3 The CELOS Management System: concept, treatments and costs

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3.1 The concept

Modern management of tropical rainforest, when aimed at sustainable production of high quality timber, is generally based on low impact intervention, harvesting of single, large stems of valuable timber species, and sufficient restoration time after logging to allow forest recovery. Various detailed sets of criteria and indicators exist which serve to guide the management approach adopted and to verify its application (e.g. ITTO 1998; see also Chapter 8).

When the CELOS Management System (CMS) was formally proposed in the 1980s, standards for sustainability were less precisely defined. Still, CMS is based on similar principles: the management should not only result in an attractive, sustained yield; it also had to be ecologically justifiable, economically viable, technically feasible and socially acceptable. Furthermore, the system is flexible in the sense that it can be adjusted on the basis of future scientific and technical findings as well as to economic and social developments.

The main objective of the CELOS Management System (CMS) is to produce quality tropical hardwoods on a sustainable basis in the tropical rain forests of Suriname. The system was designed in the 1970s and 1980s, and reflects the conditions which then prevailed in that country and largely still apply to date (see also Chapter 1):

- Most of Suriname was – and still is – covered with tropical rain forest;
- Timber from the rain forest was – and still is – an important economic commodity for the country, although the forest is generally not particularly rich in commercial timber species and the forest-based industry was - and still is - weakly developed.
- The density of the human population in rain forest areas was – and still is – very low, with human settlements almost confined to the vicinity of the main rivers;

- Timber extraction per hectare was low, seldom exceeding 20 $m^3.ha^{-1}$, and still is modest;
- Rain forest areas in the country are generally poorly suited for conversion to permanent agriculture.

Based on these conditions, a forest management system, which requires little capital and labour input per hectare and results in an attractive return on investment, was called for. Since rain forests designated for timber production were scarcely inhabited or uninhabited, there was little need to consider social aspects other than the perceived need to create jobs for the inhabitants of forest villages. As timber yields were low, there was also no urgent need to reduce harvest intensity to sustainable levels. CMS research therefore focused rather on silvicultural treatments to stimulate the growth of timber species in their natural environment, on what is now called Reduced Impact Logging (RIL)[1], and on the ecological effects and economic costs and benefits of the methods proposed.

Thus, the CMS is a polycyclic system, in which some of the largest commercial trees are harvested while smaller trees are retained. The growth of the remaining commercial trees is stimulated through silvicultural interventions, so that a yield similar or larger than the first one can be obtained after a few decades. There is a distinct focus on silvicultural and logging methods, which are referred to as the CELOS Silvicultural System (CSS) and the CELOS Harvesting System (CHS). These are embedded in a rather conventional management planning procedure that can be summarized as follows. For each management unit of at least 25,000 ha, a management plan is prepared based on reconnaissance mapping of forest composition and terrain characteristics. The areas allocated as production forest are divided into compartments of about 200 ha and a network of roads is planned to allow timber transport by truck from the compartments to the processing plant. In a standard unit of 250 km^2, five compartments are logged annually, giving a felling cycle of 25 years[2].

The CMS mimics natural forest dynamics. In tropical rain forest, very little light penetrates through the forest canopy, and seedlings only have a chance to grow and survive where the forest canopy has been opened up, that is, where a large tree has fallen. Such spurts of fast growth in the improved light conditions of canopy gaps are called 'releases' (Brienen & Zuidema 2006). Harvesting mature trees before they deteriorate and collapse creates similar gaps where regeneration can develop. Initial growth in gaps is rather rapid, but soon increment rates drop because the young trees increasingly compete with one another when they grow bigger, and because the trees surrounding such openings tend to expand their crowns laterally and close the gap.

Deteriorating light conditions make that small individuals of canopy species are forced to grow mainly in height, which often gives them a slender appearance with a narrow oblong crown and a tall straight stem. Lack of light and severe root competition make that most of them slowly perish, and those that survive often need several 'releases',

1 The term Reduced Impact Logging (RIL) was first used by Pinard et al. (1995). It stands for efficient timber harvesting, which is executed in such a way that damage to the forest ecosystem is minimised.

2 Earlier publications mentioned cutting cycles of 15, 20, 25 and 30 years. The cycle of 25 years is based on evidence presented in this book (see Chapter 4).

resulting from the death of other trees in their vicinity, to reach the canopy. It may take a century or longer before they reach the canopy. When they become finally exposed to direct overhead light, the survivors respond to the improved light conditions by modifying their growth pattern: large, often cauliflower-shaped crowns are formed, diameter growth of stems increases, and the height increment of the trunks decreases and finally stops. However, although stem diameter increment may double or triple, competition for light and nutrients remain severe and growth therefore remains modest and mortality remains substantial (see Chapter 4 for details). The CMS silvicultural treatments reduce the competition in the canopy, but not among trees growing in the understorey, thus stimulating diameter growth of medium sized and large trees while small individuals receive more overhead light to accelerate their height increment.

The CELOS Harvesting System (CHS; Hendrison 1990) aims to diminish logging damage and to improve the efficiency of the logging operation. The operation is based on an inventory and mapping of harvestable trees and terrain characteristics. The information gathered is used for production planning, for designing an efficient network of main skid trails and for marketing purposes. The logging method prescribes directional felling; winching of the logs to the main trails, and other measures which are described in further detail in Section 3.2. Another important aspect of the CHS is that the attention to long-term aspects of forest management goes beyond efforts to minimise damage to vegetation and soil: the entire infrastructure, including the main skid trails, is designed in such a way that it can be utilised again in future harvests.

The CELOS Silvicultural System (CSS; De Graaf 1986; Jonkers 1987) aims to promote the growth of timber trees rather than to stimulate regeneration of commercial species, as logging supposedly creates sufficient openings in the canopy to secure adequate recruitment. The focus is on medium-sized and large trees, which are to be logged during the next timber harvest, but smaller trees are also meant to benefit. The favoured species include not only the currently marketable timbers, but also species, which are likely to become marketable within a few decades.

Silvicultural operations start one to two years after logging has been completed. The treatments are referred to as refinements and consist of favouring future crop trees by reducing competition through killing specific categories of trees without commercial value and by cutting lianas. The methods applied are discussed in more detail in Section 3.3. The result of such an intervention is that light conditions for the remaining vegetation are improved and that the nutrients released from the decomposing trees left on site become available for tree growth. As the effect of an individual treatment lasts eight to ten years, three refinements were foreseen during one cutting cycle.

The CMS operations indicated above are only part of the process: most of the work is done by nature itself. The system depends heavily on ecological processes such as litter decomposition, seed dispersal and pollination and it is crucial that human interventions do not jeopardise these critical processes. In other words, organisms involved in these processes need to be preserved. As scientific knowledge to date is insufficient to determine which species are essential, this can only be achieved by maintaining a high level of biodiversity.

Another critical aspect is nutrient preservation. Most rain forests grow on chemically poor soils, and nutrients are stored mainly in the living and dead biomass. Intricate nutrient cycling mechanisms exist, which need to be maintained within CMS production forest, that is, nutrients released from decomposing plant material should not be lost through leaching but should remain in the ecosystem. These aspects are discussed in more detail in Chapters 5 and 6.

The CMS is flexible in the sense that it allows future modifications resulting from technical and scientific progress or changing economic and social conditions. The CMS alters the ecosystem, but these changes are reversible in the long term, thus allowing future changes in management objectives and methods. Application of the CMS outside Suriname will generally also require adaptation of the system, depending on local conditions. For instance, where timber yields are likely to exceed sustainable levels, the sustainable cut will have to be quantified and adhered to. This implies that regeneration, growth and mortality should be monitored on the basis of permanent sample plots. In populated areas, the rights and needs of the local population will have to be taken into account. Furthermore, there may be considerations not to apply the CSS as a method to improve growth conditions of future crop trees, for instance where local site conditions seem to be adverse to treatment, such as in Suriname's savannah forests (see also Chapter 9), or if there are other options for sustainable management.

Photo 3.1. Logging technique: applying a wedge in directional felling. (Photo J. Hendrison)

3.2 The CELOS Harvesting System

In Suriname and many other tropical countries, most forest land is state-owned, while timber is harvested by private companies, which obtain logging concessions from the government. Given the limited duration of such logging licenses, these companies do not have a long term interest in the forests they exploit, and this is reflected in their operations. Logging is often done with little concern for the forest, leading to considerably more damage to vegetation and soil than strictly necessary (see e.g. Boxman et al. 1985; Hendrison 1990). Logging damage affects the ecosystem and the environment and reduces the economic value of the residual forest and should therefore be avoided. Changes in harvesting methods cannot be achieved if they are not in the interest of the ones who have to implement them. In other words, logging methods aimed at damage reduction should be economically beneficial to the logging industry.

The CHS is essentially a reduced impact logging method (RIL) as has been stated in Section 2.6.5. It includes the following elements:

- In felling and skidding, the same machines were used as in conventional logging. The method is based on improved working methods rather than on technical innovations, so it can be implemented without major investments in equipment and training.

- Logging was preceded by surveying and mapping of terrain conditions and of harvestable trees.
- These maps were used to align the main skid trails, which were 100 – 150 m apart, approximately perpendicular to the logging road and as straight as possible. These trails were as close as possible to trees to be felled, and passing watercourses was avoided or, if inevitable, a creek crossing was provisionally bridged. Given the low yield per hectare, relatively few landings were required: one landing per three to six main trails was sufficient. This led to a dendritic skid trail pattern. The main trails were opened prior to felling.
- Directional felling was applied to facilitate skidding. Trees could be felled in any direction, as long as the angle with the main skid trail was approximately 40°, and definitely not less than 10° and not more than 60°. Where necessary, wedges were used to direct the tree in an appropriate direction. Improvements in felling techniques also included safety features and measures to avoid wastage of timber.
- Winching was prescribed, mainly to reduce damage to regeneration in felling gaps. In principle, the skidders should not leave the main trails and logs should be winched to the trails whenever possible. Secondary trails were made as skidding progressed to reach logs, which could not be winched directly from the main trail.
- Frequently used skid trails were considered part of the permanent infrastructure. Studies had shown that using a trail for more than two loads led to such severe compaction that establishment of tree seedlings was prohibited for at least some decades[3]. Old trails were re-used whenever possible and were therefore mapped during the pre-harvest survey. Also, the trail network was planned in such a way, that secondary trails were used for not more than two loads.

Photo 3.2. Directional felling. (Photo J. Hendrison)

Photo 3.3. Logging technique: using choker cables for winch extraction. (Photo J. Hendrison)

3 This phenomenon is not unique for Suriname. Jonkers (unpublished results) also observed it in Peninsular Malaysia, when re-measuring the logging experiment of Wyatt-Smith & Foenander (1962) in 1977.

Photo 3.4. Logging technique: winch extraction , Mapane 1983. (Photo P. Schmidt)

The results can be summarised as follows (Hendrison 1990): extra expenditures on surveys, planning and pre-harvesting operations were more than compensated by cuts in skidding costs and improved efficiency. The CHS also led to considerable reductions in logging damage: for instance, the area under skid trails was reduced by half to a mere 5 % of the total area.

Some innovations in harvesting technology were developed to improve forest surveying and operational efficiency in the last two decades. The progressive application of Geographic Positioning Systems (GPS) in fieldwork has led to better and cheaper methods for forest inventory and operational planning. The track skidder, which is equipped with a special winch, is better suited for pulling out logs from the stump area to the trail, but is substantially more expensive in use than the traditional wheeled skidder. Efficient and low-impact terrain transport can still better be achieved by improved planning and work preparation than by advanced technology.

3.3 The CELOS Silvicultural System

The CELOS Silvicultural System is meant to stimulate the growth of the timber trees which remain after logging. Immediately after logging, working in the forest is difficult because of the logging debris. The first treatment is therefore scheduled at least one year after logging. In the CELOS silvicultural experiments, this first refinement consisted of eliminating trees without commercial value, which exceeded specified stem diameter limits, and lianas with a diameter of 2 cm and more. Although a diameter limit for trees of 20 cm dbh invariably gave the most promising results (see Chapter 4), it was not recommended to use this limit as a fixed standard for the first refinement. This is because in parts of the forest where trees without commercial value are comparatively few, a lower diameter limit is needed than in parts with more non-commercial trees if one wants to obtain the same treatment intensity and growth response. Furthermore, applying a 20-cm limit in parts of the forest where commercial trees are scarce leads to an almost complete eradication of medium-sized and large trees, resulting in a proliferation of pioneer species, lianas and weeds and possibly also in a considerable loss of nutrients through leaching. In other words: the composition of the stand should determine the diameter limits to be applied.

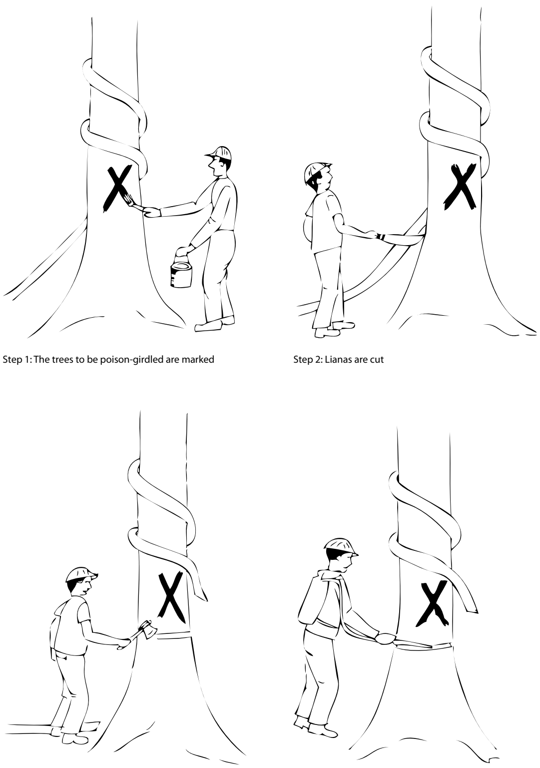
De Graaf (1986) therefore proposed to reduce the average stand density in a compartment to a predetermined level, leaving a basal area of about 12 $m^2.ha^{-1}$. This means that the basal area is reduced to approximately 40 % of the pre-felling value. The diameter limit is then based on a post-felling inventory. Jonkers (1987) presented another, somewhat less drastic approach, using two fixed diameter limits: a limit of 20 cm that applies within a radius of 10 m around a commercial stem of 20 cm dbh or larger, and a higher limit of 40 cm that applies elsewhere. In practice, the 40-cm limit will mainly be used in parts of the forest where commercial species are very scarce, e.g. due to unfavourable soil conditions. An additional advantage of this approach is that an inventory to determine the diameter limit is not required.

Trees to be killed should preferably die slowly and should remain standing in order to:

- reduce the speed of decomposition of the killed biomass, thus minimizing the loss of nutrients through leaching,
- avoid damage by falling trees and
- prevent an excessive change in microclimatic conditions at the forest floor.

In the CELOS experiments, an arboricide (2,4,5-T) was used for this purpose. The arboricide was administered to the lower stem in order to create a ring of dead phloem all around the trunk, thus permanently disrupting the flow of photosynthetic products from the crown to the roots. The techniques used were simple. Trees to be killed were marked by an experienced tree spotter, who was accompanied by a labourer who cut all large lianas with a machete (Figure 3.1). These two men were followed by a gang of three to four labourers, who frill-girdled marked trees at a convenient height with a small axe and administered the arboricide. Frill-girdling was done by making overlapping cuts over the whole circumference of the tree, forming a kind of channel. The cuts should extend just into the sapwood and make an angle with the vertical of about 45°. Next, this channel was

Photo 3.5 and 3.6. Arboricide is administered to kill the bark near the frill, thus interrupting the phloem transport from the crown to the roots. The poisoned trees die slowly, but remain standing, thus causing minimal damage to the remaining vegetation. (Photo P. Schmidt.)



Step 1: The trees to be poison-girdled are marked

Step 2: Lianas are cut

Step 3: The frill-girdle is made

Step 4: The arboricide is administered

Figure 3.1. Refinement technique (source Jonkers & Schmidt 1984)

filled carefully with the arboricide solution and thereafter 10 cm of bark immediately above it was coated with a film of arboricide (Jonkers & Schmidt 1984; Jonkers 1987). This leads to a slow death of the trees, although virtually all die within one year. Ringing the stems at two or three heights may be an inexpensive and environmentally friendly alternative to the use of arboricide. Regular stems can be ringed with a small axe, but for buttressed trees and fluted stems special tools are required.

The second refinement is scheduled eight to ten years after the first one, when the diameter growth of commercial trees starts to decline. Again, trees are killed to stimulate the growth of the commercial stand. Its scientific basis is weaker, however, as such a second refinement has been applied only in two plots of 0.64 ha each. This treatment consisted of killing virtually all non-commercial trees larger than 3 cm in diameter. Based on the results, De Graaf (1986) proposed a second treatment in which the basal area was reduced to approximately 10 $m^2.ha^{-1}$ by eliminating all non-commercial trees larger than 5 or 10 cm dbh. Jonkers (1987), however, pointed out that this would lead to the eradication of most non-commercial species. He considered that undesirable for a variety of reasons and preferred a kind of thinning, that is, a refinement similar to the first one, except that trees to be killed are selected on the basis of defects, stem form and crown form rather than on the market potential of the species. More recent findings indicate that in many cases a second silvicultural treatment is not required (see Chapter 4).

A third refinement is scheduled about five to eight years before the second harvest. Treatment prescriptions have not yet been formulated and the usefulness of this treatment still has to be shown.

3.4 Significance of operational and training aspects of the CMS

In previously executed research in Suriname and elsewhere in the tropics, the condition of the forest after timber harvesting was accepted as a starting point for silvicultural treatment. The prevailing view was that a logged-over forest should be repaired (by silvicultural interference) to regain its productivity and to yield a next timber crop, while timber harvesting could essentially be considered as the first silvicultural treatment with a strong impact on soil and vegetation. The intensity of this impact is decisive for the recuperation process. Consequently, logging and silviculture treatments have to be integrated, at least at the operational level. That means that, already at the start of the 100 % inventory, data are recorded for both logging and post-harvesting treatments. Furthermore, it is recommendable to assign the same field workers for both operational activities.

It is of utmost importance that forest managers should have a proper understanding of the operational aspects of the CMS. Both logging (CHS) and silviculture (CSS) operations should be under the responsibility of one management as was already indicated in the first provisional manual of the CMS (Van Beusekom & De Graaf 1991). A new manual for the CMS should be more in line with the FAO Code of Practices (Dykstra & Heinrich 1996), and with the requirements for certification, as explained in Section 2.6, but the emphasis will remain on the reduction of logging damage, the training of operational staff, and on the operational efficiency, as is highlighted in the following text.

Forest inventory. A pre-harvesting inventory could also serve the post-harvesting treatments provided that not only data from harvestable trees are collected, but also from future crop trees. The survey could then already produce a good picture of the post-harvesting conditions under which the refinement has to be carried out. Recording of terrain characteristics are important for both interferences. An inventory crew should be thoroughly trained for such a multifunctional survey.

Felling. Directional felling became in an encouraging way more and more accepted as a means to control vegetation damage, to recover more wood from the felled tree, and to reduce the risks of accidents. Nevertheless, fellers should be better trained and better rewarded to perform this responsible and dangerous work. They should have sufficient understanding of the consequences of tree felling for the follow-up operations, notably skidding. The extra costs of planned and careful felling are very largely recovered by a more effective lay of the logs for the consecutive skidding.

A CMS felling crew should also be able to mark or tack the logs and to record them in a form or by aid of a field scanner. Timber fellers in tropical countries are not yet appreciated as operational specialists, as is the case with their colleagues from the temperate zones of the western hemisphere, who are sometimes better rewarded than machine operators (Conway 1982).

Planning and construction of skidding trails. Actually, the planning of skidding trails is a management as well as an operational obligation. The main (primary) trails are part of the permanent forest infrastructure, because they are planned to be re-used in the next felling cycles. It means that the main trail system has to be carefully designed in accordance with terrain and hydrographical features. This trail system is constructed before felling and as a result pre-compacted before logs are transported. Finally, it is mapped and attached to the (long-term) management plan.

A permanent main trail network results not only in a substantial reduction of the affected forest area, but also in a reduction of costs in the next felling cycle when the same trails are re-opened. It is both cost effective and in harmony with the RIL approach and it can also be used to facilitate post-harvesting operations (Hendrison 1990; FAO 1997; Durrieu de Madron et al. 1998).

Photo 3.7. Preparing a felled log for winch extraction. (Photo P. van der Hout)

Skidding equipment. It is still not generally acknowledged that the articulated wheeled skidder ("skidder") is comparatively cheaper to operate and environmentally better adapted than, for instance, crawler tractors or track forwarders. There are however a few prerequisites for a proper use of this machinery. The skidder should operate on pre-designed trails, which are constructed before felling. These trails should be constructed by a crawler tractor with blade (bulldozer), and not by the skidder itself, because it is not designed for that purpose and could therefore damage (rut-up) the trail surface. Best results are obtained in flat to undulating terrain and in steep terrain if down-slope skidding is possible. In practise it means that the crawler tractor, which is needed for road and trail construction, should always be available as a standby machine in steep terrain. Skidders can also successfully be used to winch the logs from the stump area to the main trails, while for heavy logs the machine can travel directly to the stump, which demonstrates its versatility as a terrain transporter.

Landing operations. The selection, crosscutting, measurement, grading, and storing of logs at a forest landing are operations which could save timber loss and therefore indirectly forest damage. In traditional operations a wood waste of 10 % of the logs on the landing is not uncommon. This waste could be restricted by training the scaling and inspecting crew, and by designing the log yard properly along the forest road.

Post-harvesting operations. Shortly after logging in a compartment has been completed the main obstacles that could hamper the recovery of the forest should be removed. Especially watercourses should be cleaned from logs and provisional culverts which were constructed to cross creeks. Landings, which are heavily tracked or rutted or even partly swamped, should be drained in one way or another. Temporary camps or living quarters have to be dismantled and the site should be left behind without garbage. In other words, the forest environment should be recovered where possible to get back as close as possible to its original state.

Silvicultural operations, such as refining and the cutting of lianas as explained in Section 3.3, should be carried out with great care. Although this treatment is basically simple to apply, the method described in Section 3.3 should be performed accurately and safely by skilled workers. The responsibilities of the workers should be well defined: the tree spotter solely should be responsible for the selection of trees to be killed, and the worker who administers the arboricide should be responsible for the quality of the poison-girdling operation.

Job rotation. Considering the problems to recruit and to maintain operational staff in a forest environment, it is advisable to train surveyors and operators for more than one skill. All-round workers can replace each other and will be more motivated to run the logging effectively. In this way more work satisfaction could be gained and it would be easier to integrate surveying, logging and silvicultural operations.

Operational efficiency. In the CMS operational efficiency means more than organisational and costs effectiveness. It also refers to a working method that could help achieving RIL. The benefits of operational planning for costs and damage reduction have been emphasised by Hendrison (1990), Van der Hout (1999) and others. Well planned and efficiently executed logging causes far less damage to vegetation and soil than traditional logging.

The benefits of training as a means to improving operational performance are obvious. Training staff is a modest investment in human resource development that easily pays off. It also seems crucial to have skilled personal on all levels if forest and timber certification are aimed at. Although the human resource issues in forest management were not explicitly included in the original research programme, the CMS system was developed with due attention for the training of staff as a major precondition to obtain the best results.

A feed back for operational efficiency is the recording of the timber flow from the forest to the wood processing industry ("log tracking"). All operations, including inventory and long-distance transportation, should be tracked by tagging and recording the dimensions of logs from felled trees that were spotted and mapped in the forest inventory. The subsequent movement of the logs (terrain, road and river transportation) is to be followed (tracked) by recording or scanning the numbers on the tags. Log tracking is a powerful tool to get insight in the production performance and the efficiency of the forest operations.

Finally, operational efficiency is also achieved by acquiring the most suitable equipment and by operating it properly. The considerable investments which have to be made in logging machines and transport vehicles should encourage forest companies to take good care of their equipment, which has to be handled by skilled operators who are reasonably paid.

3.5 The costs of the CMS

The financial input required for the practical application of the CMS was already assessed in an early stage of its development both for silvicultural treatment (De Graaf 1986; Jonkers 1987) and for controlled logging (Hendrison 1990). Emphasis was put on the additional costs of using the CMS system when compared with traditional timber harvesting, which is carried out without planning and without post-harvesting treatments. The two major cost calculations thus refer to the implementation of the CSS and CHS, comprising the costs of growing the next crop and the costs of harvesting that crop, respectively.

3.5.1 Harvesting costs

An unambiguous assessment of logging costs is complicated and time consuming, because quite a number of preparatory activities and sub-operations should be observed to collect statistically reliable data. Hendrison (1990) calculated that additional logging costs for applying the CHS are partly compensated by increased operational efficiency. Yet, an increase of the total costs of 10-20 % was expected if the traditional system was replaced by this early low-impact logging method.

The cost perception as from the 1980s is presently outdated by new developments in forest and nature conservation management and the introduction of forest certification. The assessment of logging costs is more geared towards calculating real costs of efficient logging and additional costs for RIL-related to forest certification. There is no need anymore to compare logging costs of a conventional and a controlled system, because in the last decade quite a number of countries have enforced forest management and timber harvesting regulations, while gradually abolishing destructive logging methods. The FAO model code of forest harvesting practices (Dykstra & Heinrich 1996; FAO 1997) has meanwhile been adopted as guideline for forest operations in tropical countries, such as Guyana and Brazil. The present aim is to assess the costs of controlled logging as a required standard method to achieve sustainable forest management.

Essentially, it is not possible to provide information on logging costs with a wide range of applicability, because of the great variability in cost conditioning factors, such as forest composition and terrain characteristics. These factors vary too much from region to region and even from site to site, to develop overall standards. In addition, logging costs are often company specific in terms of production objectives, operational methods and personnel skills. Therefore, cost assessments should not be made occasionally, but regularly as an instrument of management.

The most recent updating of controlled logging costs was obtained from a field study in Suriname's Tibiti area in three forest management units (FMU1, FMU2 and FMU3) in 2005-2006 (Tropenbos 2006). The choice of these enterprises as study objects was primarily justified by the quality of their management practises. All of them are switching from conventional to reduced impact logging. The study aimed at getting insight in the cost of RIL according to modern standards.

The results of this study were updated with an inflation correction for 2010 and a sensitivity analysis was carried out to match the cost components (Table 3.1). It points out that cost variables are site specific. When compared with a similar study in Guyana (Van der Hout 1999), it is obvious that, apart from the sensitiveness of costs to site characteristics, logging costs in Suriname are structurally higher than in Guyana. The fixed costs of machinery play an important role in this respect. The prices of logging equipment are 25-60 % higher in Suriname than in Guyana and Brazil (Pokorny & Steinbrenner 2005), countries which employ the same logging methods in tropical rainforests.

Table 3.1. The costs of timber harvesting (US $ per m³) 2010

Forest management units Logging operations	FMU1	FMU2	FMU3	Guyana
Management/planning	3.00	5.10	5.50	3.90
Inventory	0.30	1.50	1.90	0.60
Road construction	o	o	4.40	2.70
Felling	1	3.80	1.40	1.50
Skid trail opening	o	2.20	o	o
Skidding	16.50	5.20	10.30	5.50
Loading	2.80	3.40	3.30	4.70
Housing	1.00	1.50	o	2.50
Others	o	o	1.70 [2]	o
Total logging	**23.60**	**22.70**	**28.20**	**21.40**

o = data not available
[1] = felling and skidding are contracted as one operation
[2] = mainly maintenance of machinery
[4] = inflation correction (22%)

The cost studies were used to derive a standard cost price for sustainable forest management and timber harvesting that could meet the standards for FSC certification, by calculating the costs of the sub-operations more carefully. This exercise was carried out with the participation of five selected logging companies, who were all applying RIL in their harvesting operations (FAO in press). Two companies had recently obtained an FSC certificate for timber harvesting (Houtwereld 2008). The assessment of the cost components on basis of the price level of 2010 is explained below (Table 3.2)

Table 3.2. Estimated cost price for RIL in Suriname (US $) 2010

Logging operations	Costs per m³
Management/planning	6.50
Inventory	2.60
Road construction	4.60
Felling	2.30
Skid trail opening	2.80
Skidding	12.40
Loading	3.10
Housing	3.00
Others	2.10
Total logging	**39.40**

Costs of management and planning. The costs of management were relatively high with a standard of US $ 7.50 per m³. Management and planning involve an important cost factor, because a price has to be paid for the benefits of RIL and sustainable forest use.

It is expected however, that these costs will decrease after more experience has been obtained with the new management systems and when more staff have been trained to support the certification process.

Inventory costs. The updated inventory costs are derived from the fee that forest inventory and surveying firms have charged forest operators to prospecting their forest management unit. The price in 2010 was US $ 2600 for a block of 100 ha, hence approximately US $ 2.60 per m^3. Inventory costs are comparatively high (6.0 % of the total cost price), but the results of a forest and terrain survey could have a strong positive impact on logging efficiency and indirectly on profits. Spending in inventory training is quickly paid back and the operational advantages are visible within a few months.

Road construction costs. Costs of road construction were not separately recorded by the concessionaries and could also not be assessed from the collected field data. The standard for Suriname for secondary roads (within a logging compartment) is tentatively set at US $ 4.60 per m^3, as could be concluded from local forest management and operational plans. In general these roads need not to be gravelled, because of their short service life.

Costs of felling. The felling costs in FMU 3 are based on RIL methods as developed by Van der Hout (1999) for Guyana. Discounted for the price level in 2010, the standard for felling costs in Suriname could be estimated at US $ 2.30 per m^3. Costs of controlled felling are not low (5.8 % of the total logging costs), but it pays to invest in proper felling methods to create favourable preconditions for the subsequent expensive terrain transport.

Costs of skid trail construction. Two FSC certified companies could provide the cost data for opening of skid trails prior to logging at US $ 2.00 per m^3. The establishment of a well-designed skid trail system is one of the cornerstones of the RIL method.

Costs of skidding. Closest to RIL are the skidding methods of the two certified companies, and as such considered representative for assessing the standard skidding costs at US $ 12.40 per m^3. Skidding takes approximately 31 % of the cost price, and even 39 % if the cost of trail opening is included. This means that emphasis should be put on operational planning and logging efficiency to reduce the skidding costs.

Costs of loading. Costs of loading are reasonably consistent in all five study objects, although the most efficient loading operations were met in FMU1 (US $ 2.80 per m^3). This is an acceptable standard for RIL.

General costs. A contingency of 10 % is included in the cost price for RIL to cover costs such as housing, communication, health care and recreation.

Summarising, the cumulative cost price for RIL operations is set at US $ 39.40 per m^3 (Table 3.2). Not included are timber royalties and concession area fees, which are fixed components, imposed by the Forest Management Act. RIL costs also do not include the costs of access forest roads and the costs of timber transportation on roads and rivers.

3.5.2 Silvicultural costs

A first indication of costs of the CSS was given by De Graaf (1986). To carry out one refinement and two liberation treatments during a 20 years management cycle, with a target harvest of 20 $m^3.ha^{-1}$, 10 man-days and 40 litres of arboricide mixture are required per hectare. This is an input of 0.5 man-day and 2 litres arboricide mix to grow 0.9 m^3 of commercial timber annually. On basis of these figures and taking into account a compound interest factor of 4 %, the discounted cost price for silvicultural interference was assessed to be 25 % of the sales price of logs delivered at a mill yard in Paramaribo. This means for the present price level (2010) about US $ 15 per m^3 round wood product, which is already substantial without the additional cost of RIL.

However, the costs of silvicultural treatment turned out to be somewhat lower when the uniform scheme was adapted towards a system of liberating future crop trees on basis of their stocking pattern (see Section 3.3). This led to a slight reduction of refinement intensity and savings on inventory costs. Furthermore, evidence presented in Chapter 4 will show that follow-up treatments may not be necessary in many cases. Thus, the projected personnel and arboricide input can often be decreased to 3 man-days and 17 litres of arboricide mixture per ha. Where one follow-up treatment is required, an additional 3 man-days and 13 litres of arboricide will be needed. On basis of these findings the costs of the CSS could be updated as follows.

The two main cost factors of applying the CSS refer to field labour and arboricide inputs. The labour costs include all sub-operations of refinement, such as spotting and marking of future crop trees, liana cutting, frilling and administering arboricide to competing trees (see Section 3.3). If the mean labour (man-day) cost is set at US $ 20.00, the labour input is US $ 60 per ha. The cost for the solution of arboricide (for instance 5 % 2, 4 D in diesel fuel) delivered at the forest site is approximately US $ 5 per ha based on the unit prices of the concentrate of US $ 6.50 per litre and of the solvent of US $ 1.00 per litre. Hence, the total costs of refinement are US $ 65 per ha (2010 price level). However, if these costs are up-rated for a period of 25 years and an interest rate of 4 %, the real costs of silvicultural intervention are close to US $ 170 per ha. The costs for growing the next crop (the second harvest) of 20 m^3 (mean yield) or 30 m^3 (high yield) would then be US $ 8.50 per m^3 or US $ 5.6 per m^3 respectively. If a second refinement is necessary after 10 or 15 years the CSS costs could exceed US $ 10.0 per m^3.

Although the costs of silvicultural interventions are not immaterial, the CSS treatment is justifiable when the reduction of the felling cycle to 25 years is taken into account. If a forest management unit can sustainably be harvested each 25 years, it would give clear economic advantages, in the first place because the same forest infrastructure can be re-used in following felling cycles. Furthermore, the FMU has already been laid out for permanent use with monitoring and research plots. Finally, less area could be allocated for timber production and more for conservational purposes. Thus, intensive forest management such as the CMS is aiming at has both ecological and economical advantages. And the aim of sustainability is best achieved when more than one harvest can be realised within the boundaries of one forest management unit.

Finally, CSS costs, which are basically the additional costs of growing timber, can partly be financed by an increased stumpage fee imposed to forestland under sustained management. On the other hand, concessionaries who have the courage to invest in forest improvement can be compensated by reducing the royalty that they have to pay for the next timber harvest.

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