitation level, the felling pattern, and the density of potential crop trees and seed trees to be left standing. At forest level, this extended planning will see itself translated into an additional harvest phase before felling, consisting of marking trees to be cut and their direction of fall, marking potential crop trees, and skid-trail alignment. Climber cutting may not necessarily be included in this exercise.
8. On felling: in Guyana, directional felling is an inextricable component of an RIL

approach, being a pre-requisite to reducing skidding damage. In Cameroon, although technically feasible, the importance of a shift to directional felling is less evident.

9. On skidding: skid-trail planning and winching are the most promising techniques for Guyana. In Cameroon, winching seems technically impossible in most cases because of the large wood diameters. It may be possible to substantially reduce damage and to increase efficiency by introducing radio communication, skidding sticks, and choker bells, and by reducing blade utilisation.

In summary, the scope for RIL appears to be greater in Guyana than in Cameroon. This is mainly attributable to the higher logging intensity and the smaller log sizes. Nevertheless, it was recognised that the beneficial effects of RIL are strongly tempered if the logging intensity is raised above a certain level. It was also recognised that there is a series of trade-offs that have to be dealt with:

- Directional felling in order to preserve PCTs can adversely affect the ease of skidding and the inherent skidding damage;
- The felling pattern formed by 'herring-bone' felling, being a prerequisite to reducing skidding damage, can, with high logging intensities, lead to a larger total gap area;
- Averting multiple tree-fall gaps, in order to form smaller canopy openings, can lead to a higher total gap area (less overlap of tree-falls).

To deal with these matters, ecological and silvicultural thresholds need to be set. Hence, research questions in the fields of forestry, silviculture, and ecology need to be attuned to one another to investigate these thresholds.

Criteria by which to assess the environmental acceptability of various harvesting practices are thus not yet fully available. Combined with the multiplicity and complexity of the trade-offs that are involved, this means that it is impossible to provide standard RIL recipes. Different approaches may be needed in different places and at different times, even within a single country. Moreover, RIL would require extended planning and pre-felling forest operations, flexible scenarios, and dealing with a series of trade-offs. Even though good harvesting practices may be a prerequisite for sustainable forestry, their introduction will definitely not be easy. Quoting Dykstra (1996) in this respect: '*If it were easy, the majority of forest harvesting crews around the world would already be doing it, and they are not…..*'.

REFERENCES

Appanah, S. and Putz, F.E. (1984). Climber abundance in virgin dipterocarp forest and the effect of pre-felling climber cutting on logging damage. *Malaysian Forester* 47(4).

Bertault, J-G. and Sist, P. (1995). Impact de l'exploitaton en forêt naturelle. *Bois et Forets des Tropiques* 245 (3): 15-20.

Blate, G. (1997). Sustainable forest management in Brazil. *Tropical Forestry Update* 7(3): 14-15.

Burgess, P. (1989). Asia. in D. Poore (ed.), *No timber without trees: sustainability in the tropical forest*. ITTO, Yokohama, Japan.

Cedergren, J., Falck, J., Garcia, A., Goh, F. and Hagner, M. (1994). Reducing impact without reducing yield. *Tropical Forestry Update* 4 (3): 9-10.

Clarke, E C. (1956). The regeneration of worked-out Greenheart (*Ocotea rodiaei*) forest in British Guyana. *Empire Forestry Review* 35: 173-183.

Crome, F.H.J., Moore, L.A. and Richards, G.C. (1992). A study of logging damage in upland rain forest in north Queensland. *Forest Ecology and Management* 49: 1-29.

Dykstra, D.P. (1996). *FAO model code of forest harvesting practice*. FAO, Rome, Italy.

Ek, R.C. (1997). *Botanical diversity in the tropical rain forest of Guyana*. Tropenbos-Guyana Series 4. The Tropenbos-Guyana programme, Georgetown, Guyana.

Fox, J.E.D. (1968). Logging damage and the influence of climber cutting prior to logging in lowland dipterocarp forest of Sabah. *The Malaysian Forester* 31 (4): 326-347.

Gullison, R.E and Hardner, J.J. (1993). The effects of road design and harvest intensity on forest damage caused by selective logging: empirical results and a simulation model from the Bosque Chimanes, Bolivia. *Forest Ecology and Management* 59: 1-14.

Hendrison, J. (1990). *Damage-controlled logging in tropical rain forest in Suriname*. Ecology and Management of Tropical Rain Forest in Suriname 4. Wageningen Agricultural University, Wageningen, the Netherlands.

Hout, P. van der. (1996). *Effects of logging with different intensities of low impact harvesting*. Tropenbos-Guyana Report 96-1. Tropenbos-Guyana, Georgetown, Guyana.

Johns, J.S., Barreto, P. and Uhl, C. (1996). Logging damage during planned and unplanned logging operations in the eastern Amazon. *Forest Ecology and Management* 89 (1): 59-78.

Koning, G.H.J. de, Keulen, H. van, Rabbinge, R. and Janssen, H. (1995). Determination of input and output coefficients of cropping systems in the European Community. *Agricultural Systems* 48: 485-502.

Leersum, G.J.R. van. (1984). *Winch systems and shortwood logging*. Internal Report. CELOS, Paramaribo, Suriname.

Malmer, A., and Grip, H. (1990). Soil disturbance and loss of infiltrability caused by mechanised and manual extraction of tropical rain forest in Sabah, Malaysia. *Forest Ecology and Management* 38: 1-12.

Mattsson-Mårn, H., and Jonkers, W.B.J. (1981). *Logging damage in tropical high forest*. FO:MAL/76/008. FAO Working Paper No. 5, FAO, Rome, Italy.

Parren, M.E. (1998, *in press*). *The effects of climber cutting on felling damage*. Wageningen Agricultural University, the Netherlands.

Pinard, M.A. (1994). The Reduced-Impact Logging Project. *Tropical Forest Update* 4 (3): 11-12.

Pinard, M.A. and Putz, F.E. (1996). Retaining forest biomass by reducing logging damage. *Biotropica* 8 (3): 278-295.

Pinard, M.A., Putz, F.E., Tay, J. and Sullivan, T.E. (1995). Creating timber harvest guidelines for a reduced-impact logging project in Malaysia. *Journal of Forestry* 93 (10): 41-45.

Putz, F.E. (1984). The natural history of lianas on Barro Colorado Island, Panama. *Ecology* 65 (6): 1713-1724.

Putz, F E. (1994). Towards a sustainable forest. *Tropical Forest Update* 4 (3): 7-9.

Sarre, A., Sobral Filho, M. and Reis, M. (1996). The amazing Amazon. *Tropical Forest Update* 6 (4): 3-7.

Steege, H. ter, Boot, R.G.A., Brouwer, L.C., Caesar, J.C., Ek, R.C., Hammond, D.S., Haripersaud, P.P., Hout, P. van der, Jetten, V.G., Kekem, A.J. van, Kellman, M.A., Zab Khan, A., Polak, M., Pons, T.L., Pulles, J., Raaimakers, D., Rose, S.A., Sanden, J.J. van der, and Zagt, R.. (1996). *Ecology and logging in a tropical rain forest in Guyana*. Tropenbos Series 14. The Tropenbos Foundation, Wageningen, the Netherlands.

Uhl, C., Barreto, P., Veríssimo, A., Vidal, E., Amaral, P., Barros, A.C., Souza Jr., C., Johns, J. and Gerwing, J. (1996). Natural resource management in the Brazilian Amazon. *BioScience* 47 (1): 160-170.

Vletter, J. de. (1993). A natural forest management pilot project in Fiji. *Tropical Forestry Update* 3 (6): 3-7.

Vries, P.G. de. (1986). *Sampling theory for forest inventory*. Springer-Verlag, Berlin, Germany.

Ward, J.P., and Kanowski, P.J. (1985). 'Implementing control of harvesting operations in north Queensland rain forests', in K. Shepherd and H.V. Richter (eds.), *Managing the Tropical Forest*. Development Studies Centre, Australian National University, Canberra, Australia.

Webb, E.L. (1997). Canopy removal and residual stand damage during controlled selective logging in lowland swamp forest of north-east Costa Rica. *Forest Ecology and Management* 95: 117-129.

Whitman, A.A., Brokaw, N.V.L. and Hagan, J.M. (1997). Forest damage caused by selection logging of mahogany (*Swietenia macrophylla*) in northern Belize. *Forest Ecology and Management* 92: 87-96.

Zagt, R.J. (1997). *Tree demography in the tropical rain forest of Guyana*. Tropenbos-Guyana Series 3. The Tropenbos-Guyana programme, Georgetown, Guyana.

REDUCED IMPACT LOGGING: A GLOBAL PANACEA? COMPARISON OF TWO LOGGING STUDIES

Achievements

- Techniques of Reduced Impact Logging have been developed.
- There is a good insight into the relative contribution of the various field operations to reduce damage and increase efficiency.

Challenges and Problems; Information Needs

- The limited integration of future silvicultural objectives in current logging practices.

Points for Future Research

- Improvement of best current practices of logging.
- Technical and organisational aspects of logging.
- Integration and comparison of logging studies conducted in different localities.
- Research questions in the fields of forestry, silviculture, and ecology must be attuned to one another to investigate the thresholds involved in Reduced Impact Logging.

Conclusions

- Reduced Impact Logging comprises many elements, which are neither always, nor everywhere, nor completely applicable in all situations.
- Silvicultural objectives should, more than is the case at present, be incorporated in the logging strategy. This puts higher requirements on quality and interpretation of the pre-logging inventory.
- While directional felling and winching are important tools in Reduced Impact Logging in Guyana, their application in Cameroon is prevented by technical constraints (the trees are too large).
- Detailed comparisons and combinations of results from logging studies from different research projects greatly enhance our views.
- Although research on forest operations can contribute greatly to the reduction of damage, technological and managerial improvements and political and legal measures are of far greater importance.
- Ecological and forestry research should be matched (e.g. by using create-use matrices).

INVENTAIRE FORESTIER D'EXPLOITATION, POUR QUELLES PRECISIONS ?[4]

Flavien Ngibaot et Gart van Leersum

Résumé

L'inventaire forestier est une étape importante de l'aménagement durable de la forêt dans le cadre d'une exploitation polycyclique. Il a donc besoin d'une certaine précision fonction des objectifs qu'on lui assigne. Afin de parvenir à un aménagement durable, l'intégration des considérations sylvicoles (tiges d'avenir, semenciers, structure de la forêt, …) dans les opérations d'inventaire forestier d'exploitation s'avère nécessaire. En somme, il s'agit de penser au devenir de la forêt avant toute exploitation afin de garantir une production satisfaisante pendant les rotations subséquentes. L'une des stratégies minimisant les impacts négatifs sur la forêt serait de trouver des voies et moyens susceptibles de réduire les dégâts d'exploitation. A cet effet, la littérature propose une panoplie de mesures donc la faisabilité n'a pas été évidente dans les forêts du site d'étude caractérisées par : un faible densité des arbres exploitables, leurs gros diamètres et leurs poids excessifs. En définitive, une bonne supervision des travaux en forêt, une formation adéquate du personnel et une rémunération conséquente seraient l'une des meilleures solutions à une exploitation durable de la forêt dans le sud Cameroun.

Summary

Forest inventory is an important step in sustainable forest management within the framework of a polycyclic logging. Therefore, it needs some precision according to the objectives assigned. In order to achieve a sustainable forest management, silvicultural considerations must be integrated during forest harvesting inventory (potential crop trees, seed trees, forest architecture,…). On the whole, it is important to give pride of place to the future of the forest before any logging activity in order to guarantee a sustainable production of wood in subsequent rotations. One of the strategies aimed at minimising negative logging impacts, is the reduction of logging damages. In this respect, literature proposes a panoply of measures, which were not feasible in the forest under study, characterised by: low density of harvestable trees, their large diameters, and their enormous weights. In the long run, a good supervision of forest operations, an adequate training of workers and a consequent remuneration of personnel may be one of the best solutions to achieve sustainable logging in south Cameroon.

INTRODUCTION

Les ressources forestières d'un pays constituent un patrimoine qu'il faut gérer. Il convient donc d'en connaître les principales caractéristiques (Hubert, 1984). L'analyse de la ressource en bois se fait grâce aux inventaires forestiers (Minef, 1998). Dans un peuplement forestier de quelque nature que ce soit, l'inventaire forestier se propose de déterminer avec une précision donnée (qui n'est pas forcement la meilleure) un certain nombre de paramètres liés au peuplement lui-même ou plus généralement au massif forestier. De manière plus synthétique, on peut dire que l'inventaire permet d'inventorier une forêt, bien que ce terme ait une acceptation trop étroite en français (Hubert, 1984). En effet l'inventaire forestier couvre un domaine beaucoup plus large qui est fonction des divers objectifs qu'on lui assigne. Le choix des paramètres de l'inventaire est étroitement lié aux objectifs qu'on s'est fixés et classés par ordre de priorité afin de permettre de privilégier (meilleure précision) les plus intéressantes. Dans le présent document, l'objectif principal à privilégier est aménagement durable de la forêt que l'on peut traduire par une équation du type : Aménagement forestier = Exploitation +

[4] Published earlier in Nasi, R. *et al.* (eds.), 1999. La gestion des forêts denses africaines aujourd'hui. CIRAD, Montpellier, France. (Published on CD-ROM).

Sylviculture. Or, exploiter une forêt conduit indubitablement à la formation des dégâts et dans le pire des cas à son dénuement. Si tel est le cas, les aménagements forestiers subséquents se dérouleraient donc dans une biomasse dépourvue d'arbres susceptibles de garantir une production future et satisfaisante de bois d'œuvre. Dès lors, la réduction des dégâts d'exploitation en soi apparaît alors comme une mesure adéquate pour la sauvegarde de ne serait-ce qu'une partie de la production et pour la protection de la biomasse résiduelle. Ainsi donc, n'est-il pas judicieux de se faire une idée de l'avenir de la forêt (lire : des semenciers, des tiges d'avenir, de la structure de la forêt, etc.) avant toute exploitation ? Dans le cadre d'un aménagement durable de la forêt, il semble difficile de répondre par la négation. Par conséquent, nous nous pencherons sur sa faisabilité en intégrant les considérations sylvicoles avant et pendant l'exploitation forestière au lieu de ne les considérer qu'après exploitation. Pour ce faire, nous focaliserons notre attention sur une des étapes fondamentales d'aménagement qu'est l'inventaire forestier suivant le plan ci-dessous :
Bref aperçu du site d'étude ;
Quelques types d'inventaires forestiers en cours au Cameroun ;
Technique d'inventaire forestier d'exploitation couramment utilisée et ses impacts.
Ceci nous permettra alors de dégager éventuellement la nécessité et la possibilité d'améliorer la pratique d'inventaire en cours dans le site en vue de la réduction des dégâts.

I- BREF APPERÇU DU SITE D'ETUDE

Le site d'étude du Programme Tropenbos Cameroun (PTC) fait partie de la forêt dense humide sempervirente. Il est situé entre 2º 47'et 3º 14' de latitude Nord ; 10º 24' et 10º 51' de longitude Est. Il couvre une superficie totale d'environ 200.000 hectares intégrant largement la concession de la compagnie forestière Wijma (compagnie détenue par des étrangers)
Le climat est du type équatorial à 4 saisons. Les précipitations et températures moyennes annuelles sont de 1722 mm et de 25º C respectivement.
Quelques caractéristiques de la forêt du site d'étude :

- Diversité spécifique : riche.
- Espèces exploitables : dispersées.
- Topographie (pentes) : < 20 %.
- Diamètre des arbres : parfois > 200 cm.
- Diamètre moyen : 120 cm.
- Production: 0,5 arbres = 6 m³/ha.

II- TYPES D'INVENTAIRES PRATIQUÉS AU CAMEROUN

On distingue de manière générale trois types d'inventaires au Cameroun (MINEF, 1998) :

1- Inventaire national de reconnaissance : taux de sondage 0,1% ; totalité des forêts ; permet de délimiter les forêts domaniales et les Unités Forestières d'Aménagement (UFA) ;
2- Inventaire aménagement : taux de sondage : généralement 1% ; totalité de l'UFA ; au moment de l'élaboration d'aménagement ou de sa révision : permet de découper les UFA en UFE (Unité Forestières d'Exploitation) et d'estimer la possibilité de l'UFA ;
3- Inventaire d'exploitation : taux de sondage : 100% ; permet une estimation quantitative et qualitative des tiges ; totalité de chaque parcelle ; un an avant l'ouverture de l'AAC (Assiette Annuelle de Coupe) soumise à l'exploitation.

III- TECHNIQUE CLASSIQUE D'INVENTAIRE FORESTIER ET SES IMPACTS

Cet inventaire s'est déroulé dans un bloc de 100 ha de la parcelle I2 -D2 de l'assiette de coupe 1222 de la compagnie forestière Wijma suivant la technique suivante :

1- Matériel et méthode

Matériel: très simple, comprend une boussole, des machettes, un ruban, une corde, des papiers, des crayons et la peinture. Les piquets de jalonnage et les pinceaux sont fabriqués à partir du matériel végétal prélevé sur place en forêt.

La composition de l'équipe : un chef d'équipe, un chaîneur, un marqueur, un boussolier, des machetteurs et des prospecteurs. L'effectif peut atteindre 20 personnes.

Méthode: l'inventaire proprement dit se déroule de la manière suivante :

- A l'aide d'une boussole et d'une machette, l'équipe de prospection ouvre le layon de base (l'une des limites d'une AAC de superficie 2.500 ha) sur une longueur de 5 km dans la direction est-ouest à partir d'un point de base indiqué par le Ministère de l'Environnement et des Forêts (MINEF). Cette AAC est en suite subdivisée en blocs d'inventaires de 100 ha.
- La technique de matérialisation des layons de base et secondaires se résume ainsi : à partir du point de départ d'un layon ouvert par les machetteurs, le chaîneur accroche une corde de 20 m de long à sa ceinture et progresse avec 5 petits bâtons de 5 cm de diamètre et d'un mètre de long environ qu'il fixe dans le sol tous les 20 m. Au dernier bâton, le marqueur qui le suit coupe un piquet, y inscrit 100 m ou l'un de ses multiples et l'implante à l'endroit indiqué. Ce marqueur qui aura par ailleurs arraché tous les cinq petits bâtons sur son passage, les remet à cet endroit au chaîneur et l'opération continue jusqu'au chaînage complet.
- Au moment de la prospection dans un bloc de 100 ha (1000 x 1000 m²) toute l'équipe de prospection retourne au point de base. Chaque prospecteur se place au point d'intersection entre le layon de base et le layon secondaire (tous les 100 m) muni d'un papier simple, d'un petit pot de peinture, d'un crayon et d'une machette. Il reçoit par ailleurs du chef d'équipe une série de 10 nombres qu'il affectera aux arbres prospectés. La prospection ne commence que lorsque le dernier prospecteur signale sa présence effective sur son layon de travail. Chaque prospecteur couvre une bande de 100 m de large (50 m de part et d'autre du layon secondaire). Face à un arbre commercialisable, il lui attribue un numéro, le peint sur une partie de son fût, l'inscrit sur son papier aussi bien que le nom de l'espèce, sa distance approximative par rapport au layon de base et secondaire, et une estimation grossière du diamètre du fût utile.
- Les prospecteurs se déplacent lentement mais pas tous à la même vitesse. Dans sa progression, le prospecteur nº 1 signale à haute voix la présence d'un piquet de distance et la distance correspondante au prospecteur nº 2 qui, à son tour, le répercute au nº 3, et de proche en proche, jusqu'au prospecteur le plus éloigné. Le cortège peut à nouveau s'ébranler.
- Seules les espèces conformes aux exigences du demandeur sont inventoriées. Si le fût utile est très court (< 6m), tordu, ou renfermant beaucoup de nœuds, ou si l'on suspecte que l'arbre serait creux ou malade, le prospecteur y inscrit un signe en forme de V à l'aide de sa machette, ce qui signifie que l'arbre a été effectivement repéré mais ne satisfait pas aux exigences du marché.
- Dans sa progression, chaque prospecteur indique sur son papier les positions des cours d'eau, les pistes pour piétons, les plantations et les campements des pygmées rencontrés. A la fin de la journée, le chef d'équipe transforme ces 10 papiers en un document d'inventaire.
- Au bureau, ces données seront reportées sur des cartes topographiques au 1:5.000 qui ne sont qu'un agrandissement des cartes au 1:200.000.

Remarques: Il ressort de ce qui précède que :

1- Seul un nombre limité d'espèces commercialisables figurent sur la carte. En effet, malgré la présence d'au moins 15 espèces commercialisables sur le marché international, la Wijma focalise son attention principalement sur les espèces aptes aux exigences de constructions marines et de traverses de chemin de fer (*Lophira alata* et *Erythrophleum ivorense*).
2- Seules les espèces commercialisables ayant un diamètre supérieur au diamètre minimum d'exploitabilité et exempts de défauts figurent sur la carte. Les tiges d'avenir n'y figurent pas.
3- Chaque prospecteur couvre une bande de 100 m de large : cette prospection sur une largeur de 50 m de part et d'autre du layon secondaire est sujet à caution dans le site d'étude où la forêt est irrégulière et

dominée parfois par un sous-bois opaque en plus de la présence de nombreuses Arécacées épineuses. Dans ces conditions, il semble donc difficile de ne pas oublier certains arbres.

4- Les positions des arbres par rapport aux layons de base et secondaire ne sont que des approximations. Il en est de même pour les cours d'eau, les pistes, etc.
5- En confrontant les cartes aux réalités du terrain, on trouve parfois que la position des arbres sur la carte ne correspond pas toujours à celle sur le terrain. Dans certains cas, les arbres d'un bloc sont retrouvés dans le bloc adjacent.

2- Impacts de ce système d'inventaire

21- Sur l'efficacité des opérations d'abattage et la réduction des dégâts

Le concept nouveau dans le jargon des techniques d'abattage et de la Réduction des Impacts d'Exploitation (R.I.E) est à n'en pas douter **l'abattage dirigé**. Plusieurs auteurs en font mention (Matsson-Marn et Jonkers, 1981 ; Hendrison, 1990 ; Malmer et Grip, 1990 ; Gullison et Hardner, 1993 ; Cedergren, 1994 ; Pinard *et al.* 1995 ; Pinard et Putz, 1996 ; Johns *et al.*, 1996 ; Whitman *et al.*, 1997) pour les buts suivants : réduction des dégâts sur les tiges d'avenir, facilité du débardage, réduction des dégâts sur le fût à abattre, création des trouées multiples.

Sur les cartes, la position des arbres est représentée par un cercle à l'intérieur duquel sont inscrits : le nom de l'espèce, son diamètre et le numéro de prospection. Ce cercle a sensiblement 1 cm de diamètre ce qui représente 50 m sur le terrain à l'échelle 1:5.000. Par conséquent, la position des arbres sur la carte et les distances qui les séparent présentent d'énormes aberrations. En plus, la séquence d'abattage n'est pas indiquée sur la carte comme le prescrit la littérature.

Le fait marquant cependant est que l'imprécision de ces cartes ne semble généralement pas poser de problèmes sur l'efficacité de l'équipe d'abattage. En effet, la perte de temps pour retrouver le prochain arbre à abattre est négligeable. Ceci s'explique par le faible densité des arbres exploitables, mais aussi et surtout par le fait que l'une des trois personnes de l'équipe d'abattage se transforme en prospecteur et a suffisamment du temps pour localiser l'emplacement exact du prochain arbre et même, de découvrir ceux non prospectés par l'équipe d'inventaire au moment où l'abatteur s'évertue à achever l'abattage d'un arbre ou à le tronçonner (13 à 15% des arbres abattus mais non prospectés).

En ce qui concerne la réduction des dégâts dans la forêt du site d'étude, les expériences menées ont prouvé que l'abattage dirigé est techniquement réalisable malgré les grands diamètres des arbres et la présence des contreforts. Cependant, ces expériences ont mis en exergue le fait que le nombre d'arbres détruits, ébranchés ou écorcés (diamètre à hauteur de poitrine (dhp) > 10 cm) tant par l'application des techniques de l'abattage dirigé que celles dites conventionnelles est sensiblement le même et tourne autour de 18 à 30 par trouée. Parmi ces 18 à 30 arbres/trouée, on y dénombre seulement 1 à 2 tiges d'avenir (dhp > 30 cm) quelle que soit la technique d'abattage utilisée. En d'autres termes, le nombre de tiges d'avenir détruites par l'abattage conventionnel est très faible, mieux encore le nombre de tiges d'avenir à sauver par recours à la technique d'abattage dirigé n'est pas significatif. En outre, le cas des tiges suspendues suite à l'abattage conventionnelle représente moins de 1 % et les dégâts sur le fût ne sont pas inhérents uniquement à cette technique d'abattage. De ce qui précède, les effets bénéfiques attendus de l'abattage dirigé ne se feront ressentir que dans des cas rares dans le site d'étude. Par ailleurs, le délianage non plus n'a pas prouvé son efficacité à réduire l'ouverture de la canopée à cause d'un nombre limité de lianes.

22- Sur les performances et la réduction des dégâts de débardage dans les conditions classiques de l'exploitation forestière.

En ce qui concerne le débardage, les concepts se rapportant à la R.I.E font état entre autres de : la planification détaillée des pistes de débardage sur la carte d'inventaire, la matérialisation de ces pistes dans la forêt, et le débuscage par un déploiement optimal du câble de débardage. Nous allons examiner la faisabilité de tous ces concepts dans le site d'étude et leurs impacts sur les performances du débardage et la réduction de dégâts.

221- Planification des pistes de débardage

La planification des pistes de débardage au sens de la R.I.E ne se limite pas seulement à une simple indication des pistes de débardage primaires et secondaires. Ici, on doit planifier tous les mouvements des engins et l'ordre d'extraction des billes. Ceci a pour résultante une carte spéciale avec une légende appropriée. Cette planification a été réalisée sur une carte d'inventaire au 1:5.000 pour l'extraction de 165 billes par un caterpillar 528 (Cat.528).

222- Matérialisation des pistes de débardage dans la forêt

Beaucoup d'auteurs recommandent de le faire à l'aide de la peinture ou par des flaches sur certains arbres. Ceci peut se faire avant ou après abattage. Dans le site, on l'a fait après abattage en utilisant de la peinture et en présence du conducteur du Cat. 528 afin de lui donner l'occasion d'apprécier lui-même ses aptitudes à négocier certains obstacles dans le tracé. Mais au moment du débardage, la réalité fut autre. L'appréciation du conducteur une fois sur son engin était par endroit très différente de celle qu'il avait hors de son engin. D'où parfois la nécessité de dévier du tracé primaire ou de créer des pistes parallèles parce que le sol ne pouvait plus supporter le passage répété du Cat.528. En définitive, l'ordre d'extraction des billes fut modifié considérablement.

223- Débuscage

Le débuscage a généralement pour vocation de réduire les dégâts en ce sens qu'il réduit les mouvements des engins autour de la souche. A cet effet, on dispose les billes de telle manière que les engins ne puissent pas s'écarter des pistes secondaires en vue de les atteindre grâce au câble qui les traîne sur une distance de 30 à 50 m sous l'action du treuil.

Le débardage de ces 165 billes a montré de grandes limites dans l'applicabilité de ce concept de la R.I.E. Le temps de l'élingage ne s'est pas amélioré même avec l'utilisation d'un bâton spécial de débardage à cause des grands diamètres des grumes (Ø > 100 cm) et de leurs poids (> 6 tonnes). En effet, ce bâton n'est pas fonctionnel dans la plupart des cas. Par ailleurs, les essais de débuscage ont souvent conduit à des effets contraires, l'engin reculant sous le poids de sa charge créant ainsi des dégâts parfois insoupçonnés. La technique dite "herring-bone" n'est non plus applicable ici à cause des mêmes raisons. En somme, il apparaît donc que lorsque la densité des arbres exploitables est faible, les arbres de grandes dimensions et lourds, la nécessité et la possibilité de passer de la méthode conventionnelle à la méthode préconisée par la R.I.E. ne sont pas évidentes.

CONCLUSION

Compte tenu de la nécessité d'intégrer les considérations sylvicoles, écologiques et sociales dans l'exploitation forestière dans le sud Cameroun, l'inventaire forestier d'exploitation a besoin de plus de précisions. A cet effet, la cartographie devra tenir compte des tiges d'avenir et les semenciers qu'on protégerait dans la mesure du possible. Pour y parvenir, la surface de prospection couverte par un ouvrier devrait diminuer pour minimiser "l'oubli" de certaines essences. Ces informations additionnelles exigent également une amélioration de l'échelle des cartes d'inventaire. Cependant, comme il est souvent admis que le nombre d'arbres à y reporter double juste en prenant en compte les arbres de 10 cm en dessous du DME (Diamètre Minimum d'Exploitabilité) et triple quand on prend en compte les arbres de 20 cm en dessous du DME, on risquerait se retrouver devant un stock d'arbres qu'on ne pourrait localiser que dans des cartes à très grande échelle. Mais le principal reproche formulé à l'égard de ces cartes à grande échelle est qu'elles ne sont pas très pratiques sur le terrain, il est en effet plus facile de manager une seule carte à petite échelle sur le terrain que plusieurs feuillets d'une même carte à grande échelle. Reste donc à trouver l'échelle la plus appropriée qui allie maniabilité et efficacité en forêt.

Les concepts de la R.I.E. sont des aspects de la “foresterie de précision”. On peut améliorer la précision de l’inventaire en y incluant autant d’informations possibles dictées par la littérature, mais on n’arrivera jamais (ou difficilement) à la “foresterie de précision” sans : 1) des forestiers de terrain qui en plus de ces données importantes d’inventaire acceptent de se donner la peine d’entrer en forêt pour une supervision rapprochée des opérations, 2) une formation adéquate des ouvriers en fonction des objectifs poursuivis, 3) une rémunération conséquente.

BIBLIOGRAPHIE

Cedergren, J., Falck, J., Garcia, A., Goh, F. et Hagner, M., 1994. Reducing impact without reducing yield. *Tropical Forestry Update* 4(3): 9-10.

Gullison, R.E. et Hardner, J.J., 1993. The effects of road design and harvest intensity on forest damage caused by selective logging: empirical results and simulation model from the Bosque Chimanes, Bolivia. *Forest Ecology and Management* 59: 1-14.

Hendrison, J., 1990. *Damage-controlled logging in tropical rain forest in Suriname*. Ecology and Management of Tropical rain forest in Suriname 4. Wageningen Agricultural University, Wageningen, the Netherlands. 204p.

Hubert, L., 1984. *Cours d’inventaire forestier*. Centre Universitaire de Dschang, (ENSA), Dschang, Cameroun. 278 p. (document interne).

Johns, J.S., Barreto, P. et Uhl, C., 1996. Logging damage during planned and unplanned logging operations in the eastern Amazon. *Forest Ecology and Management* 89(1): 59-78.

Malmer, A. et Grip, H., 1990. Soil disturbance and loss of infiltrability caused by mechanised and manual extraction of tropical rain forest in Sabah, Malaysia*. Forest Ecology and Management* 89(1): 59-78.

Mattsson-Marn, H. et Jonkers, W.B.J., 1981. *Logging damage in tropical high forest*. FAO. FO: MAL/76/008. Working paper Nº 5. UNDP/FAO Forestry Development Project Sarawak, Kuching, Malaysia.

MINEF, 1998. *Directives nationales pour aménagement durable des forêts naturelles du Cameroun*. Ministère de l’Environnement et des Forêts, Yaoundé, Cameroun. 43 p.

Pinard, M.A. et Putz, F.E., 1996. Retaining forest biomass by reducing logging damage. *Biotropica* 28(3): 278-295.

Van Der Hout, P. et Van Leersum, G.J.R., 1998. *Reduced impact logging: a global panacea?* In: Tropenbos. Research in tropical rain forests: its challenges for the future: 185-203. The Tropenbos Foundation, Wageningen, the Netherlands.

Van Leersum, G.J.R. et Okie, S., 1995. *Forest inventory practices in the Wijma concession in south Cameroon*. Intermediate studies. Tropenbos Cameroon Programme. 18 p. (document interne).

Whitman, A.A., Brokaw, N.V.L. et Hagan, J.M., 1997. Forest damage caused by selection logging of mahogany (*Swietenia macrophylla*) in northern Belize. *Forest Ecology and Management* 10: 313-322.

LISTE DES ABRÉVIATIONS

AAC : Assiette Annuelle de Coupe
DBH : Diameter at Breast Height (diamètre à hauteur de poitrine)
DME : Diamètre Minimum d’Exploitabilité
MINEF : Ministère de l’Environnement et des Forêts
PTC : Programme Tropenbos Cameroun
RIE : Réduction des Impacts d’Exploitation
UFA : Unité Forestière d’Aménagement
UFE : Unité Forestière d’Exploitation

Logging In south Cameroon: current methods and opportunities for improvement[5]

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SUMMARY

Forestry operations in the rainforests of south Cameroon should be adapted to the prevailing physical, biotic and socio-economic conditions. Terrain used for logging is often steep and rugged. The forest contains many very large trees, but few of those belong to marketable species. Forest is an important resource for the population, and forestry should be planned and executed in close consultation and/or cooperation with them. Much effort has been put in improving forest management, but logging operations have changed little in recent years. Less than one tree/ha is felled, and logging damage is therefore limited. About 30% of the felled timber are left in the forest. Some elements of Reduced Impact Logging, such as winching and improved instruction and supervision, can reduce logging damage, wastage and negative effects for the local people and wildlife substantially, but other elements, such as liana cutting and directional felling, are less suitable under the prevailing conditions.

Keywords: logging, forest management, rainforest, Cameroon

INTRODUCTION

Efforts have been made in many countries to reduce logging damage in rainforests. Early publications by Mattson Marn and Jonkers (1981) and Hendrison (1990) indicated that considerable damage reduction can be achieved by introducing proper planning procedures and rather simple modifications in existing logging methods. In the 1980s and 1990s, there was a growing awareness of the need to manage rainforests in a sustainable way, and this led, among others, to more attention for reduced impact logging (RIL). Many studies were executed in Asia, Australia and Latin America (e.g. Crome *et al.,* 1992; Blate, 1997; Johns *et al.*, 1996; Webb, 1997; Van der Hout, 1999; Bertault and Sist, 1995; Pinard and Putz, 1996; Cedergren *et al.*, 1994), and all these advocate similar changes in logging methods.

In Africa, RIL received less attention. In Cameroon, two RIL studies have been executed. The Tropenbos-Cameroon Programme (TCP) started in 1994 with RIL and other studies aimed at developing methods and strategies for sustainable rainforest management. Another study was executed in the eastern part of the country (Durrieu de Madron *et al.*, 1998).
Cameroon has an enormous diversity in climatic, physiographic and biotic conditions, and in people. Rainforests occur in the south of the country. The 200,000 ha Tropenbos research site is located in the South Province, 50 - 100 km from the coast. Logging methods should ideally be adapted to the physical and biotic environment and to socio-economic conditions in the region for which they are developed. These aspects are therefore discussed before going into more technical aspects.

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THE SOCIAL DIMENSION

The population density in most of the rainforest zone of Cameroon is 5 -15 people/sq. km, but there are also large uninhabited areas, especially in the east, and densely populated areas near cities and in areas with fertile volcanic soils.
There are many ethnic groups in the rainforest zone. In the TCP site alone, there are five Bantu ethnic groups and the Bagyeli pygmies. The Bantu main means of subsistence is shifting cultivation. Nevertheless, they heavily depend on bushmeat for their protein supply, and also use many other non-timber forest products (Van Dijk, 1999). The Bagyeli form a small minority. Although they practise shifting cultivation, their main means of subsistence are gathering and hunting. A Bagyeli family is strongly linked with a particular Bantu clan, with whom they exchange forest produce for agricultural goods.

Forest management and logging operations should be compatible with the way of living of the local people, and with their traditional law. In this traditional law, there hardly exists property of land. It is rather a "bundle of rights" where one family or individual may have the right to practise agriculture on a piece of land, while others may have the right to hunt or to collect other forest produce. This offers opportunities for combining timber production and the use of forest resources by the local people.

PHYSICAL AND BIOTIC FEATURES

The TCP site is located on poor soils of the Pre-Cambrian Central African Shield. The physiography is undulating in parts, but more often hilly or mountainous and highly dissected. Easily accessible parts are mostly used for shifting cultivation, and logging has to be practised mainly in difficult terrain. Substantial tracts of land are too steep for agriculture as well as logging, and are used only for gathering and hunting.

The rainforests of Cameroon vary considerable in species composition. There is a clear sequence of vegetation types from the very humid coastal zone towards the somewhat drier areas further to the north and east. According to Letouzey (1985), the rainforest at the TCP site belongs to the mid-altitude evergreen forest dominated by Ceasalpinaceae. This family is indeed well presented, but the most important timber species is Azobé (*Lophira alata*), which is characteristic for the low altitude evergreen forest. A recent survey showed a basal area of 34 m^2/ha, which is well above the pan-tropical average. The number of species found among trees >10-cm dbh ranges from 70 to 86 per hectare (Foahom and Jonkers, 1992). Vegetation is highly influenced by man. This applies particularly for the extensive areas of secondary forest, but also for most "primary" forests. In past centuries, when the people lived scattered in the forest, shifting cultivation was practised with primitive tools, and large trees were often spared on fields because they were difficult to fell. This seems to have had a long lasting impact on the forest structure.
Remarkable is the high number of very large emergent trees (Table 1). These giants reach heights of 50-60 meters, and their trunk diameters often measure 1 to 2.5 meters or more. Unfortunately, only some of these trees belong to marketable species, and the average logging intensity is well below one tree/ha. Noteworthy is also that the spatial distributions of large trees of Azobé and some other timber species are clumped. Felling tends to be concentrated in such clumps, and other parts of the forest are affected little by felling. As these species regenerate well on shifting cultivation fields, and hardly in undisturbed forest, such clumps are believed to originate from such fields abandoned in past centuries.

Table 1. Diameter class distribution in a Cameroonian rainforest (165 ha, n/ha)

10-30 cm dbh	30-50 cm dbh	50-70 cm dbh	70-100 cm dbh	> 100 cm dbh
379.3	55.1	17.0	8.5	7.1

The fauna in most forests is not particularly rich because of hunting pressure. Logging also has an impact on fauna. The noise of logging equipment chases larger animals away, and it may take many years before they return. Moreover, it stimulates hunting as logging tracks provide easy access to the forest and because demand for bushmeat increases due to the presence of logging personnel (Van Dijk, 1999).

FOREST MANAGEMENT PLANNING

The forestry situation in Cameroon is changing rapidly. Until recently, gazetted permanent production forest was almost non-existent, and timber production was in fixed-term concessions of one to five years. Since 1999, short-term concessions are no longer issued and large permanent forest management units are being established, for which forest management plans have to be made. Concepts for such plans have been developed, and are being elaborated further. With evolving insights in the complexity of managing Cameroon's forests, management plans are becoming increasingly complex. From a purely timber production oriented plan, the concept now develops into a detailed scenario including the rights and obligations of all actors concerned during the preparation and execution of the plan (ONADEF, 1991; 1997), and local people's participation.

In Cameroon, forest management planning should include land-use planning to determine the exact boundaries of permanent production and protection forest in consultation with the local people. After marking the boundaries, annual logging coupes will have to be planned in time and space and the annual yield has to be determined, based on a forest inventory and again in consultation with the population. To allow people to hunt and to preserve the fauna, an annual coupe should not cover a large continuous area and completely surround a village, but rather of logging compartments that are not adjacent to one another.

Thereafter follows the operational planning of logging and other forestry activities within the first annual coupe. A specification of how logging should be executed has to be part of forest management planning, based on adequate rules and regulations. In Cameroon, however, the official 'Guidelines for logging enterprises' (MINAGRI, 1988) hardly poses restrictions on skidding and felling other than minimum felling limits, but forest inventory rules exist (ONADEF, 1992).
A logical set of harvesting and management guidelines is required for proper monitoring during and verification after the lease period of a concession. It should be possible to hold a concessionaire accountable for needless logging damage. Ideally, the concessionaire should also be obliged to switch to production technologies, which further reduce damage to the residual stand.

CONVENTIONAL LOGGING

In order to assess the need for improvements in logging methods, the operations of one of the best-organised logging companies in Cameroon and the resulting damage were studied.

Logging operations
Before logging starts, the company arranges compensations for possible damage to agricultural fields and other losses and inconveniences with the villagers. The operations start with a 100% inventory. Only trees, which the concessionaire wants to harvest, are enumerated and plotted on 1:5,000 maps. These trees are always very large, and produce timber of export quality. Their average diameter is 116 cm and their average bole volume 13 m³. Maps are used for harvest and marketing planning, for truck road alignment and for felling, and occasionally also for skidding.

Felling is done in teams of two or three men. The felling technique is simple, and trees are usually felled in the direction of their natural lean. The direction is rarely but successfully altered in case of possible damage to agricultural fields. Trees are subsequently crosscut and topped without any information on log lengths desired further down the production chain. Felling productivity is three trees per effective working day per feller.

Skidding is carried out with D7 dozers and Caterpillar 528 skidders. The D7 constructs trails to felled trees and prepares logs for skidder transport to the landing. Trail construction is mostly from felling gap to felling gap and is seldom guided by inventory maps. Logs are skidded one at a time, and skidding on steeper slopes than 20% is avoided. The large log sizes and difficult terrain lead to a production of only five logs per skidder per day. At the landing, logs are further crosscut to improve their appearance. Log transport is by trucks with a loading capacity of 25-35 tonnes.

Logging administration and reporting comprises recording of the daily production per crew. The system serves for payment of bonuses and monitoring of stocks in the forest and on the landing. The administration forms for felling, skidding and transport are poorly attuned. As tree and log numbers on the various forms do not correspond, these records cannot be used for monitoring the production chain.

Logging damage

Logging damage was studied in twelve 25-hectare plots, randomly chosen within a 2500 ha working coupe. Only 5% of the area incurred disturbance as result of logging (Table 2). This can be soil compaction or vegetation clearing by logging machines, or damage caused by falling trees. Disturbance is so low because only 0.3 trees/ha were felled, which is substantially less than the 0.7 harvestable trees/ha recorded in the inventory.

Table 2: Logging damage in twelve 25 hectares plots

Logging activity	Damage level (% area disturbed)
Felling	1.4%
Skidding	1.1%
Road and landing construction	2.7%
Total	5.1%

The main reason for the low production is that parts of the forest were not entered because of steep slopes, poor stocking and/or presence of agricultural fields. It is therefore not surprising that damage per plot varied considerably, ranging from 0% to 25% in the plot with the highest felling intensity (1.8 trees/ha felled). Another reason for the low yield was that the concessionaire had temporarily increased the minimum felling diameter and reduced the list of species to be harvested because of low timber prices.

It is remarkable that half of the damage was caused by truck road and landing construction, which is usually a minor cause. This is because the terrain is highly dissected, and roads were built on each of the many ridges. Furthermore, roads were made very wide to allow quick drying after rains. Log landings were also oversized, and unnecessary landings were made, that is, landings without connecting skid trails. The crews had been instructed to create landings every 500 meters, which was observed rigidly. About 30 % of the damage due to roads and landings could have been avoided.

Avoidable skidding damage includes dual trails, shortcuts and trails not leading to a felled tree. About 20% of this type of damage could have been avoided, and was caused by:

- Rain and unstable, saturated ground conditions. This is considered the single most important factor. Skidding continues in bad weather until the output is almost zero, leading to rapid deterioration of the trails, which can sometimes be used for only one passage.
- Lack of supervision. Machine operators can set their own standards of work. As long as they produce enough logs, their supervisors remain on the landing and inspect only logs that reach there.
- Lack of environmental awareness among operators and supervisors. Few operators see a need for damage reduction, and most feel that the forest will recover anyway.
- Dozers entering felling gaps. Needless manoeuvring in felling gaps caused 10% of the total skidding damage.

Reducing the area of felling gaps by making gaps overlap is not feasible, as distances between felled trees are generally too large. The large distances between harvestable trees also reduce the need for careful planning of felling directions to facilitate skidding, as it is always possible to approach logs under the best possible angle. Directional felling may be useful for preserving future crop trees and trees producing non-timber forest products.

Timber recovery
Part of the harvestable timber does not reach its final destination. Reducing timber wastage is an aim of RIL, as it makes the operation economically more attractive. Timber losses were therefore investigated.
The quantity of timber delivered at the sawmill was 70% of the amount felled. Most losses occurred during felling (21%). As much as 7-10% was lost because good-quality top parts of the stems were cut off and left in the forest. Other felling losses consisted mostly of inferior timber such as conical butt ends and hollow or poorly shaped trunks.
Losses due to skidding (4%) consisted mainly of good-quality logs left along trails. At landings, another 4% loss occurred, mainly due to cutting off both log ends to give the timber a better appearance. Some good logs were left at landings due to oversight.

Underlying causes for timber losses during logging are:
- High quality demands imposed by the sawmill and sales branch of the company.
- Natural factors like tree rot.
- Poor reporting and administrative procedures. The log flow is not monitored in a way that timber losses can be traced.
- Inadequate monitoring and supervision, especially in relation to the quality of the work, e.g. assessing abuse of machines, need for training among operators, wastage and logging damage.
- Remuneration and incentives for forest labourers. These payments are based on quality and quantity of timber arriving at landings and not on easily obtainable indicators for the quality of their work such as the volume recovered per tree harvested.

REDUCED IMPACT LOGGING

Conceptual framework
When devising a RIL method, a wide range of harvesting operations and pre- and post-logging activities has to be considered. Table 3 provides a list of such operations, which is based on above-mentioned and other publications (e.g. FAO, 1996) as well as the authors' views at the onset of the project. This list was used as a conceptual framework in the TCP logging research. The study looked into the technical feasibility of the elements and the need of their introduction in Cameroon.

Table 3: Potential elements for a RIL method for tropical rainforest.

Harvesting phase:	Features/issues/purpose
Inventory	
Scale of maps	1: 5000, balance between information density and size
Full topography	Location of dissections in terrain, obstacles to skidding
Inventory unit size	20-50 ha, prospector density and communication
Marking/mapping of timber trees	including their natural lean
Marking/mapping of PCTs	Preserve potential crop trees (PCTs)
Marking/mapping of NTFP trees and sites	Safeguard supply of non-timber forest products (NTFPs)
Report	Submit information to planning department

Table 3 (cont'd): Potential elements for a RIL method for tropical rainforest.

Harvesting phase:	Features/issues/purpose
Planning	
Assignment of buffer zones	Forest protection within working coupes
Tree selection:	
*Assignment of trees to be preserved	Seed trees, trees of importance to local people
*Assignment of trees to be felled	Percentage of harvestable stock
*Felling pattern	Scattered or clumped
Felling direction	Avoiding NTFP trees, PCTs, adverse angle with trail, single or multiple tree felling gaps
Skid trail alignment	Design system of unambiguous, shortest tracks
Report	relay planning outcome to local people/ prescriptions to field crews
Report	Feed back alignment results to planning
Other pre-felling activities	
Climber cutting	Well in advance, at individual tree level
Girdling of timber trees	Reduction of crown weight
Marking of skid trails	Extra orientation for felling direction of trees
Road and landing construction	
Clearing width	Depending on orientation towards sun
Wildlife corridor	Connected crowns of bordering trees
Durability	Shape, compactness, top layer material
Felling	
Tree selection	Only felling of trees indicated by planning
Felling direction	Check whether planned direction is realistic
Directional felling	Avoid damage to PCT and NTFP trees, avoid unfavourable angles
Cross-cutting	} Avoid skidding problems
Topping	} According to log size preferences outside forest
Report	Relay information to skidding crews, feedback planning department.
Skidding	
Marking of skid trails	Present unambiguous trail to operator
Construction of skid trails	Computer aided, computer controlled?
Construction of creek crossings	Hollow trees as culverts, feller present
Stump operations/winching of logs to trail	Reduction tertiary trails/stump site damage, communication
Skidding to landing	Remain on trail, terrain conditions

Table 3 (cont'd): Potential elements for a RIL method for tropical rainforest.

Harvesting phase:	Features/issues/purpose
Report	Relay information to transport crew, feed-back planning department
Post-harvest operations	
Felling gaps	Sanitary operations on trees, diseases, growth stimulus
Skid trails	Ploughing, blocking, removal of culverts
Main roads	To remain open for local population
Feeder roads	Blocked to prevent re-logging and hunting
Bridges	Blocked to prevent re-logging and hunting
Landings	Ploughing, 60 cm depth

Field experiments

Potential adaptations to conventional logging, aimed at damage reduction, were identified and tested individually. Thereafter, a field comparison (200 ha) was made between conventional and modified logging. The analysis of this experiment is yet to be finalised. Furthermore, the impact of liana cutting on logging damage was assessed in a 28 ha experiment. Liana cutting nine months before felling was compared to a control treatment.

Summary results

<u>Liana cutting</u>

Liana cutting did not have a noticeable effect on felling damage, in spite of the large numbers of lianas present (Parren and Bongers, 1999). This is probably because felled trees are all emergents, which tower high above surrounding trees. Lianas in such emergent trees seldom connect crown of these trees to neighbouring crowns, and therefore contribute little to felling damage.

<u>Harvest inventory and skid trail alignment</u>

With the available level of topographic precision, detailed tree inventory data are not sufficient to plan logging operations in difficult, irregularly dissected terrain. Enlarged topographic maps used to plot inventory results are too inaccurate for 'precision forestry' purposes. When designing a skid trail system, a double field check is needed before marking trails. Even then, frequently used trails deteriorate, forcing the machines to deviate from the intended pattern. Alignment of skid trails based on detailed inventory maps was tried. The outcome was that the skid trail pattern is determined mainly by terrain conditions. However, involving local villagers in skid trail alignment with the aim to protect sites important to them is a promising option, and so is the use of topographic information from aerial photographs, remote sensing or radar imagery. Geographic Information Systems can also be of use (Durrieu de Madron *et al.*, 1998).

<u>Felling</u>

Directional felling proved to be technically feasible. Only the very few trees without a clear natural lean are difficult to fell in a desirable direction. Directional felling can serve to protect potential crop trees and trees yielding non-timber forest products. However, damage to trees to be preserved is low under conventional felling and preliminary results indicate that directional felling hardly reduces damage. The main reasons are the scattered spatial distribution of trees to be preserved and the horizontal visibility, which is usually 30 meters or less while the bulk of a felled tree's crown penetrates the crown layer at a larger distance. This makes it difficult for fellers to choose a proper felling direction. By far the largest improvements are expected from refresher courses in controlled felling and improved crosscutting instructions.

<u>Skidding</u>
Skidding offers little scope for improvement along lines developed outside Africa. Reduction of tertiary skid trails through winching and pre-felling alignment of trails on the basis of a detailed harvest inventory were considered promising techniques in this respect, and have been tried. Winching over long distances was seldom possible because of log weights and volumes, obstruction by the bucked, conical butt end and hilly and slippery terrain. Winching over short distances gave better results.
Supervision of skidding operations has immediate positive effects on damage reduction. Restrictions related to rainfall also has a positive impact on damage, but leads to output reductions in all production phases that may outweigh the benefits.

DISCUSSION

Logging damage has been measured in the concession of a comparatively well organised enterprise, which applies planning and control. Although logging methods have improved little in recent years (see Evans, 1990; Gartlan, 1990), comparison of this operation with the full range of RIL elements is unlikely to show dramatic differences under the current low harvest intensities. About 20% of the damage can be avoided, meaning that logging damage could have been 4% instead of 5%. No doubt a comparison with practices of less organised enterprises puts RIL in a more favourable position.
Still, there is a need to reduce damage, not only to preserve future crops, but also to reduce negative effects for the local population and wildlife. The concepts and activities to achieve this are not new, with the exception of involving the local population directly in forestry activities. Better communication, reporting and supervision will diminish damage and improve the utilisation rate of felled timber.

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REFERENCES

Bertault, J-G and Sist, P. (1995). Impact de l'exploitation en forêt naturelle. *Bois et Forets des Tropiques* 245(3): 15-20
Blate, G. (1997). Sustainable forest management in Brazil. *Tropical Forestry Update* 7(3): 14-15
Cedergren, J, Falck, J, Garcia, A, Goh, F, and Hagner, M. (1994). Reducing impact without reducing yield. *Tropical Forestry Update* 4 (3) 9-10
Crome, F H J, Moore, L.A. and Richards, G.C. (1992). A study of logging damage in upland rainforest in north Queensland. *Forest Ecology and Management* 49: 1-29
Durrieu de Madron, L., Forni, E. and Mekok, M. (1998). *Les techniques d'exploitation à faible impact en forêt dense humide camerounaise*. Série Forafri Document 17, CIRAD-Forêt, Montpellier, France.
Evans, W.R. (1990). *The sustainability of logging in Cameroon: selected case studies*. Fountain Renewable Resources, Banbury, United Kingdom.
FAO. (1996). *Forest Codes of Practice: contributing to environmentally sound forest practices.* FAO Document 133, Rome, Italy.
Foahom, B. and Jonkers, W.B.J. (1992). *A Programme for Tropenbos Research in Cameroon*. The Tropenbos Foundation, Wageningen, The Netherlands.
Gartlan, S. (1990). *Practical constraints on sustainable logging in Cameroon*. Paper presented at the Conférence sur la conservation et l'utilisation rationnelle de la forêt dense d'Afrique Centrale et de l'Ouest. African Development Bank, IUCN, WorldBank, Côte d'Ivoire.

Hendrison, J. (1990). *Damage-controlled logging in tropical rainforest in Suriname*. PhD thesis, Wageningen Agricultural University, Wageningen, The Netherlands.

Johns, J S, Barreto, P, and Uhl, C. (1996). Logging damage during planned and unplanned logging operations in the eastern Amazon. *Forest Ecology and Management* 89(1): 59-78

Letouzey, R. (1985). Notice de la carte phytogéographique du Cameroun. P. Lechevalier, Paris, France.

Mattson Marn, H. and Jonkers, W.B.J. (1981). *Logging damage in tropical high forest*. Project FAO/MAL/76/008 working paper 5, Sarawak Forestry Department, Kuching, Malaysia.

MINAGRI (1988). *Guidelines for logging enterprises*. Ministry of Agriculture, Yaoundé, Cameroon.

ONADEF (1991). *Canevas de Plan d'Aménagement Forestier*. Office National de Développement des Forêts, Yaoundé, Cameroon.

ONADEF (1992). *Normes d'inventaire de reconnaissance des ressources forestières*. Office National de Développement des Forêts, Yaoundé, Cameroon.

ONADEF (1997). *Guide d'élaboration des plans d'aménagement des forets de production du domaine forestier permanent de la République du Cameroun*. Office National de Développement des Forêts, Yaoundé, Cameroon.

Parren, M. and Bongers, F. (1998). *Forest lianas and pre-felling climber cutting in southern Cameroon*: a silvicultural evaluation. Paper presented at the Forafri conference, Libreville, Gabon, October 1998.

Pinard, M A. and Putz, F E. (1996). Retaining forest biomass by reducing logging damage. *Biotropica* 28(3):278-295

Van der Hout, P. (1999). *Reduced impact logging in the tropical rain forest of Guyana*. Tropenbos-Guyana Series 6. Tropenbos-Guyana Programme, Georgetown, Guyana.

Van Dijk, J.F.W. (1999). *Non-timber forest products in the Bipindi-Akom II region, Cameroon*. Tropenbos-Cameroon Series 1. Tropenbos-Cameroon Programme, Kribi, Cameroon.

Webb, E L. (1997). Canopy removal and residual stand damage during controlled selective logging in lowland swamp forest of north-east Costa Rica. *Forest Ecology and Management* 95: 117-129.

Improvements in logging methods

W.B.J. Jonkers (editor)[6]

Summary

A Reduced Impact Logging (RIL) method was compared to conventional logging as practiced in Cameroon. Results show that RIL leads to a substantial reduction in logging damage, and indicate that RIL is not more costly than conventional logging.

Introduction

Based on the experiences, described in the earlier articles included in this document, a provisional Reduced Impact Logging (RIL) method was designed for further testing. The improvements to be tested included a detailed pre-felling inventory, directional felling, and modifications in skidding operations. Improvements in road and landing alignment and construction and post-harvest operations could not be included in the test, although such improvements are certainly worth considering. Pre-felling activities other than marking of skidtrails were also not included, as previous tests had shown them to be ineffective. This experimental logging method was compared with the concessionaire's conventional logging practice in terms of productivity, efficiency in timber utilisation and logging damage.

The test was executed in the period November 1997- January 1998. A test site was chosen near Mvié, in the southern part of the TCP research area. The terrain at this location is steep and hilly, and comparable to the research site near Ebom, where earlier experiments were conducted (see Jonkers and van Leersum, this volume). The landscape thus posed the same kind of access problems for the logging operations, and was classified as marginally suitable for timber production (Hazeu *et al.*, in press). Furthermore, the weather conditions during the test were unfavourable. The high precipitation hampered not only the skidding operations, but also the data recording. This site was richer in harvestable trees than most of the TCP research area.

Objective of the test

The objective of the study was to assess the impact of specific improvements in logging operations on logging damage and input of manpower and machinery.

Logging methods

The logging methods compared in the test are the following:

Conventional logging is the concessionaire's existing practice, as described in the other articles in this document. It is one of the best organised logging operations in Cameroon, executed with good machinery, by on-the-job trained forest labourers with a salary and bonus scheme, and guided by experienced supervisory staff. There is a fair amount of operational planning. The operations include:
- a full inventory in 100-hectare blocks of harvestable trees above 80 cm dbh. The mapping scale is 1:5000, and tree positions given are indicative only. Terrain characteristics like streams, gullies and slopes are indicated, but no contour lines (for more details, see Ngibaot and van Leersum, this volume);
- chainsaw felling following the natural lean;
- road and landing construction with D8 bulldozers;
- skid trail construction with D7 bulldozers; and
- log skidding with Caterpillar 528 wheeled skidders.

D7 dozers may also be used for log recuperation. Skidder operators may apply winching.

Experimental logging differs from conventional logging in the following respects:
- the pre-felling inventory is more precise and detailed. Tree positions and topographic features are assessed more exactly. The 100 ha blocks are divided in 100-m wide strips, surveyed by a ream of 5 men. The

[6] Based on the work of G.J.R van Leersum, E. Laan and F. Ngibaot.

inventory results are mapped at scale 1:2000 to allow for plotting of felling directions and the alignment of the skid trails prior to their construction.
- directional felling is prescribed. Whenever possible, the tree is directed away from potential crop trees visible from the stump and into an existing (felling) gap or a young patch of forest. The direction of fall has to remain within 90 degrees from the tree's direction of natural lean;
- pre-felling skid trail alignment is applied, aimed at minimising skidding distances and the area under trails;
- skid trail construction is with Caterpillar 528 skidders whenever possible;
- winching of logs from the stump to the skid trail is applied wherever possible; and
- controlled skidding, using Caterpillar 528 skidders whenever possible and applying a logical sequence of the skidded logs, return trips over the same tracks (no loops) and a careful approach of the logs to reduce damage in the stump area to the minimum.

In situations where wheeled skidders cannot operate, D7 bulldozers are used.

Methodology

The experiment consisted of two adjacent 100-ha blocks, separated by a main logging road. Conventional logging was applied in one block, and experimental logging in the other. Centrally in each block, there is an assessment plot of 33 ha. Harvest intensity in both blocks was about 1.5 trees/ha. Care was taken that data recording did not interfere with the logging operations. In the experimental logging block, a Cameroonian feller was employed who had successfully followed a field course on directional felling, given the year before by two felling instructors from the IPC Vocational Training Centre in Schaarsbergen, the Netherlands.

In the assessment plots, the following aspects were studied:
- inventory and work preparation;
- felling efficiency (time and methods);
- felling damage (gap areas, damage to trees);
- skidding efficiency (time and methods);
- skidding damage (area under skid trails).

Felling damage to trees was assessed for marketable species, which had attained a diameter at breast height (dbh) of 10 cm or more. Marketable species in this context means species currently harvested by the concessionaire. These are *Distemonanthus benthamianus, Entandrophragma utile, Erythrophleum ivorense, Lophira alata*, *Milicia excelsa, Pterocarpus soyauxii* and *Staudtia kamerunensis*. This category, which represents only a small proportion of the entire tree stand, was chosen because a tree feller should be able to recognise the species.

Logging activities were as described in the previous section. In the method and time studies, all activities were recorded in principle, and so was the time required per activity and per tree, using stopwatches. Planned and actual felling directions were recorded, and log volumes were measured. In conventional logging, the planned direction is the direction of natural lean. It was intended to follow the experimental and conventional methods simultaneously with two research crews and to establish complete sets of data per individual tree from felling to landing. This could not be fully achieved, partially because logging activities could not be delayed by data recording, meaning that there was a time constraint, which led to missing data, and partially because of logistic constraints and bad weather. The fieldwork of the conventional inventory could not be studied because it had been completed in the absence of the research team.

The areas damaged were measured. The lengths of skid trails were recorded, and the width was assessed at regular interval (50 m). Gaps were defined as openings in the canopy, and assessed with the Brokaw (1985) method.

Felling damage to trees was recorded in two categories: fatal damage (stem uprooted, split, bent or broken, bark injured over more than 30% of the stem circumference and/or more than 25% of the crown lost) and other injuries. Recording was done after felling, meaning that a few completely destroyed trees may have been overlooked. Skidding damage to trees was not assessed, as too many affected trees were destroyed beyond recognition.

Results

Inventory

The experimental inventory method is described in detail elsewhere in this document (Ngibaot and van Leersum, this volume). The main difference between this method and the current common practice in logging operations

is, that in experimental logging, a 100-m wide inventory strip is surveyed by a team of five, whereas in the conventional practice, a team of two has to cover the entire forest. Furthermore, in the conventional method, the two men together assess the same trees, while in the experimental set-up, each team member does all recording in his part of the strip. This change allows a more precise localisation of the timber trees and terrain features. Still, the number of man-hours required for the experimental operation is only 0.5 man-days/ha. Time required for the conventional method could not be assessed accurately, but seems only slightly less than in the experimental inventory. This is mainly because in the conventional system, the inventory team often walks more or less zigzag from one tree to another, while in the experimental method prospectors can proceed almost in a straight line.
In the conventional method, it took the crew's foreman one day to prepare the 1:5000 inventory map. On this map, the harvestable trees were represented by their inventory codes, written in circles of 11-cm diameter, corresponding to 55 meters in the field. Rocky outcrops and slopes in the terrain were seldom indicated.
This kind of map allows a rough indication of where and how skid trails could best open up the block. The map may also give some indication of the direction of fall that best facilitates skidding. However, if trees stand less than 55 m apart, which is quite common, the relative position of the trees vis-à-vis each other cannot be determined, as the circles may not overlap. When there is a cluster of trees, the circle for a particular tree may be drawn at a considerable distance from its true location. The possibilities of using this map in planning felling and skidding are therefore very limited.

Preparing the inventory map for experimental logging took the same amount of time. The representation of the harvestable trees on the map is equal to the above, but due to its larger scale (1 : 2000), the proposed alignment of the skid trail could go into more detail, taking into account the direction of fall and relative distances of the trees. The map also shows more indications of inaccessible areas. However, the level of topographic precision was not sufficient to make skid trail alignment a straightforward desk job. When marking the trails in the forest, some important deviations from the original (desk) plan had to be made.
The logging blocks were well stocked in comparison with the rest of the concession. On average, 1.5 harvestable trees were recorded per hectare in each of the blocks.

Felling

The technical quality of the felling operation was assessed by measuring the deviation from the foreseen felling direction and by estimating factors related to efficient skidding. Data could not be collected for about 50% of the conventionally felled trees, while the data set for the experimentally logged plot is almost complete. Table 1 summarises the felling results under the two schemes.

Table 1. The implementation of conventional and experimental felling.

Feature	Conventional felling	Experimental felling
Number of trees felled (complete records only)	26	50
Average diameter of felled trees (cm)	93 (S.D. = 16)	91 (S.D. = 15)
Range of diameters (cm)	70-136	70-138
Trees rejected before/whilst/after felling	1	1
Range of deviations from planned direction of fall[1]	0°-90°	0°-140°
Average deviation	26° (S.D. = 23°)	26° (S.D. = 32°)
% of trees within 10° from the planned direction	38	40
% of logs with additional crosscut at base	38	30
% of trees divided into two logs	15	4
% of logs which *seem* well crosscut	97	98
% of logs where cable *seems* to pass well	66	88
% of logs where pushing *seems* necessary	38	22
% of logs where dozer *seems* necessary	0	16

[1] Planned direction in conventional logging is the direction of natural lean, and in experimental logging the technically feasible direction in which the least damage is done to the commercial stand.
S.D. =standard deviation

Both samples were similar in the average sizes of the felled trees, and in size class distribution. In the experimental logging block, 40% of the trees was felled in the desirable direction. This is very low, compared to the 95% obtained by the IPC instructors during the felling course. In three cases, the actual direction of fall deviated more than 90° from the desirable direction. When evaluating these extreme cases with the feller, it turned out that while felling, he realised that the chosen direction of fall was incompatible with the natural lean.

Either the natural lean was too pronounced or differed too much from the feller's assessment to force the tree in the desired direction. To avoid that the saw got stuck in the kerf, the feller had to change the direction of fall.
In conventional logging, only 38% of the trees were felled in accordance with their natural lean. Apparently, the fellers had difficulty in assessing the lean correctly. This conclusion also explains the rather poor result of the experimental felling, where the natural lean is also one of the factors to be considered.

Felling efficiency

Time studies were hampered by the weather. The records on conventional felling were obtained during six incomplete working days, during which 32 trees were felled. Data on experimental felling could be collected in six complete working days, during which 65 trees were cut. Daily productivity is therefore a poor parameter, and only time records per tree felled were included in the analysis. All trees felled during the recording period were included, also if they were outside the 33-ha assessment plot. Interrupted felling cycles and incomplete records were omitted in the analysis.

For the purpose of the time study, a feller day's work can be considered as a cyclic activity, consisting of the following sub-activities:

1. Looking for the tree. This is the transfer time to the next tree. The transfer time from the landing to the first tree of the day is left out of this study.
2. Rest, preparation and maintenance (RPM I). The time between the arrival at the site of a tree to be felled and the actual cutting of the tree. The rest period for the feller and his aid and activities such as debarking of the tree by the aid, refuelling of the chainsaw and sharpening of the chain have been grouped together to keep the execution of the time study feasible. The justification for this grouping lies in the fact that during these activities, the feller enjoys a moment of relative physical rest. RPM I also includes the time required assessing the tree's natural lean and the desirable direction of fall. The aid was not sent to look for potential crop trees in the direction of the natural lean.
3. Felling the tree. This is the time between the saw's first contact with the tree till the moment of fall. Delays due to the saw getting stuck in the kerf during felling are included, but have also been singled out for further analysis.
4. Rest, preparation and maintenance (RPM II). After the fall of the tree, the feller may take a short brake and sharpen the saw's chain, whilst the aid clears the area where the tree will be topped or crosscut.
5. Crosscutting. This is the time used for gross cross cutting of the tree, including delays due to the saw getting stuck in the kerf. These delays are again also singled out. Crosscutting a tree was carried out without specific instructions regarding the log-lengths mostly needed by the sawmill or for export. Time used for measuring the trunk is also included.
6. Rest, preparation and maintenance (RPM III). When all work is done, the feller and aid paint their initials on the tree stump, they may deliberate on which tree to cut next and take a rest.

The duration of these sub-activities for both logging methods is presented in Table 2. Table 2 shows that the introduction of experimental logging does not lead to an increase of the total felling time per tree. In the experiment, experimental felling took even less time than the conventional method, but this difference was not statistically significant ($t = 0.976$, $df = 67$, $p >> 0.05$). This applies also for most sub-activities, except for crosscutting and the combined periods of rest, preparation and maintenance.

Search time in experimental felling was slightly more than in the conventional method, in spite of the better inventory maps. This difference was not statistically significant ($t = -0.789$, $df = 67$, $p >> 0.05$), and is probably because the crews had little experience in map reading, and because individuals happen to walk at different speeds.
Preparing for the felling (RPM I) took more time in the experimental set-up, because the assessment of the best direction fall takes a few minutes. Again, the difference was not significant ($t = -1.957$, $df = 67$, $p = 0.55$).

Table 2. Time required for felling a tree, per sub-activity and per logging method.

Features and activities	Conventional felling	Experimental felling
Number of trees (sample size)	16	53
Average diameter (cm)	94 (17)	91 (16)
Searching (min:sec)	3:00 (3:14)	3:53 (4:04)
RPM I (min:sec)	2:38 (2:32)	4:17 (3:04)
Felling (min:sec)	10:00 (9:19)	6:32 (2:47)
RPM II (min:sec)	3:17 (2:20)	4:26 (3:45)

Crosscutting (min:sec)	7:08 (4:22)	3:44 (2:53)
RPM III (min:sec)	1:08 (1:13)	1:35 (1:17)
Total felling time (min:sec)	27:12 (13:11)	24:27 (8:45)

Complete records only. RPM= rest, preparation and maintenance. Figures in brackets are standard deviations.

The felling itself took less time under experimental conditions, probably because more care is given to placing the proper cut, but the difference was again not significant (t = 1.468, df = 15.815, p >> 0.05).
Preparation for crosscutting (RPM II) took somewhat longer under the experimental method, as one would expect. The experimental method requires a more careful selection of the spot on the bole where to crosscut and more work to clear it. The difference was again not significant.
Crosscutting took significantly less time in the experimental scenario than in conventional logging (t = 2.130, df = 67, p = 0.037). This is mainly because of less crosscutting at the base (30 % vs. 38 %, Table 1) and in the middle of the tree (4 % vs. 15 %, Table 1). When considering crosscutting at the top only - something always occurring once per tree under both schemes - the difference remains significant, however. Under experimental conditions, the bole is apparently better situated vis-à-vis the ground surface for crosscutting (see Table 1) or the feller takes more time to prevent the saw getting stuck in the kerf (see Table 4).
The rest period after crosscutting (RPM III) is about the same for both logging methods. When adding up the three RPM periods, the totals for both logging methods differ significantly (t = -2.362, df = 67, p = 0.021). Under the experimental scenario, the feller takes significantly more time for the combined activities of rest, preparatory activities and maintenance. This aspect was analysed in more detail (Table 3).
Table 3 reveals that in conventional felling, the feller spends considerable time on saw maintenance and problem solving (mainly trying to release the chain from the kerf). In the experimental method, the feller spends much less time on these activities, but takes much more time to “rest” when switching from one activity to another. This extra time for “resting” is not all lost time, as it includes also the time required for deciding how to execute the next activity best. Conclusion: under conventional conditions the feller is mostly occupied with physical activities in between the 'productive' activities of felling, crosscutting and transfer to the next tree, whereas under the experimental scheme he takes more time to rest and think.

Table 3. Duration per tree of rest periods, maintenance and other minor felling activities under two felling scenarios.

Activities	Conventional felling (n=16)	Experimental felling (n=53)
Tree preparation (min:sec)	0:10	0:45
Saw maintenance (min:sec)	3:42	2:27
Problem solving (min:sec)	1:09	0:46
Rest & miscellaneous (min:sec)	1:58	6:19
Total time per tree (min:sec)	7:00	10:18

Table 4 provides details on the organisation of the work under the two scenarios. These figures basically show that in either case, the feller already grabs the chainsaw to start felling when the aid is still removing bark from the tree. Apparently, the extra time needed to make a careful assessment of the possibilities for directional felling did not exceed the time normally needed to by the aid for bark removal. Furthermore, the figures show that no matter the method, only few trees were felled and crosscut without interruption. Refuelling the saw and filing the chain are the main causes for delay. Under experimental conditions work was interrupted more frequently, mostly for miscellaneous non-productive activities.

Table 4. Supplementary data on felling and crosscutting.

Feature	Conventional felling (n=16)	Experimental felling (n=53)
Preparation by the aid still going on at the start of the felling	81%	91%
Felling and crosscutting with breaks for saw maintenance and refuelling only	75%	66%
Felling and cross cutting with breaks for other reasons than saw maintenance/refuelling	16%	26%
Felling and crosscutting without any break	9%	8%

Felling damage

It has been argued above that experimental felling has been executed rather poorly with only 40% of the trees falling into the desired direction. In spite of that, the method caused considerably less damage to the vegetation.

Table 5 presents a summary of the damage incurred during felling in the 33 ha plots, showing that the number of trees damaged in experimental logging was about 25% less than under conventional logging. If only marketable trees are considered, this percentage is even close to 50%.
The difference in number of trees felled (47 vs. 46) and in the average diameter of felled trees (99 vs. 91 cm) may accounts for part of the difference in damage, but most of the damage reduction is the result of improvements in felling methods. One reason is that under experimental felling, tree crowns were often directed to an already existing felling gap, thus creating little additional damage. In conventional logging, only two of these "multiple tree gaps" were observed while in experimental felling, there were 6.

Table 5. Damage to the vegetation due to conventional and experimental felling (33 ha per treatment)

Features and damage categories	Conventional		Experimental	
	Total	Mean per felled tree	Total	Mean per felled tree
1. All felling gaps				
Number of trees felled	47		46	
Average diameter (cm)	99		91	
Number of trees damaged	1289		861	
Number of marketable trees damaged	142		73	
2. Single tree gaps only				
Number of trees felled	43		34	
Average diameter (cm)	96.7		92.7	
Standard deviation (cm)	18.5		15.2	
Number of trees damaged	1207	28.1	657	19.3
Number of trees fatally injured	837	19.5	468	13.8
Number of marketable species fatally injured	91	2.1	43	1.4

Even if only 'single' tree gaps are considered, which is a requirement for statistical comparison, the differences between the two logging methods remain considerable (Table 5). Statistical analysis resulted in significant differences between the felling methods regarding the number of trees damaged per felled tree ($t = 4.446$, $df = 75$, $p = 0.000$), the number of fatally damaged trees per felled tree ($t = 3.283$, $df = 75$, $p = 0.002$) and the number of fatally damaged trees of marketable species per felled tree ($t = 2.415$, $df = 75$, $p = 0.018$), all at $\alpha = 0.10$. One may therefore conclude, that experimental felling achieved its objective of reducing damage to the vegetation, in spite of the rather poor way it was conducted.

The diameter distribution of damaged trees under the two scenarios was also explored. A Kolmogorov-Smirnov test on the distributions of the trees injured in the four main damage classes expressed per tree in Table 5 led to non-significant results for all categories at $\alpha = 0.10$. This means that it could not be proven that experimental felling spares the larger trees more than the smaller ones or vice versa.

Last, the sizes of the "single tree gaps" were analysed (Table 6), using data from inside the 33-ha plots supplemented by data from trees in its immediate surroundings. Experimental logging led to slightly smaller gaps, but this is probably due to the smaller average size of the felled trees. An effect of the felling method on gap size could not be proven at $\alpha = 0.10$ ($t = 1.059$, $df = 44$, $p = 0.295$).

Table 6. Gap size in relation to felling method.

	Conventional felling	Experimental felling
Number of trees	36	48
Average diameter (cm)	99	90
S.D. (cm)	19	13
Average gap size (m^2)	764	720
S.D. (m^2)	403	450

S.D. =standard deviation

Skidding

Skidding is basically the transport of logs from the felling site to the landing at the roadside. The activities can be divided into six categories: preparation of the trails, driving over the trail to the felling site, activities at the felling site (stump operations), transport over the skid trail to the landing and activities at the landing. Activities at the landing were omitted in the analysis, as they are the same for both skidding methods, and stump operations received special attention. Data collection on skidding was not strictly confined to the 33-ha plots, and not all aspects of skidding could be analysed in full.

Stump operations can be considered as a cyclic activity, consisting of six sub-activities:

1. Approaching the tree. This is the machine's transfer from the (planned) skid trail to the point near the felled tree where the skidder/dozer stops to unroll the winch cable. In conventional logging, the machine generally moves to a point very close to the stump; in experimental logging, the machine remains at the largest feasible distance from the felling site.
2. Turning and pushing. Upon arrival in the vicinity of the stump, the ideal position of the skidder is with its rear end facing the log to facilitate subsequent winching. In cases where the log is not cross cut well or the cable will not pass well underneath the log, the operator has to approach the stump and pushes or lifts the log somewhat.
3. Unrolling the cable. Having positioned the machine adequately, the skidder operator puts the winch in reverse and the aid approaches the log with the cable.
4. Attaching the cable. Upon arrival at the log, the aid slings the cable around the bottom or top end of the log.
5. Winching. After a signal from the aid, the operator winches the log to the skidder.
6. Return to the trail. When the log is hauled in, the skidder returns to the trail and continues towards the landing.

The most important differentiating factors between both skidding methods are listed in Table 7. It shows striking differences between the two scenarios as well as some remarkable similarities.
Communication with the skidder boy is an important element of experimental skidding. It is to indicate the operator where to turn his engine, how (where and under which angle) to approach the log, where to stop and unroll the cable and whether or not pushing is deemed necessary. Communication is therefore much more frequent than in conventional skidding (see Table 7) and contributes to a controlled way of working.
This communication enables the skidder to remain at a distance from the felled log in most cases. Pushing of the logs happened in only 10% of the cases - and only when really necessary – compared to 60% under conventional skidding. Pushing is only necessary under extreme circumstances (heavy logs, slopes, impossibility to crosscut well, etc) when the log is approached in the right way, but cannot be abandoned totally from the controlled skidding scenario.
The cross cutting rate under conventional logging (90%) is so good, that it could be improved only marginally (98%). The same applies for the ease with which the cable passes underneath the log. The good cross cutting rate confirms the findings of the felling study (97% and 98% respectively, Table 1).
In experimental skidding, the skidder should avoid entering the gap area in order to minimise damage to vegetation and soil. This was indeed done less frequently than in the conventional operation, but still more frequently than expected (15%). The assistant was apparently only partially successful in telling the skidder operator where to turn his machine, leading to more problems in approaching the log. Another main reason for entering a gap area to winch the log to the machine is that upon felling under the prevailing hilly terrain conditions, the stem may slide a couple of meters away from the stump. This adds to the winching distance, which may become longer than is technically feasible.

Table 7. Overview of the implementation of conventional and experimental skidding

Activity/feature	Conventional skidding	Experimental skidding
Number of logs	33 (= 100%)	49 (= 100%)

Average diameter (cm)	93	90
Average length (m)	11.5	11.4
Average weight (tonnes)	6.89	6.39
Problems in approaching the log	6%	18%
Communication with skidder boy	33%	90%
Place of turning the skidder:		
On the trail/in the forest	72%	85%
In the gap	28%	15%
Average angle of approach and winching	68°	69°
Log well crosscut	90%	98%
Cable passes successfully	88%	90%
Pushing of the log	61%	10%
Necessary pushing of the log	9%	10%
Unnecessary pushing of the log	52%	0%
Winching of the log only	15%	61%
Pushing and winching of the log	6%	2%
Linking up of the log only	24%	18%
Pushing and linking up of the log	55%	18%
Attaching the cable at:		
The bottom end of the log	76%	61%
The top end of the log	24%	39%
Average winching distance (m)	10.8	7.8
Problems with skidding to main trail	18%	16 %

The difference between the two systems with respect to entering the gap area is reflected in the difference in winching rate (21% for conventional logging versus 63% for experimental logging). Winching is applied in conventional logging mainly when it is the only way to recuperate a log from otherwise inaccessible places. Winching distances are often considerable under such conditions (15 – 20 meters). The distances, over which logs are intentionally winched in experimental logging, are therefore well within the range the crew was already used to (see Table 7).
The frequency of problems, which the skidder operator encounters when driving to and from the stump area, is similar under both schemes. It could not be shown, that pre-skidding flagging of the trails leads to fewer obstacles in the form of slopes and trees on the trail. This may be due to poor skidtrail alignment and/or to the more difficult terrain in the experimental block.

Skidding efficiency

In the skidding time study, the focus was on the stump operations (Table 8). Experimental stump operations are to reduce skidding damage rather than at improving the efficiency of the operation, and are therefore an investment in future yields.

All stump activities took more time in experimental logging than in conventional logging, and most differences are statistically significant. Much more time was required in experimental logging for “approaching the tree” and “return to the trail”, while one would expect these elements to be determined by the terrain conditions rather than by the skidding method. The crew working in the experimental plot was instructed to abandon felled trees only if skidding was really impossible, while the crew in the conventional plot had to follow the instructions of the concessionaire and could in practise do what they considered appropriate. In the experimental plot, four trees were particularly difficult to approach (time required for approach 11, 12, 17 and 29 minutes respectively), and these four fully account for the observed differences in “approach” and “return” times. The skidding crew in conventional logging is paid on a per log basis, and generally leaves logs, which are very difficult to extract, in the forest. In conventional skidding, the longest approach time was less than 8 minutes. So, the extra time spent on stump operations was mainly due to decisions to extract or to abandon poorly accessible logs. If such decisions are made on the same basis, one may expect that stump operations take 2 to 3 minutes more per felled tree under experimental skidding than under the conventional method.

Table 8. Duration of stump operations in conventional and experimental skidding. First trees of the day excluded, times are averages per log and figures in brackets are standard deviations.

Features and activities		Conventional skidding		Experimental skidding	
Number of logs (complete records only)		32		35	
Average diameter	(cm)	93	(16)	90	(15)
Average length	(m)	11.41		11.32	
Approaching the tree	(min:sec)	0:59	(1:42)	3:38	(5:38)
Turning and / or pushing	(min:sec)	0:39	(0:33)	1:25	(0:51)
Unrolling the cable	(min:sec)	0:29	(0:21)	0:47	(0:42)
Attaching the cable	(min:sec)	1:21	(1:09)	1:50	(0:53)
Winching	(min:sec)	0:46	(0:53)	1:43	(2:26)
Return to the trail	(min:sec)	0:46	(0:37)	1:43	(2:44)
Total stump time per tree	(min:sec)	5:01	(3:12)	11:01	(7:27)

Time required for the preparation of the trails, driving over the trail to the felling site and transport over the skid trail to the landing are largely determined by the distances between the landing and the felled trees. These operations took less time in experimental logging than in the conventional operation, but this may be partially due to a shorter distance between the landing and the 33-ha plot. A better impression of the time saving can be obtained from the data presented in Table 9. One may assume, that the time required for each of these activities increases linearly with the length of the trails. In experimental logging, the trail length within the 33-ha plot was about 11% less than in the conventionally logged plot, so one may expect a time saving of about 10% for each of these operations.

Skidding damage

Skidding damage was assessed in the 33-ha plots and the results are summarised in Table 9.

Table 9. Skidding damage

Feature	Conventional skidding	Experimental skidding	Difference
Size of the plot	33 ha	33 ha	
Number of trees skidded	42 trees	43 trees	+ 2.4 %
Total trail length	3297 m	2994 m	- 9.2 %
Average inclination of trails / standard deviation	3.5 % / 4.6 %	3.7 % / 7.1%	+ 5.7 %
Average trail width	4.28 m	4.07 m	- 4.9 %
Trail length per tree	78.5 m	69.6 m	- 11.3 %
Skid surface per tree	339.6 m^2	295.3 m^2	- 13.0 %
Skid surface per plot	14263 m^2 /4.32 %	12783 m^2/ 3.87 %	- 10.4 %
Avoidable trail length per tree	11.2 m	4.1 m	- 63 %
As percentage of total trail length	14 %	6 %	- 57 %
Avoidable skid surface per tree	55.3 m^2	31.4 m^2	- 40%
As percentage of total skid surface	16%	11%	- 31%
Vegetation cover left on trail	29 %	47 %	+ 62 %

In the conventionally logged plot, 4.3% of the area was under trails. This is in line with earlier findings (see Jonkers and van Leersum, this volume). Both the total trail length and the average trail width were smaller in the experimentally skidded plot, leading to a 10.4% reduction of the total area under trails. Expressed per felled tree, the reduction is 13%. This is a considerable difference, but even in experimental skidding, the trails are locally unduly long and wide and about 11% of the damage could have been avoided. It is possible that a crew with more experience in the experimental skidding methods would have produced even better results.

An important finding is that after experimental skidding, the vegetation had not been fully destroyed over 47% of the trail length. These parts of the trail network have been used for the extraction of one or two felled stems only, and are likely to recover more rapidly than other sections, not only because vegetation remained but also because there is less soil compaction. In the conventionally logged plots, only 29% of the trails still had some vegetation.

Discussion, conclusions and recommendations

Most other Reduced Impact Logging studies were conducted in a kind of "laboratory situation", where the researcher determined when each activity could start. This to ensure that there was sufficient time to record all data accurately. In this test, the logging crews were instructed to work without paying attention to the research team. Both approaches have advantages and disadvantages. The "laboratory situation" disrupts the usual course of the operations to some extent, and may therefore lead to distorted results. The approach adopted here better reflects the routine application of the logging methods concerned, and that is a great advantage. The main disadvantage of this method is that because the research team has little control over the events and has to be very alert, it is more likely that some data are not recorded, as happened in the present test. This applies especially for conventional logging. In experimental logging, the sequence of activities was prescribed beforehand by the research team and it was therefore relatively easy to anticipate on the next action of the logging crew concerned. In conventional logging, the research team had no say in what the logging crews would do next, and they were often caught by surprise when the logging crews decided to do something unexpected. For example, when the felling crew found a tree overlooked in the inventory, they might have started to cut it before the research team had measured its size or even before they were present.
The incomplete records due to such events and other causes could not be included in the analyses. This shortcoming of the test made it impossible to study all aspects of both logging methods in detail.

Lacking data hampered in particular to the analysis of the inventory, as cost figures on the conventional method are missing. **It could be shown, however, that the inventory method applied in experimental logging is not expensive and rather accurate**. It is recommended to do further research into inventory costs and techniques, but mainly for other reasons than the accuracy of the present data set. The method presented in this document was developed before GPS equipment that can be used in closed forest was available. The introduction of such equipment may lead other inventory methods, which are more precise, faster and cheaper.

The experimental felling method proved effective in reducing damage to the forest, and was at least as cost efficient as the conventional technique. A yet unresolved problem is that some trees were felled, which could only be skidded with great difficulty. Trees which cannot be skidded economically are better left standing, and either the inventory method has to be refined in such a way that these trees can be identified on a map, or instructions for the felling crews have to be adjusted for this purpose.

The experimental skidding method also led to less damage than the conventional method. It is probably also at least as cost efficient, although the evidence to prove that is rather unsatisfactory.

Summarising, one may conclude, that the test discussed in this contribution has fulfilled its objective, although the evidence is not always satisfactory. The test has shown that damage reduction through improved logging methods is possible. Furthermore, it seems that it does not lead to an increase in total costs. Recommendations for research include to do further studies in inventory methods, using GPS, and to develop ways to avoid felling trees, which cannot be harvested economically because of adverse terrain conditions.

Worldwide, the timber industry is reluctant to improve its logging methods, in spite of promising research findings (Putz *et al*., 2000) and critical reviews of current logging practices (for Cameroon e.g. WRI, 2000). Opponents to change in Cameroon may argue, that logging damage in conventional logging is so little that it is not worth while to invest in improvements in logging. This is a matter of opinion. Most people living in the Tropenbos-Cameroon research area consider logging unduly destructive (see van den Berg and Biesbrouck, in press). Anyway, sustainable forest management implies that needless damage to the forest should be avoided. This study indicates that this can be achieved with little or no extra costs. **It is recommended that the Cameroonian timber industries start themselves with Reduced Impact Logging trials, so that they can gain experience before they implement RIL techniques as a routine method**.

References

Berg, J. van den and Biesbrouck, K. (in press). *The social dimension of rainforest management in Cameroon: issues for co-management*. Tropenbos-Cameroon Series. The Tropenbos-Cameroon Programme, Kribi, Cameroon.

Brokaw, N.V.L. (1985). Treefalls, regrowth and community structure in tropical forests. In: S.T.A. Pickett and P.S. White (eds.). *The ecology of natural disturbance and patch dynamics*. Academic Press, London, United Kingdom. Pp. 53-69.

Hazeu, G.H., van Gemerden, B.S., Hommel, P.W.F.M. and van Kekem, A.J. (in press). *Suitability classification of forest land in the Bipindi – Akom II – Lolodorf region, south Cameroon*. The Tropenbos-Cameroon Programme, Kribi, Cameroon.

Putz, F.E., Dykstra, D.P. and Heinrich, R. (2000). Why poor logging practices persists in the tropics. *Conservation Biology* 14 (4), 951-956.

WRI (2000). *An overview of logging in Cameroon*. A Global Forest Watch Cameroon Report. World Resources Institute, Washington D.C., USA. 67 p.