LOGGING RESEARCH FOR THE DESIGN OF A FOREST MANAGEMENT PLAN IN SOUTH CAMEROON.

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ABSTRACT

The F1 project "Logging, Damage and Efficiency" is one of several other forestry research projects within the Tropenbos Cameroon Programme. The objective of the study is to design a rational timber harvesting system, with emphasis on restriction of damage, improvement of efficiency of operations and a sound interaction with the local population in the area. The design should take into account the latest developments in global logging research, as far as local conditions permit.

The study was carried out in several working coupes of one of the best organised logging companies in the country. It started with an inventory of current logging practices and linked these practices to the damage levels and patterns in the area. Potential adaptations to the current logging method were then identified and tested in the forest. At the moment the test results are being analysed and the proposed harvesting system is being described.

The study has gained better insight into the extent and the nature of conventional logging damage as well as the current utilisation rates of felled timber.

The technical aspects of the rational harvesting system to be proposed will greatly resemble the current 'best practice' in the area. The results of the research show that substantial damage reduction can not be expected, due to the study area's specific forest composition, the large timber dimensions and the relatively poor cartography service available to the forestry sector.

The most significant difference between current best practice and the model logging system lies in the insertion of a pre-felling planning phase in order to give room to silvicultural considerations and the inclusion of local people's interests. For a shift to "precision forestry", with the objective of maximum damage reduction, far better topographic information of the area is needed and maybe a move will have to be made to advanced teledetection methods. Apart from the possible legal obstacles, possibilities for the local population to guide and co-supervise logging in the area are present. The presence of the logging company in a certain (coupe) area will have to be continuous in order to establish relationships of mutual understanding and benefit between these two stakeholders.

INTRODUCTION.

With the ever-evolving insights in the complexity of the management of Cameroon's tropical forests, the management plans are becoming increasingly complex. From a relatively simple, that is purely timber production focused management plan, the concept now seems to develop into a rather detailed scenario including the rights and obligations of all parties concerned during the preparation and execution of the plan (ONADEF, 1991; ONADEF, 1997). Much emphasis is nowadays placed on local people's participation. Whether this aspect is sufficiently elaborated remains at the appreciation of the social scientists within the Tropenbos Cameroon Programme and will be dealt with during this seminar.

As much as there is a need for codes of practice vis-à-vis the local population, a further specification of how a logging company executes or should execute the logging activities has to be part and parcel of a forest management plan. Surprisingly, governmental concepts of how concessionaires should execute their logging activities have seen very little reform over the last decade. Prescriptions for logging road and landing construction are sometimes mentioned, but clear regulations concerning felling and extraction of the trees - normally the two most damaging operations - still do not exist. The 'Guidelines for logging enterprises' of 1988 in Cameroon (MINAGRI, 1988) do not pose restrictions on the logging exercise. It does not mention, for instance, any guidelines for skidding operations. Felling should be carried out causing the least possible damage, without further specification. Only inventory has recently been subject of a guideline (ONADEF, 1992).
A logical set of harvesting and management guidelines should be developed for Cameroon to enable proper monitoring during and verification after the lease period of the concession. It should be made possible to hold a concessionaire accountable for the damage created in the forest. Ideally, the concessionaire should also be obliged to switch to production technologies, which further reduce damage inflicted to the residual stand. To that end, FAO has recently developed some very generic codes of practice for logging with damage reduction and improvement of utilisation rates as primary objectives (FAO, 1996). Furthermore, CIFOR, amongst other organisations, is trying to integrate these codes into local sets of criteria and indicators for sustainable forest management (Prabhu *et al*, in press). Putting these codes, criteria and indicators into practice for the case of Cameroon is now much needed.
The Tropenbos Cameroon Programme can contribute to a further specification of the codes of practice and criteria and indicators for logging and silvicultural operations in the rain forest of Cameroon. The F1 research project, entitled "Logging, Damage and Efficiency' was formulated with the objective of designing a rational timber harvesting system, with emphasis on restriction of damage, improvement of efficiency of operations and sound interaction with the local population. The outcome can well serve as a guideline for the design of codes of practice for the logging industry in Cameroon.
The F1 project started in March 1994 and will finish by the beginning of 1999. Various sub-studies are still being executed and data is still being processed. This presentation gives an overview of some of the most important results and of how they put the quest for reduced impact logging in its perspective.

CONCEPTUAL FRAMEWORK.

Publications on reduced impact logging for sustainable forest management have been on the increase since the start of the Tropenbos Cameroon Programme. Many researchers - 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 - have taken up the topic and all describe its advantages. In addition, international organisations such as FAO, IUFRO and CIFOR have held consultative meetings on the issue of reduced impact logging (FAO, 1996). So far, very few results on reduced impact logging have been recorded for the African tropical moist forest.
Table 1 gives a summary of the common denominator for the harvesting and post harvesting operations amongst the above and various other publications (e.g. de Vletter, 1993; van der Hout, pers. com.) as well as the author's opinions at the onset of the project. Together they make up the outline of what could be called the logical framework of a model harvesting

system for sustainable timber logging. It is within this framework that the logging research in the study area has taken place.

Table 1: Characteristic elements of a model timber harvesting system for tropical moist forests.

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
climber cutting	well in advance, at individual tree level
girdling of timber trees	reduction of crown biomass
marking/mapping of potential crop trees	to spare them - gives an indication of tree population
marking/mapping of NTFP trees and sites	to spare them - with local people's participation
report	relay information to planning department
Pre felling logging activities:	
planning	
*assignment of buffer zones	forest protection within the working coupe
*tree selection	
**assignment of seed trees	1 per 10 ha per species (>60 cm)?
**assignment of harvestable trees	60% of harvestable stock? trees to be spared for local people
**felling pattern	scattered or clumps?
*felling direction	avoiding NTFPs, pct, 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
marking of skid trails	extra orientation for felling direction of trees
report	feed back alignment results to planning
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 NTFPs, avoid unfavourable angles
bucking	} avoid skidding problems
cross cutting	} according to log size preferences outside forest
report	relay information to skidding crews, feed-back planning dept.

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
report	relay information to transport crew, feed-back planning dept
Road and landing construction:	
clearing width	depending on orientation towards sun
wildlife corridor	connected crowns of bordering trees
durability	shape, compactness, top layer material
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

From the above table can be perceived that the experimental logging concept more than ever implies planning of activities at tree level. The decisions concerning the felling of a tree are no longer based on harvestable diameters and physical state of the tree at the discretion of the feller. They should now be based on the tree's position vis-à-vis the surrounding trees, its place in the species population, its role in the ecosystem and its importance to the local population. In addition, the new concept foresees more feed back of information from the harvesting exercise to the silviculturalists and more relay of tree bound information between the harvesting phases themselves. The F1 study looks into the technical feasibility of the above mentioned components and the necessity of their introduction in Cameroon.

METHODOLOGY

Research site.

The concession where the study was carried out is situated in the evergreen moist tropical forest zone. Emergent trees in the area reach heights of up to 50-60 meters and their trunk diameters may measure up to 2.5 meters. A recent survey showed a basal area value of 31 m^2/ha, which is well above the pan-tropical average. The number of species found amongst trees of >10 cm dbh ranges from 70 to 86 per hectare (Foahom and Jonkers, 1992). According to the vegetation map of Letouzey (1985), the forest belongs to the mid-altitude evergreen forest dominated by *Ceasalpinaceae*. This family is indeed well presented, but the most important species is Azobé (*Lophira alata*), characteristic for the low altitude evergreen forest. The logging company is particularly interested in this species for marine constructions and railway sleepers.

Figure 1. Location of the study area

A substantial part of the forests has in the past been subject to slash and burn agriculture. Young secondary forests and lands currently used for agriculture are restricted to the vicinity of roads and cover 16% of the area. Old secondary forests cover about 33% and 'primary' and selectively logged stands occupy the remaining half of the total area. The presence of Azobé indicates that most 'primary' forests are in fact very old secondary stands (Letouzey, 1985).

The study area is sparsely populated (five inhabitants/km^2). Most people live along the roads, which form the boundary of the concession area, and along the major truck roads inside. The local population consists mainly of Bantu's who practise shifting cultivation for subsistence and produce cacao for cash on smallholdings. Gathering and hunting used to be the mainstay of the pygmy minority and still is important, although these people are gradually becoming sedentary farmers (Foahom and Jonkers, 1992).

The climate is hot and humid, with average temperatures of approximately 25 °C and a mean annual precipitation of 2000 - 2500 mm. Two rainy seasons and two dry seasons can be distinguished. The periods December-February and July -August are comparatively dry with a mean monthly precipitation of 80 mm or less. The wettest months are April, May, September and October, with an average monthly rainfall of 200-400 mm. These figures justify the classification as a tropical rainy monsoon climate (Am) sensu Köppen (Foahom and Jonkers, 1992).

The landscape is variable. The terrain is undulating to hilly, with locally some very steep slopes (80%), especially in the eastern part. Altitudes are mostly low, ranging from 100 m in the western part to 1000 m in the east. Weathering of pre-Cambrian parent material has lead to predominantly poor, acid and ferrallitic sandy clay soils in the area (Foahom and Jonkers, 1992).

According to the land classification map made by the Programme (Hazeu, pers. com.), three landscape types can be distinguished in the research area. Figure 1 shows the coupes 1222 and 1223 in the Programme's study area, where this specific study was conducted. These coupes are located in the intermediate landscape region with altitudes of 350 -500 m. a.s.l. and locally very steep slopes. During the field work, the terrain turned out to be heavily dissected.

Description of current logging practices.

Trying out the blueprint of the model logging method in Cameroon primarily involves comparison with the current logging practices in the country. To that end, the research has started with a description of the logging operations of one of the best-organised logging companies in Cameroon in the South Province. The reason for choosing the best possible organisation ('close to best practice' cf. de Koning *et al.*, 1995) is manifold:

* The model harvesting system strongly hints in the direction of more (tree level) planning and communication. The company already incorporates a high degree of planning in the logging activities. Testing the validity of the model's last details to be added can thus best take place with the 'next best', practical alternative in this respect. For illustration: comparing the latest model vacuum cleaner with a broom is not very challenging.
* Field-tests and comparisons are, due to their expensive nature, invariably very small-scale activities. When choosing the sites for comparison, one risks selecting the most ideal places, without knowing how representative these are for normal, conventional logging. Without careful study of production figures obtained over longer periods, one may overlook the overriding conditions during logging. The company, because of its planned way of work, possesses a great amount of cost and production figures, which help to put the comparison of an experimental set-up with a current practice in a more realistic perspective.

* The company, by practising some form of planning and reporting, has already validated these aspects of logging for Cameroon. If the Government of Cameroon should decide to adopt the majority of the recommendations of this study and enforce them in the logging sector as a whole, a close example of how they can be put to practice in a profitable fashion will already be at hand.

The description comprises a time and method study of the phases: inventory, felling, skidding, landing operations, truck road and landing construction and transport. Financial, administrative and general managerial aspects were included as much as possible, with the objective to better understand the rationale behind what can be perceived in the forest and what is proposed in the conceptual framework of table 1. This description should already give an indication of the most damaging operations and provide the scope for possible adjustments for the reduction of damage.

Damage study.

A systematic damage study was carried out in twelve 25 hectare plots in working coupe 1222 (2500 ha, Fig 1). The study assesses the amount of logging disturbance in a specific working coupe and tries to specifically correlate damage patterns with harvest levels and terrain conditions. For this study, damage has been defined in terms of the disturbance of the soil and vegetation projected at ground level, demarcated by the last injured seedling and tree branch or the last inundated sapling (in case of water logging at creek crossings). Soil compaction may be minimal (in the case of felling) or severe (skidding, landings, roads) in the measured area. The unit of measure is m^2 disturbed area per m^2 plot surface (25 ha) and can consequently be expressed in percentages. The expression in surface and the actual mapping of the surfaces was opted for in view of the communication with disciplines like ecology and social science within this multidisciplinary research programme.

In addition to this systematic damage survey, a smaller, less representative damage sample (4 x 25 ha) was taken in the working coupe of a local, least organised logging enterprise at Bivouba in the South Province. The primary objective here was to assess the re-utilisation of old truck and skid roads in a previously logged over concession. This study also provided insight into damage levels and patterns, which can be correlated to production method and technology level.

Field experiments.

In a third phase, potential adaptations to the operations with the aim of damage reduction were identified and tested. Finally, a small-scale field comparison (120 ha) was made between conventional and experimental logging. Now the test results are being analysed and the proposed harvesting system is being described.

SYNTHESIS OF THE PRELIMINARY RESULTS.

1. Description of logging operations.

Forest harvest inventory is carried out by the concessionaire at 100% level and the result is plotted on 1: 5.000 maps. The inventory is carried out per working coupe of 2500 hectare. Within the coupe a 1000 x 1000 meter block is enumerated by a crew of 4-5 persons, working a 100 meters apart. Only the trees with a diameter well above the cutting limit of only the species that the concessionaire may be interested in are enumerated. The topographical foundation for the inventory map is obtained through enlargement of the Government's 1: 200.000 maps and field data. The resulting maps are used mainly for harvest and marketing planning, for truck road alignment and for felling. To a far lesser extent, these maps are also used for skidding.

Felling is carried out in two or three men's team of which one handles a Stihl chainsaw with only some very basic features. The felling technique is rudimentary. Harvestable trees are always emergent, with diameters at breast height of 116 cm and a bole volume of 13 m^3 on average. Few commercially important species have buttresses. The trees are 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 bucked and crosscut without any information on the log lengths desired further down the production chain. The felling productivity in the study area was monitored for 6 months and calculated at three trees per effective working day per feller.

Skidding is carried out with D7 dozers and Cat 528 skidders. The D7 constructs the trail to the stump site and prepares the log(s) for transport to the landing by the Cat 528. Trail construction is mostly going from gap to gap in the forest, rarely guided by an inventory map, which to that effect is too rough anyway. Tree skidding is executed one tree or one log of a tree at a time. Prolonged activities under terrain inclinations of more than 20% are avoided. The large tree dimensions and the adverse terrain conditions in basins and on hills lead to a skidding productivity of five logs per skidder per day (over a period of 6 months). At the landing site, logs are further cross-cut to improve their appearance before transport and sale.

Truck roads are aligned on the basis of the 1: 5000 inventory map and extensive reconnaissance in the forest. Roads are cleared with a D8 dozer at a rate of approximately 100 meters a day, highly depending on the terrain conditions. Felling of large trees and additional clearing of vegetation alongside the road for more rapid drying of the road surface is carried out by fellers. Road grading is partly carried out by D7 dozers and partly by graders. Compaction with vibrating smooth rollers is not practised.

Log transport is carried out with a fleet of 12-16 dolly trucks with a loading capacity of 25-35 tonnes.

Logging administration and reporting comprises recording of the daily production per crew. The administration format may differ substantially between crews and is primarily geared towards recording the amount of logs produced per day. The system serves for the payment of bonuses and the monitoring of stocks in the forest and on the landing. Due to a lack of corresponding tree and log numbers on the various forms, these reports can at present not be used as a monitoring tool for the utilisation rate of felled timber.

2. Damage.

The disturbance level in the study area due to logging under conventional conditions ('close to best practice') has been estimated at 5%. This means that 5% of the area designated for logging has incurred disturbance, either in the form of compaction of the soil by the logging machines or removal of forest vegetation and damage to standing trees through falling trees. The subdivision of this damage level can be found in table 2 below.

Table 2: Average level of disturbance of the forest due to logging activities. Measured in 12 plots of 25 hectares within a working coupe of 2500 ha. Difference in total is due to rounding off.

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

This total of 5.1% is well below what was expected and is primarily related to the low harvest level in the coupe. The calculated average yield in this study amounts to 0.3 trees per hectare, which differs greatly from the 0.7 tree/ha expected from the inventory results. This difference could have four causes:

* The area presented problems of accessibility. In addition, some patches in the forest were very poorly stocked with harvestable trees and consequently not entered by the concessionaire.
* The distance of the southern coupe boundary to the village of Ebom is only 2-3 km and so the forest contains large patches under agriculture, which were skipped by the concessionaire.
* During the study, the concessionaire maintained a temporary shortened list of species to be cut for reasons of marketing.
* The concessionaire is only interested in trees from the larger diameter classes. Some inventoried trees do not reach the desired dimensions.

The composition of the total damage level needs clarification. Half of the damage comes from truck road and landing construction. Normally, this category would not be greater than 10% of the total damage. In the study area, however, the following exceptional situations occur:

* Road density is very high in the parts where logging takes place. Roads are not very far apart from each other, each following one the many ridges in the heavily dissected terrain. In this way, skidding on the swampy downhill slopes and basins is kept to a minimum.
* Road width is great. The study was carried out in a 'vente de coupe', which is a working coupe allotted to the concessionaire only shortly before logging. The roads through this coupe are constructed only very briefly before actual logging takes place. Only little time is available for the roads to dry up and the concessionaire therefore exposes the road to the sunlight as much as possible by opening the trace excessively broadly (fig 2).
* The log landings in the area are extremely oversized (fig 2), possibly for the same reason as above. In addition, unnecessary landings can be perceived; landings with no connecting skid trails. This coincides with the instruction to construct landings every 500 meters, which is observed too rigidly by the forest crew.

Based on the damage maps, the amount of avoidable road construction has been estimated roughly at 30%.

The overall disturbance level in coupe 1222 may be low, but there is great local fluctuation. According to the measurements in the sampling plots, the damage can vary locally from 0% to 25% of the area. The corresponding harvest levels can locally go up from 0 to 1.8 tree per hectare. Figure 2 shows the damage patterns in four sample plots.

From these damage maps, in combination with a method study carried out in the area, the logging damage (skidding damage more specifically) can be described and correlated to various variables.

Hilly terrain does not necessarily lead to increased skidding damage levels as one would expect (van Leersum, unpublished data). Facing hilly conditions, the forest crew may decide not to enter the area or, if they do, the machine operators tend to be extremely careful in their movements in order not to get stuck and incur production losses. On the other hand, flat terrain, especially in the poorly drained basins, may lead to high degrees of avoidable skidding damage. The relative ease of movement on flat terrain makes the creation of extra skid trails the easiest solution to bypass deteriorating terrain conditions. This practice is firmly rooted in the operator's belief that the forest will be able to unconditionally cope with the damage incurred (van Leersum, unpublished data).

Figure 2: Logging damage patterns in four sample plots in working coupe 1222. Landings, truck roads and skid trails in black, felling gaps are dotted. Source: de Hart and Kampen (1995) and Ndjofang (1996).

Harvesting more trees leads to more disturbance of the forest. Even in the plots with the highest harvest levels, the felling and skidding damage still increase proportionally with the number of trees felled. The distances between the trees to be felled in the current logging density range (up to 1.8 trees/ha in our study) is still too large for the tree crowns to overlap substantially in a multiple tree gap. The multiple tree gap is more of a conglomerate of neighbouring tree gaps than an area where felled tree crowns meet and overlap. The increment in total felling damage or felling gap area per tree consequently does not decrease with an increase in the number of trees per hectare harvested (van Leersum, unpublished data).

The distance between two consecutive trees to be logged is on average 92 meters and is so large that careful planning of the trees' direction of fall to facilitate subsequent skidding is not necessary. There is always enough room to approach the tree under the best possible angle. However, the skidding maps show that at higher harvest intensities (and thus under shorter tree distances, around 50-60 meters), the frequency of trees extracted under adverse angles increases and that the skidding pattern turns messy. The necessity to plan and communicate more carefully during skid trail construction does become apparent then (van Leersum, unpublished data).

Dozers entering the gap area is a frequent phenomenon as this always happens. On average an area of 50 m2 round the stump is compacted by the dozer. The total amount of avoidable damage incurred this way, amounts to 10% of the total skidding damage. This practice roots firmly in the tendency amongst dozer operators to leave the log at the stump site under the best possible conditions for further transport by the skidder. Best possible conditions here means the stump area clear of undergrowth and felling debris. Moreover, the log is pushed through its cross cutting kerf to make sure that the log is loose from the rest of the felled tree. The log should also be partly lifted from the ground so as to facilitate the attachment of the winch cable and ease the pulling by the skidding crew. This log lifting with a dozer blade causes considerable extra damage in an already sensitive microenvironment (van Leersum, unpublished data).

The amount of avoidable skidding damage has been assessed at roughly 20% of the total skidding damage (van Leersum, unpublished data). Avoidable damage comprises the obvious parallel trails, shortcuts and trails not leading to any harvestable tree within the context of conventional logging. The combination of damage maps and method studies revealed that the most important factors for the creation of avoidable damage are:

* Rain and unstable, saturated ground conditions. This is probably the single most important factor. Logging in the area is practically a year round activity with only a break in October/November. During the week, skidding is only stopped when the daily output starts to equal zero. In other words, skidding continues under even the most humid conditions. It is then not very surprising that a skid trail rapidly deteriorates immediately after the first passage of a dozer or skidder.
* Deviation from the planned skid trail tracé. This follows from the above. It is noteworthy here that some degree of good quality on-the-spot-skid trail planning already exists in the area, but that this planning can not outweigh the consequences of entering the forest under moist conditions.
* Lack of control of machine movements in the forest. The machine operator is his own boss; he can set his own standards of work as long as he produces the logs on the landing, there is nobody around to check on him. This used to be different several decades ago (Mâry, pers. com.), but nowadays the supervisors of the logging operations largely remain on the landing and only inspect the logs that effectively reach the roadside.

* Lack of environmental sensitivity amongst the operators and supervisors. Again, this follows from the precedent point. Having been asked specifically about their opinion on the necessity of damage reduction, most operators replied that the forest will regenerate anyway.
* Large volumes per tree. The diameters are such that even with the shortest log length of 6 meters for sawn wood, the corresponding weight of the resulting volume becomes hardly manageable for the current generation logging machines. The skidding damage around the stumps, due to the skidding machine manoeuvring and manipulating badly crosscut logs or logs stuck in the mud, constitutes 10% of the total skidding damage.
* The skidding machines are not up to their task under these circumstances. Bulldozers are not even designed for forest operations other than road and landing construction. Adaptations are thinkable to make this machine a more adequate forestry machine, but they have not met with manufacturers' attention or interest so far. The skidders are indeed typical forestry equipment, but for the African timber dimensions, the largest machine, a Cat 528, is even too small and lacks sufficient traction. Larger equipment, how contradictory this may seem, would surely perform better under the given situations and thus create less damage. Unfortunately, the project could not experiment with adjustments to machinery at a practical scale.

3. Efficiency

Increasing efficiency of operations (i.e. increasing timber recovery rates from felled trees) leads to less forest area affected and less damage created by a logging company per period. Koops (1996) did a post-harvest study on timber losses from felling to saw milling in the study area. His results are summarised in figure 3.

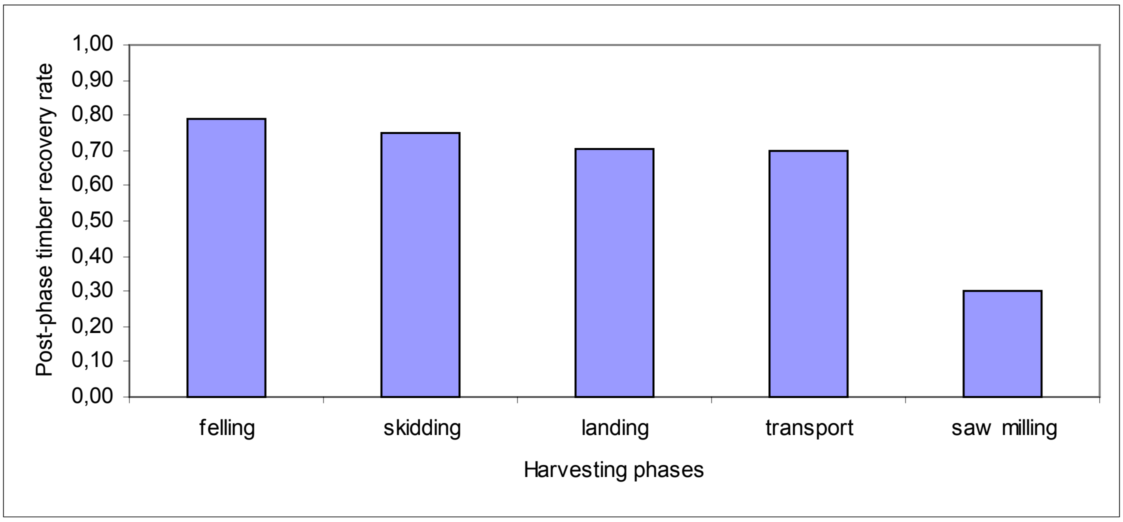

Figure 3: Efficiency of various sawn wood harvesting and processing phases. Values (%) indicate the average cumulated relative decrease in timber volume per felled tree after each phase. Source: Koops (1996).

It was felt that this study did not need to be preceded by a complete inventory of the standing stock in order to measure the efficiency of the inventory and the retrieval of enumerated trees in the felling phase. Other research had already shown that 15% more trees are felled than inventoried, thus demonstrating the relative inaccuracy of current inventory techniques, which eventually pass unsanctioned (Leersum, unpublished data).

Figure 3 shows that the amount of timber eventually delivered at the sawmill amounts to 70% of what had been felled initially in the forest. Most of the 30% timber loss occurs during felling. The 21% loss in this phase consist of abandon of the conical butt end of the log (15%). This part of the bole will be rejected by the sawmill and/or may have split during felling. Rot and badly shaped trees and logs take up 6%. Suspended trees, trees broken after fall or lost in a valley bottom generally amount to less than 1% (van Leersum, unpublished data). Only a rough, very conservative estimate was made of the amount of timber lost because of bad bucking of the tree, i.e. cutting off the crown part at too low an altitude. The calculated 7-10% was confirmed by the concessionaire (Hollander, pers. com.). During skidding, 5% of the logs does not reach the landing. Logs abandoned on the skid trails account for this considerable amount. The reason for abandon here may lay in interruptions during skidding due to difficult terrain conditions causing machine problems. Logs are then left alongside the trails and the machines are towed to the landing. From the logs actually arriving at the landing, another 6% loss has to be extracted, due to crosscutting of muddy or infected cross sections at both log ends. This is done to give the log a better appearance after skidding as clients may arrive to hand pick the logs they desire. This selection is based on the exterior in general, but more specifically on the growth ring pattern. Being overlooked for transport is another reason for loss of timber at the landing site. Waiting periods for logs to be transported of well over 3 months have been recorded (van Leersum, unpublished data). A survey of harvestable trees omitted for further logging during road and landing construction as well as estimates of losses during truck transport report totals below 1% (van Leersum, unpublished data).

When looking beyond logging in the timber production chain, the largest single most timber loss (43%) can be recorded in the sawmill. This is mostly due to internal deficiencies of the wood, the round log shapes and to a far lesser extent to the inappropriate log length assortment entering the mill. Log perishing on stock in the sawmill's log yard does not represent considerable losses (Hollander, pers. com.) The recovery rate in the sawmill of an export company in a duty free zone seems low because it is defined as only the fraction of exportable timber per volume of incoming logs. Second grade timber, still usable for local use in neighbouring villages is considered a loss and is disposed of at virtually no cost to middlemen. When comparing the volume of sawn export timber with the volume of the tree felled, one arrives at the remarkably low timber recovery rate of 30%.

From the above, it follows that the main causes for timber loss during logging are:

* Quality demands on the harvested produce imposed by the sawmill and the export branch within the company. This may be by far the single most important issue.
* Natural factors like tree rot.
* Reporting and administration. At the end of the logging exercise it remains unclear which part of the felled tree has been removed from the forest and which parts are still there to be extracted. Lack of relay of information and feedback between harvesting phases makes it difficult to quantitatively monitor each logging phase.
* Monitoring and supervision. This concerns a qualitative check by forestry professionals on the work done in the forest. It is to check the abuse of machines, to detect necessities for proper training amongst the operators, as well as to assess the waste and damage created in the forest.
* Remuneration and incentives for the forest labourers. The actual system is based on the shape and volume of the timber at the landing site. It is not based on relatively easily obtainable indicators such as: the timber volume per tree harvested or per quantity of fuel used. This allows for deterioration of felling and skidding techniques.

Field experiments

Within the conceptual framework presented in table 1, some field experiments were carried out to assess the technical feasibility of some, for Cameroon crucial components. Below is a first brief overview of what has been tried out on an experimental scale.

Felling

Directional felling proved to be technically feasible in the study area. Only the rare occasion of a tree with no clear natural lean presents a problem to make the tree fall (into a particular direction). Assessing the natural lean is hampered by the fact that the tree to be felled is emergent and the crown layer closes around its stem at already low altitudes. Visual assessment of the presence of trees to be protected near the tree to be felled poses problems. The visibility in the thick understorey is limited to 30 meters on average and this is exactly where the bulk of the felled tree's crown penetrates the crown layer. Only far more detailed inventory maps would undo this obstacle. However, the damage to potential crop trees is low under conventional felling (Parren, pers. com.). Preliminary results of a field comparison indicate that directional felling does not alter this low level. The explanation may lie in the forest composition itself; in whichever direction one may wish to fell a tree, there is always a small, potential crop tree around to be hit. Climber cutting neither appears to have great damage reduction impact (see Parren and Bongers, 1999). By far the greatest improvements in felling efficiency can be expected from refresher courses in controlled felling and better cross cutting instructions.

Skidding

Skidding does not offer great scope for improvement along the lines which have been developed outside the African continent. Reduction of tertiary skid trails through winching and previous alignment of skid trails on the basis of more detailed harvest inventory are the major promising techniques in this respect. Both have been tried in the study area. Winching over long distances resulted impossible because of the log weights and volumes, obstruction by the bucked, conical butt end and the hilly and slippery terrain. Most attempts ended in the skidder or dozer being pulled to the stump instead of the other way round. Alignment of skid trails based on more detailed inventory maps was executed as well. The outcome of this experiment was that not so much the design of the skid trail grid matters, but rather the terrain conditions. Especially on the wet slopes and the basins, the terrain seriously deteriorates after the first passage. In order to reduce the skidding damage around the stump, various prototypes of a skidding stick were tested with the objective to facilitate the attachment of the logs to the cable of the skidder/dozer. In the relatively few cases where the stick seemed necessary, it did not yield success. Radio contact between someone at the stump site and the dozer operator for better guidance of the latter in his approach of the logs, was also tried, but to no avail.
Supervision of skidding operations has proved to have immediate positive effects on damage reduction. Restrictions related to the precipitation in the area may also have immediate positive effects for damage reduction, but possibly the opposite for the company’s earning capacity. Possibly, as this is still subject of further research. Ground skidding in the study area is difficult. Even the newest skidders and dozers can just cope with the hilly and wet terrain. Improvements in the sphere of improved dozer/skidder traction, possibly implying larger machines, seem to contribute substantially to damage reduction in the area. Harvest scheduling on a yearly basis has still to be looked into.

Harvest inventory

Given the current level of topographic precision, more detailed inventory work in the field does not lead to a better planning tool for logging. The irregularly dissected terrain with great local variations in elevation, still make it impossible to draw a skid trail system without the necessity to double check in the forest before marking the trails in the forest. Even then, the frequency of utilisation of the trails forces the machines to deviate from the intended pattern. Increasing the precision of work and map scale has been experimented with, but to no avail. The blown up topographic map, on which the inventory results are plotted, is too inaccurate for 'precision forestry' purposes. Obtaining topographic information through more costly aerial photographs or radar images of the working coupe may lead to far better results in this respect. This topic, however, could not be included in the research.

Field reporting

Some drafts of improved daily report systems for field crews have been designed and tested. The final draft has not been tested so far.

DISCUSSION

With the current low harvesting levels in the tropical lowland forest of south Cameroon, damage levels remain equally low. At a level of less than 0.5 trees per hectare, the proportion of the area under disturbance approximates 5%. Whether this level - or twice this level - is well or little above the ecologically, sociologically or silviculturally permissible, is yet unclear.

Logging damage has been measured in the concession of a relatively well organised enterprise, which already operates with a relatively high degree of planning and control. The comparison of this logging practice with the full range of Reduced Impact Logging aspects will therefore not show dramatic differences. No doubt a comparison with the practices of a less organised enterprise may put RIL in a more favourable position.

The amount of obviously avoidable damage under best practice conditions has been estimated at approximately 20% for skidding and 30% for truck road construction. Total logging damage could thus be reduced to 4% at the maximum. And they should of course, as anything avoidable when it comes to forest disturbance should be avoided. The price of this damage reduction has not been subject of this debate. The concepts and activities to achieve this reduction are not new in Cameroon. Better communication, reporting and supervision during the various logging phases will already on behalf of the concessionaire, diminish most of the avoidable damage and improve the utilisation rate of felled timber. Other factors, in government sphere (forest zoning, taxation, etc) and outside the scope of daily forest operations, seem to have an even greater impact on the possibilities of taking logging to the required level for sustainable forest management.

With these low disturbance levels, it seems difficult to encounter the sense of more planning during the logging exercise. Even at higher than the actual harvesting levels - as in various sample plots of the damage study -, the necessity to improve planning does not seem evident. Planning is, however, not only meant for damage reduction, but also for the accommodation of forest management (= silvicultural) aspects and for the inclusion of local people's interest in the forest.

The forest management aspects are not part of this study. They are subject of the F2 project: "Growth, regeneration and mortality in managed natural forests". This project has recently completed a large scale forest inventory, which will enable the computer simulation of various planning scenarios during logging. The outcomes of this simulation will put the inclusion of a planning moment in the model harvesting system in its proper perspective.

Furthermore, the significance of the F3 project: “Lesser known species” can also be demonstrated. Also the results from the ecology projects in the Programme and the F4 study: “Forest dynamics in disturbed evergreen forests”, like for instance the preferred gap size and -distribution, still need to be incorporated in the logging scenarios.

As for planning for the sound interaction between logging and the local population, the project has so far gained some insights to be shared within the Tropenbos Cameroon Programme. The time is ripe, as so far, specific draft scenarios have still to crystallise from the interdisciplinary discussions. Nevertheless, some contribution to the discussion can already be made concerning the logging activity.
The 'model' harvesting system foresees various moments in its execution, when people can play an active role in safeguarding their interest. The guiding principle here is: if the local people are concerned with their forest, let them be there when a decision is being and damage is about to be made. Turning to table 1, we can distinguish the following moments:

- Inventory: A forest inventory with participation from the local people ('participatory forest inventory', cf. Ambrose, pers. com.) puts all tree individuals and forest sites of interest to the local population on the inventory map. This map then forms the basis for the silvicultural considerations in the company's planning department or directly for the negotiations between logging company and local people. Objective criteria to determine what people could reasonably claim still need to be developed. These criteria should be as objective as those to be in place for the logging company should.

- Pre-felling planning activities: The assignment of the eventual trees to be felled and the alignment of the skid trail system should include this 'negotiation' between local people's value and logging/silvicultural considerations. Objectivity may be accomplished through rules established by the Forest Administration. These rules should be clear for all. In case of disagreement between logger and people, the Forest Administration should decide.

- Felling, skidding, road and landing construction: in these harvesting phases when the actual disturbance of the forest is taking place, the local people should be present to record whether is adhered to the actual plans. Local people can record whether proper use is made of felled timber, whether logs mistakenly remain behind in the forest or any other abuse of the forest resource.

Training local people in the inevitable map reading and the principles of damage recording has proved to be technically feasible during the project. Strengthening of negotiation power was not a topic. In this respect, it is the author's conviction that the negotiation power of the local people increases when the relationship between the logging company and the local people is maintained at a high level in between two cutting cycles of approximately 30 years apart. The more needs to be done by the local population and logging company in conjunction during the remainder of the cutting cycle, the more committed these two will have be towards each other. The current short presence of the logging company in a certain (coupe) area hampers the establishment of this long lasting, more profound relationship between the two stakeholders.

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