THE CELOS MANAGEMENT SYSTEM:

A PROVISIONAL MANUAL

edited by

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National Reference Centre for Nature, Forests and Landscape (IKC-NBLF).

The National Reference Centre for Nature, Forests and Landscape (IKC-NBLF) of the Department of Nature, Forests, Landscape and Wildlife of the Ministry of Agriculture, Nature Management and Fisheries has recently been created to fill up the apparently existing gap between policymaking and research. Like that of the Department the scope of its work is concerning the rural areas in the Netherlands, with an accent on nature, forests, landscape and wildlife. Besides that the Centre aims to realise in this respect its intermediate function in the very wide field of development cooperation as well.

Scientific knowledge might be used by policymakers more profitably. It is one of the main tasks of the Centre to secure the inflow of information into the policymaking proces and to guarantee its accesability for it. The availability of relevant information is also of great importance for a number of targetgroups in the case of education and extension work concerning nature conservation/management, forests, landscape and wildlife in relation to both the rural areas in the Netherlands and in developing countries.

Forestry Department, WAU (Wageningen Agricultural University).

The Forestry Department of the WAU has a long standing tradition in research in tropical forestry. Being the offspring of a forestry course for colonial foresters heading for the Netherlands Indies, its tropical section has been concentrating on Indonesia and Suriname for many decades. Actually more attention is given to other regions in the tropics.

The educational tasks of the Department, apart from the academic Forestry curricula for Dutch students, since a number of years include an MSc course Tropical Forestry for foreign students.

Stichting BOS (Foundation for Netherlands Forestry Development Cooperation).

Objectives of BOS

* to promote and improve the quality of the work and cooperation of Dutch tropical foresters in developing countries,
* to exchange information between tropical foresters, (Dutch) institutes on forestry development in the tropics, and other parties concerned,
* to increase public awareness of the importance of tropical forests and forestry in the tropics.

Activities of BOS

* to compile and publish a newsletter in which all types of information on tropical forestry are incorporated,
* to publish a series of BOS desk-studies, called BOS-Documents,
* to establish and maintain a register of tropical foresters called BODIS,
* to maintain contacts with all kinds of organizations, national and international,
* to keep up a question-answer service for people and organizations on any kind of aspect of tropical forests and tropical forestry.

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FOREWORD AND ACKNOWLEDGEMENTS

In this manual the Celos Management System (CMS) is described, a system to manage the tropical lowland mesophytic forests of Suriname. The Celos Management System may very well meet the requirements established by the International Tropical Timber Organization (ITTO) for a sustainable management system of natural tropical forests. It aims at the production of quality timber within ecologically and economically acceptable limits.

The CMS is a polycyclic system with a harvest each 20-25 years. The choice for a polycyclic approach is based on results of trials in Suriname and will not be discussed in this manual. The investigations on which this manual is based, were executed in the period 1965-1982. Due to political circumstances the investigations were stopped before their scheduled time. For the history and details of the investigations in Suriname is referred to De Graaf (1986), Jonkers (1987) and Hendrison (1990).

The idea of this manual is to arrange conveniently all relevant information concerning the Celos Management System, so that managers of forest units can apply the system on a practical scale. It is almost completely based on information already published (see Literature). In order to improve readability, in the text almost no references are made to the literature.

The manual is in first instance meant as a guide to manage on a permanent, sustainable basis the largely modified tropical rain forest of the Forestry Belt of Suriname. It is not meant as a guide to exploit primary, virgin forests, swamp forests or xerophytic (savanna) forests. The guide may have a wider area for possible application (e.g. parts of northern South America), but this is discussed in Section 1.2.5.

This publication is a kind of *prototype, a first edition* that needs to be corrected by experiences on larger scale obtained in the field. Not all aspects of the system were tested during sufficient time on a large scale. Where doubts or uncertainties exist, these are explicitly mentioned in the text. On some items there is divergence of opinion. In that case the practice with the longest experience is mentioned in normal letter-type, while possible alternatives are written down in a smaller letter-type. This, however, does not mean that the alternative is inferior to the practice with the longest experience. In long-term experiments on practical scale the alternatives might even prove to be better.

In the guide the interest is focused on aspects of management concerning harvesting and silvicultural treatments. The manual deals only briefly with other aspects of tropical rain forest management, like land evaluation, issue of concessions, road construction etc. For more details on these items, which are equal or comparable for many management systems, is referred to other manuals (see Literature).

As to the contents of the guide, it may be observed that the section on harvesting (chapter 2) is placed before the section on the silvicultural treatments (chapter 3). It might be argued that for a better understanding of the idea of sustainability it is preferable to deal with the silvicultural section before the harvesting section. However, the literature on which this manual is based, uses the same sequence as applied in this manual. Besides, as is argued by ITTO, "*harvesting operations should fit into the silvicultural concept, and may, if they are well planned and executed, help to provide conditions for increased increment and for successful regeneration*" and "*the harvesting intensity and the design of harvesting pattern should be integral parts of the silvicultural concept*" (ITTO, 1990 sections 3.2 and 3.1.3). The harvesting method described in this manual very well meets these requirements.

The author was helped by an attending group, consisting of the following persons: Ir. P.L.J.M. Noelmans (National Forest Service), Ir. A. Schotveld (Ministry of Agriculture, Nature Management and Fisheries), Dr. Ir. N.R. de Graaf (Agricultural University Wageningen) and Ing. W.G. Kloppenburg (BOS Foundation). To all members of the attending group the author expresses his sincere gratitude for their valuable observations and information.

1. GENERAL

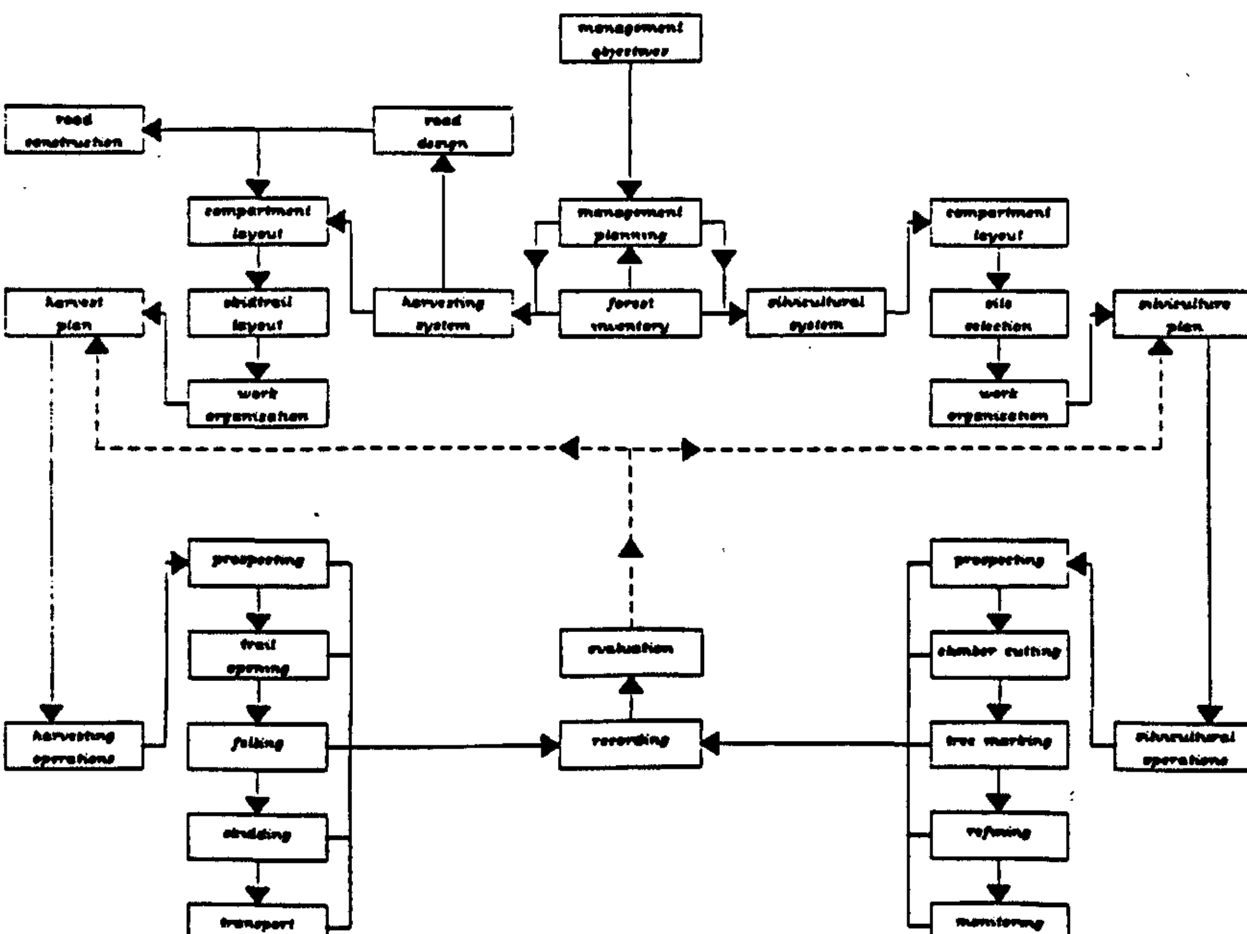
1.1. Introduction

The CMS is a polycyclic management system for tropical rain forests, with defined objectives and planned harvesting and silvicultural treatments. It is a polycyclic system because it aims at a forest in which several generations of trees are present which will be harvested in different harvests that take place each 20-25 years.

The CMS may be classified as a modern forest management system as it includes the economics of harvesting of commercial timber and silvicultural treatment within the limitations of the ecological stability of the forest.

The CELOS Management System consists of two components, viz. the CELOS Silvicultural System (CSS) and the CELOS Harvesting System (CHS). See for more details the flowchart (Figure 1). The CELOS Silvicultural System (CSS) is a system that aims at the increase in growth of commercially attractive tree species. The CELOS Harvesting System (CHS) aims at efficient logging with a minimum of damage to the remaining stand and soil.

Figure 1: Flowchart of the CELOS Management System.



1.2. Area and circumstances for possible application

First, some important aspects of the situation in which the CMS was developed will be dealt with, followed by some specific aspects of the two components of the CMS, viz. the CELOS Silvicultural System and the CELOS Harvesting System. In this way the reader may get an impression of the possibilities for application of (parts of) the CELOS Management System in his/her specific economic, social and ecological circumstances.

1.2.1. Climate

According to the Köppen's classification the climate of Surinam is tropical. The mean annual temperature is 26°C with a daily amplitude of 8°C. Although the relative humidity is high (usually about 80% during the daytime and 95 % at night), the climate in the coastal plain is comfortable because of the north-east trade-wind.

The rainfall is high, between 1700 and 2500 mm/y, gradually decreasing from the interior to the north-west coast. There are two rainy seasons, the main one from April to August and a short rainy season from December to January. There are also two dry seasons, one in August to November and the other from February to March. However, this seasonal pattern is not sharp, a dry month in Surinam may still have a rainfall of more than 60 mm.

1.2.2. Soils

In the area where the research for the CMS was executed, the soils belong to either the Zanderij formation or to the old basement complex. The dominant soil types are Ferrasols (lateritic soils) or Oxisols often with a high percentage of clay. They are reddish or yellowish in colour and weathered to a considerable depth. The texture of the Zanderij formation varies from sands to sandy clay loams, and that of the basement soils from sandy clay to clay. The drainage is medium to good and the structure stable. The soils are old, very low in exchangeable minerals. Generally the pH - H_2O ranges between 3.8 and 4.4 and the Cation Exchange Capacity (CEC) is low (2.7-1.6) with a high aluminium saturation (80 % and more). Nutrient reserves in weatherable minerals are virtually absent. Soil profiles rarely show distinctive horizon boundaries. The O-horizon, on top of the mineral soil, consists of organic matter of 1-3 cm thickness and is constantly in a process of decomposition. The landscape is easily accessible and slightly undulating.

1.2.3. Forest

The CMS was developed in mesophytic forests in the Zanderij Belt in Suriname. These forests are rich in species. About 500 tree species have been identified and 100-150 species are usually found per hectare. Climbers and epiphytes are common and palms tend to be frequent. Floristic composition, canopy height and size class distribution vary considerably from place to place. The average height of taller trees is usually 30-50 m, although some emergents may grow to 60 m or more. Diameter class distributions are mostly well balanced and trees of some species may reach diameters of 150 cm. Commercial species tend to be fairly well represented, with some stands containing trees of species on the CELOS commercial species list (49 species, see Appendix 1) with diameters at breast height bigger than 15 cm, at densities as high as 100 trees per ha. Total standing volume of all species per ha is approximately 200 m^3 (see appendix 3). Total basal area of an undisturbed forest is approximately 31 m^2/ha (with a 5 cm dbh lower limit).

1.2.4. Socio-economic considerations

Another important aspect of the CMS is that it was developed in a situation of low population-pressure on the forest. No special measures for the conservation of the forests were necessary. There is almost no pressure to convert forest into agricultural land or to use the forest for extensive cattle-breeding. Other systems to manage or to exploit the forest, like uniform plantations of Pinus caribaea var. hondurensis, strip planting with exotic and local species and the preparation on a large scale of charcoal, did not prove to be a success in the Surinamese circumstances.

The level of education of potential forest labourers is low, and qualified staff is scarce. Forest labour is relatively expensive, because labourers have to be transported into the forest and provided with living quarters and facilities.

Abundance of forest, shortage of staff and capital, and extensive exploitation methods, all point to an extensive management system with a low input per hectare.

1.2.5. Possible applications

Probably the CMS system is almost always socially acceptable in low-population areas, because it is simple to implement and has the further advantage of creating employment for the rural people.
In principle the CMS does not exclude management of units of forest by local communities. However, it should be added that no experiences exist in this field. If experiments in this respect are undertaken, it is recommended to let the community-enterprise work as commercially as possible and to have it organized in a way similar to the system described below.

The two components of the CMS were designed for the mesophytic forests of the Forestry Belt in Suriname and not for swamp forest or xerophytic forest. For possibilities for the management of these types of forests, and in general for other types of management systems, is referred to Lamprecht (1989).

1.2.5.1. CELOS Harvesting System (CHS)

The CHS is not only applicable in the rain forests of Suriname (or similar forests), but in many lowland rain forest areas provided that sustained production is envisaged, and consequently logging intensity is restricted. The feasibility of the system is determined by terrain conditions rather than by forest characteristics. Everywhere in the tropics where wheeled skidders and crawler tractors can operate, that is where terrain conditions allow machine traffic, CHS can be used economically.

Terrain slope is probably the main limitation of CHS. The system is not compatible with cable yarding methods. *The maximum slope for economic skidding and crawling should not exceed 25 %* and the bearing capacity of the soil should preferably not exceed strength class 3. Further conditioning factors, such as log dimensions and spatial distribution of commercial trees, are of minor technical interest because the logging methods can be modified to handle, for instance, sizable logs or to harvest poorly stocked parts of the forest.

1.2.5.2. CELOS Silvicultural System (CSS)

The silvicultural component of the system, CSS, can be implemented successfully in selectively harvested stands similar to those found in Suriname, provided that sufficient sound commercial trees and regeneration have survived logging. The CSS was developed in Suriname, and is based on the concept of "biomass dependent site quality", i.e. a situation in which large parts of the nutrients of the whole ecosystem are concentrated in the biomass, and not in the soil. If, in that situation, large parts of the biomass are removed or killed (e.g. clear felling), the high temperatures together with the poverty of the soil and subsoil, menace the long-term productivity of the soil. This may result in an irreversible degradation of the site. The only way to maintain the nutrient store in the original ecosystem seems to be to maintain a large biomass, which slowly releases and recycles its nutrients. Therefore, the CSS aims at interventions in the forests which do not kill a too large part of the biomass.

The Celos Silvicultural System is a method of growing good quality timber in relatively short felling cycles in previously lightly exploited (preferably by using the CHS-method) or undisturbed high mesophytic forest in Suriname. No pulpwood, wood for charcoal or other wood assortment of low unit value is grown deliberately. Forest severely devastated by for example heavy exploitation, cannot be upgraded cheaply and easily by this system, and restrictions on the exploited volume and exploitation methods must be enforced to safeguard the forest.

It is supposed that the CSS will be most successful in first instance in the Forestry Belt of Suriname and perhaps - more or less adapted - in the northern parts of South America where the conditions are roughly similar to the conditions in Suriname. In parts of the world where site quality depends less on the quantity of standing biomass (sites with rich soils), other silvicultural systems may be more appropriate.

1.3. Objectives, means and golden rules of the system

CMS has the following specific *objectives*:

1. Sustained production of quality commercial timber;
2. A harvesting volume of approximately 30 m^3 per ha in a felling cycle of 20-25 years;
3. Maintenance of (almost all) the ecological, conservation, and protective functions of the forest;

These objectives are reached, using the following *means*:

1. Controlled logging to restrict damage to the remaining stand, forest soil and harvested product;
2. Silvicultural tending and monitoring of the remaining forest between harvests;
3. Recording of all forest operations for cost and management control.

In the CMS the following *golden rules* are applied:

a. Keep it sober and simple ("Kiss") and efficient;
b. Keep the quantity of the standing biomass high;
c. Preserve the uneven aged character of the forest;
d. Minimize damage to forest soil and remaining stand;
e. Protect the fauna as much as possible;
f. Protect the populations of key-species important for the functioning of the ecosystem;
g. Preserve the existing hydrological system as much as possible.

In fact, this whole manual is based on the above listed rules.

Every person working in the company which manages the forest - from managing director to forest labourer - should be aware of these rules and should try to apply them whenever possible.

Rule (d) implies that, if possible, harvesting activities should take place in the dry season. Rule (e) implies that everybody tries to minimize the influence of logging and silvicultural treatments on the fauna and that hunting is restricted or prohibited.
Rule (f) may imply that key-species of trees and lianas important for the survival of seed-dispersing animals like bats and monkeys are protected to a certain extent.
Rule (g) means that roads and trails should be planned carefully and that bridges and culverts should be properly maintained in order to avoid (permanent) stagnation of water.

1.4. Constraints

There are a number of constraints to application of the CMS in tropical rain forest areas which are:

1. Legislative requirements;
2. The management unit;
3. Logging intensity;
4. Type of venture;

These constraints will be discussed below.

1.4.1. Legislative requirements

Sustained yield management implies *permanent allocation* of an area for forestry and so does CMS. At least a long-term concession, in principle indefinitely renewable or type of ownership is needed to stimulate investment in sustained production. The responsible authority, for instance the Forest Service, has to have the legal and material means to implement large-scale management of rain forest areas.

1.4.2. The Management Unit

The gross area of a standard management unit is about 22,500 ha, and may range from 20,000 to 25,000 ha depending on forest and terrain factors. Larger ventures may include more standard units.

In the CMS logging operations are executed by a team consisting of two felling crews, one crawler crew and two wheeled skidder crews working in one logging compartment. Approximately 125-150 m^3 of timber per effective working day can be harvested, which means - counting with 150 effective working days per year - an annual production of 18,750 - 22,500 m^3. For a target harvest of 30 m^3/ha, the annual coupe ranges from 625 to 750 ha. Counting with a felling cycle of 25 years, the area of production forest ranges from 15,625 to 18,750 ha. One can estimate that about 20 % of the forest is non-productive or unmanageable, so the gross area of the management unit is about 22,500 ha and may range from 20,000 to 25,000 ha.

1.4.3. Logging intensity

Logging intensity has to be restricted because of two reasons:

1. The damage to the remaining stand has to be restricted. In CMS logging activities are carefully planned and logging intensities to 46 m^3 can be acceptable in order not to damage too much the remaining stand.
2. Because of the harvest nutrients are extracted from the forest ecosystem. In order to minimize loss of nutrients, a logging intensity of 30 m^3/ha should preferably not be exceeded.

A combination of these two aspects leads to the conclusion that *preferably logging intensity should not exceed 30 m^3/ha*. However, flexibility is required to avoid damage to vulnerable sites on the one hand, and insufficient harvesting of well stocked stands on the other hand.

In Surinam the proportion of commercial species is relatively small and often all prospected commercial trees (minimum dbh 35 cm) can be harvested without risk of excessive logging damage. In other countries the situation might be different (e.g. stands rich in commercial species) so that logging intensity should be restricted.

1.4.4. Type of venture

A private commercial venture based on allocated forest land has a vested interest in the regeneration of the remaining stand in order to stay in business. Other possibilities are a venture owned by the government or by a local community. In general it is not recommended to have the Management Unit managed by a State Forest Service, because execution of the work and control on the observance of the rules should be seperated.

Various ventures - each of them managing only a relatively small area of forest - could sell their roundwood to a modern, efficient, large-scale wood-based industry. A problem is that in many countries the roundwood market is absent: large ventures have there own concessions and wood-processing industry, and do not depend much on private firms for supply of logs, whereas smaller concessionaires own their own small, and often not very efficient saw-mill. A change in government policy is needed to overcome this situation, and a new generation of entrepreneurs is needed to develop a roundwood market.

In areas where suitable sites for sustained-yield forest management are scattered, these areas are best managed by independent, self-supporting companies rather than by large enterprises. Large enterprises (or a forest service managing a hugh area) should divide their big concessions into smaller units of approximately 22,500 ha, which can be managed as independent ventures with the company as shareholder. Each of these units should be managed in an independent way and should dispose of its own equipment. Exchange of personnel between the units should be limited as much as possible. The personnel of a unit should get a good knowledge of the situation in the unit and a good "relation" should grow between the area and the personnel of the unit. Of course, part of the infrastructure, like roads and landings can be shared by various units.

1.5. Mechanization

The CMS is a modern management system, using mechanization and technology to control costs, to prevent damage, and to improve working conditions. For one management unit the following equipment is necessary:

- 1 crawler tractor with winch, type D_3 or D_4;
- 2 wheeled skidders, 160-180 horse-power (250 hp is too much)
- powersaws and other felling equipment (see 2.4.2.2)
- jeep for transport of labourers to the field
- spare parts
- machetes, paint, arboricide, callipers, measuring tapes (25 m), diesel etc.

Because of the dimensions of the logs to be harvested, generally manual skidding and transport is out of the question.

1.6. Personnel and work organization

Each management unit of 20,000 to 25,000 ha requires *1 field-manager*, responsible for all harvesting and silvicultural operations, while *1 assistant manager* is in charge of logging operations. In the first phase (from year 1-7) approximately *24 labourers* are needed. From year 8-16 extra man-power is needed to execute the second silvicultural treatment. From year 16 on the third silvicultural treatment is also executed, which implies again extra man-power. From that year on the Management Unit can work at full capacity, for which some 39 labourers are needed (see table 1).

One of the principles of the CMS is a *job rotation system*, introduced because of the following reasons:

1. Job rotation is likely to lead to more *enthusiasm* and *involvement* of personnel. Damage reduces when the same crews are responsible for prospecting, felling and skidding. In traditional logging systems, the lack of interest demonstrated by the workers is a weak point. Such a management system gives insufficient attention to the physical and social aspects of the working method and environment. A prospecting crew, for instance, doing the same job year in year out, can complete their work in a 25 ha area in less than four hours and spend the rest of the day hunting. There is no sense of achievement or responsibility.
2. Each member of the personnel possesses a diversity of skills. This will allow for a *more flexible organization*.

Training and rewarding of workers are part of the policy of sustained management. The *basic training* of forest workers should include:

* tree identification
* tree mensuration
* log scaling and recording
* preparation and reading of maps
* handling of powersaw, wheeled skidders and crawler tractors, used in harvesting operations.
* safety measures necessary in the forest
* golden rules of CMS
* principles of both CSS and CHS
* necessity of job rotation

Especially in the harvesting system, the objective of damage control demands complete adherence to the harvesting regulations, which comprise well planned and carefully executed operations. Successful conversion to the CMS requires special attention to staff training at all levels so that they become committed to damage-controlled logging and silvicultural tending and monitoring of the remaining forests between harvests.

It is very important to emphasize the *safety rules* that should be applied during the field activities. Everybody working in the management unit or visiting it, should stick to the same safety rules. Safety clothing etc. (see also Section 2.4.2.2) should be provided by the employer and its use should be enforced. A relatively low investment may prevent serious injure and loss of well-trained personnel.

As to the *rewards for labour*, a premium system should give incentives for quality work, including damage prevention and logging efficiency. No emphasis should be placed on extra production, as this may lead to wood damage and wood waste and no real economic advantage.

The company should also emphasize its own *identity* by the use of badges, caps, etc. The personnel should be proud to work for a company that contributes to the national economy and its development, but at the other hand tries to work in a sustainable way so that future generations also may receive benefits from the same forest.

Table 1: Requirements of personnel per Management Unit (except administration and services; annual coupe 750 ha, 1 man-year = 220 working days).

	Man-years
1. Management	
1 field-manager, full-time	1
1 assistent field-manager, full-time	1
2. Prospecting	
1 crew of 5 labourers 20 ha/day	
750/20 x 5 = 187.5 mandays	1
3. Harvesting	
2 felling crews of 3 men, full-time	6
1 crawler crew of 3 men, full-time	3
2 skidder crews of 2 men, full-time	4
4. First silvicultural treatment	
3 mandays/ha over 750 ha: 2250 mandays	10
Total until year 7	26
5. Second silvicultural treatment	
3 mandays/ha over 750 ha: 2250 mandays	10
Total from year 8 until year 15	36
6. Third silvicultural treatment	
1.5 mandays/ha over 750 ha: 1125 mandays	5
Total from year 16 on	41

1.7. PLANNING

1.7.1. National and regional planning

Proper planning at national, regional, forest management unit and operational level reduces economic and environmental costs and is therefore an essential component of long-term sustainable forest management. As is shown in Fig. 2, before the design of a management plan can start, policy planning

Figure 2: Types of planning.

Scale level	*Type of plan*	*Contents of plan (indicative)*	*Type of planning*
National	More Years Plan	National ratio between forest-use-types, based on the desires of the society and forest typology	Policy Planning
Regional	Regional Forest Plan	Rough indication of the regional ratio between forest-use-types	
Local (Management Unit)	*Management Plan:* Long Term Vision	Location of forest-use-types per management unit	Forestry Planning (Planning of design and of management)
	Medium Long Term (10 years)	Description of development of the forest per Management Unit; setting of priorities for the coming planning period, balancing financial aspects.	
(Management Unit, Compartment, Inventory Unit)	*Working Plan:* Short term (max. 4 years)	Confrontation of management measures with financial possibilities; Implications for personnel and equipment.	Executive Planning

needs to be executed on a national and regional level. A forest can fulfil many functions. These functions can be subdivided into four categories: regulatory functions (climate regulation, regulation of hydrology, etc.), carrier functions (habitat for native tribes, areas for recreation, nature reserves, etc.), information functions (spiritual and religious information, scientific information, etc.) and production function (fuelwood, timber, non-woody products, genetic sources).

On a national scale the total forest area and the proportion of each forest-use-type have to be determined. A forest-use-type is a type of forest that should fulfil certain functions. It is clear that in a certain part of forest not all possible functions can be optimized at one time. For instance, if in a certain part of the forest the production function is emphasized, this generally cannot be combined with the function as nature reserve: the nature reserve should be located in another area. Other functions can very well be combined, for instance nature reserve and (restricted) recreation. On the national scale the proportion of each forest-use-type depends on the wishes of the society and the ecological possibilities. On a regional and local level the national priorities have to be translated, taking into consideration local circumstances like distance from important towns and local ecologic possibilities.

The starting point of CMS is a forest area, allocated as a permanent management unit (with most important function the production of timber) either by law or by ordinance. The unit should be planned and designed with the aid of all available information such as aerial photographs, terrestrial inventories, topographic and soil maps. A topographic map, scale 1:25,000 and a soil map scale 1:100,000 are indispensable. If not available, a topographic map can be designed using aerial photography.

1.7.2. Design of a management plan

1.7.2.1. Long-term vision and identification of major forest-use-types

The first step in the design of a management plan is the identification of major forest-use-types, for instance high forest for timber production or for nature conservation, swamp forest for recreation, marsh forest along creeks as protective forest, etc. For each forest-use-type clear objectives have to be designed. Also an outline is needed of the way each forest-use-type should be managed.

Generally high forest is allocated as production forest and marsh forest along creeks as protection forest. Freshwater swamp and savannah forest can be investigated for fish-breeding, recreation and nature reserve.

For production forest the management system described in this publication may be used (both the silvicultural and the harvesting system). The composition of the commercial stock and the site class may indicate the felling cycle. In the CMS a felling cycle of 20-25 years is envisaged from which an annual coupe of approximately 625 to 750 ha is derived for a standard unit of 22,500 ha.

It has to be taken into account that also part of the production forest should be allocated as *forest-for-zero-management*. In that part no logging or silvicultural treatments are executed. It is necessary to preserve part of the forest in the original structure and composition for the following reasons:

1. As a point of reference for the future. The effects of treatments can best be evaluated if part of the original forest is conserved. Future managers and foresters should have an idea how the original forest looked like.
2. As a source of species diversity of especially the high forest (in future some non-commercial species may become important). The reserves may also function as sources of seeds.
3. As a refuge for seed-dispersing animals, like monkeys.

The forest-for-zero-management should be considered as an indispensable part of the production forest. It should fit to the following requirements:

1. Representative for the productive forest in the Management Unit;
2. Located in a central part of the Management Unit;
3. Clearly separated from the rest of the Unit by creeks, roads or other clearly visible boundaries.
4. Area dedicated for this function: approximately 5 % of the superficies (some *1000 ha* per Management Unit).

For the whole management unit a *long-term vision* on the development of the area is needed. Should the proportion of each forest-use-type remain the same, or, if possible, should it change on the long-term? A kind of *zonation* might be introduced, for instance a central part of forest with the explicit objective to conserve nature, surrounded and protected by production forest. Also long-term financial aspects should be dealt with in the long-term vision, and priorities for management measures have to be determined. Management objectives should be set rationally for each forest management unit. Formulation of objectives should allow the forest manager to respond flexibly to present and future variations in physical, biological and socio-economic circumstances, keeping in mind the overall objectives of sustainability.

1.7.2.2. Compartment lay-out

Compartment lay-out is widely used in management systems in tropical rain forests. The method is based on the division of a forest area into harvesting (or logging) compartments of 100-400 ha. In the CMS such a compartment is not only restricted to an organizational unit for timber harvesting, but it is also a silvicultural unit. A term that denotes the integration of logging and silviculture is management compartment.

Boundaries of the compartment are formed by creeks, swampy sites, slopes, and inventory lines and forest roads where there are no natural boundaries. Generally terrain and forest characteristics are the most important factors influencing the lay-out. Production factors may influence the lay-out, but management compartments do not necessarily have to yield equal volumes. The target volume should be derived from cost minimization including the cost of moving machinery from compartment to compartment.

1.7.2.3. Road design

In management planning road design is also an important issue. An example of the secondary road system (branch roads) is shown in appendix 2. *These roads are projected on the watershed boundaries on sites of adequate soil strength.* Compartment and road design are matched to obtain a well balanced lay-out. There is a tendency to economize on road construction by increasing skidding distances. It is, however, recommended to find the economic optimum between terrain and road transport. The most economic way is to let the trucks enter into the primary trails as far as possible, using for the trailer the piggy-backing system. When the truck with the trailer reaches the landing along the primary trail, it turns round and the trailer is placed into its normal position to load the logs. This system can only be used when the trucks have the proper equipment, inclusive low-pressure tyres, and when weather conditions allow transport along the skid trails without damaging too much the soil.

A well designed road system can reduce the impact of road construction substantially. Useful guidelines have been given by Hamilton (1988) to minimize adverse effects as erosion and soil disturbance.

1.7.3. Working plans

Also short term planning is needed in order to implement the management measures that are described in general terms in the management plan. Working plans should comprise a period no longer than four years. In this plan the personnel and material implications of the measures proposed in the management plan are further worked out. Compartments to be logged in the planning period are indicated, as well as the allocation of all-weather and dry-weather areas, and areas to be excluded from harvesting. Logging operations and subsequent silvicultural treatments are planned per inventory unit (see also Section 2.3).

In some countries - generally not in Suriname - it may be necessary to design a fire management plan. The fire management plan may include regular opening of boundaries between the management unit and other areas, and between forest blocks within the management unit. In areas being logged or already logged, additional safety measures such as restrictions on use of fire, keeping corridors between blocks free of logging debris, etc., should be specified. Advanced warning systems, including those that are satellite based should be used.

2. CELOS HARVESTING SYSTEM (CHS)

The CHS has two objectives:

1. Reduction of damage to the remaining stand and soil caused by felling and logging;
2. Executing the felling and logging operations as efficiently and economically as possible.

As to the first objective, in Surinam it proved to be possible to reduce the damaged area from 25.4 % in the conventional system to 14,1 % in the controlled CHS system, and even to 11.6 % if in the CHS system a hydraulic winch was used, whenever possible, to transport the logs from the stump area to the skid trail (see table 2).

As to the second objective, the CHS proved to be cheaper than conventional systems. In conventional systems logging costs varied from US$ 24.10 to 29.45/m^3, while in CHS total logging costs were US$ 20.25/m^3 (1988 prices). The higher costs in CHS because of the introduction of new activities like prospecting and planning are more than compensated by a much more efficient use of the crawler and skidder (less machine hours per m^3 of extracted timber).

Table 2: Logging damage in controlled and uncontrolled harvesting systems in Suriname. Damaged area expressed as percentage of total logged area. Logging intensity 15-20 m^3/ha.

Method of logging	*Felling damage*	*Damage because of*		*Total damaged area*
		main trails	*sec. trails*	
Conventional (uncontrolled)	10.5	8.2	6.7	25.4
Controlled	6.8	4.2	3.1	14.1
Controlled + use of winch	6.5	3.8	1.3	11.6

In order to reach the above mentioned objectives of the CHS, a method is used in which the following elements are essential:

1. Prospecting and mapping all harvestable trees before any harvesting activity is executed;
2. Detailed planning of harvesting activities;
3. Logging operations which aim at minimal damage to the remaining stand and soil;
4. A good administration so that the efficiency of field activities can be checked.

These elements will be treated below in detail.

2.1. Opening up the forest within the compartments

This activity is done by cutting lines 1 to 2 m wide through the vegetation in both north-south and east-west direction to divide each compartment into plots of 400 x 250 m (see appendix 2). The 400 m line has a North-South orientation. In this way the length of the line gives an indication of its orientation for anyone lost in the forest. Distances are marked on the pickets. However, pickets may be damaged or quitted during road maintenance. Marking can also be done using magnetic points, buried in the subsoil of a road or a path, which can be located with a detector. This system demands some investment in equipment, but it is very safe.

It is estimated that a team of 5 men can cut 2.5 km line per day, thus the estimated number of man-days per hectare is 0.20.

2.2. Prospecting

2.2.1. Enumeration and mapping of potentially harvestable trees

The importance of prospecting cannot be stressed enough. A 100 % enumeration of harvestable trees (minimum dbh 35 cm) is vital to achieve the aims of damage control, sustained yield and logging efficiency.

Attention should be paid to the training of a prospecting crew because "prospectors" or tree spotters have to identify harvestable trees quickly and assess tree dimensions accurately. As tree enumeration in CMS serves both logging efficiency and silvicultural follow-up, field staff needs to be trained for both operations.

Each management compartment (total area between 100 and 400 ha) is divided into units of usually 10 ha (see for subdivision of the Management Unit Figure 3). Each unit is subdivided into 10 sections of 40 x 250 m.

Figure 3: Subdivision of Management Unit.

```
Management Unit (approximately 20,000-25,000 ha)
                    |
Compartment (approximately 100-400 ha)
                    |
Inventory Unit (400 x 250 m = 10 ha)
                    |
Inventory Section (40 x 250 m = 1 ha)
```

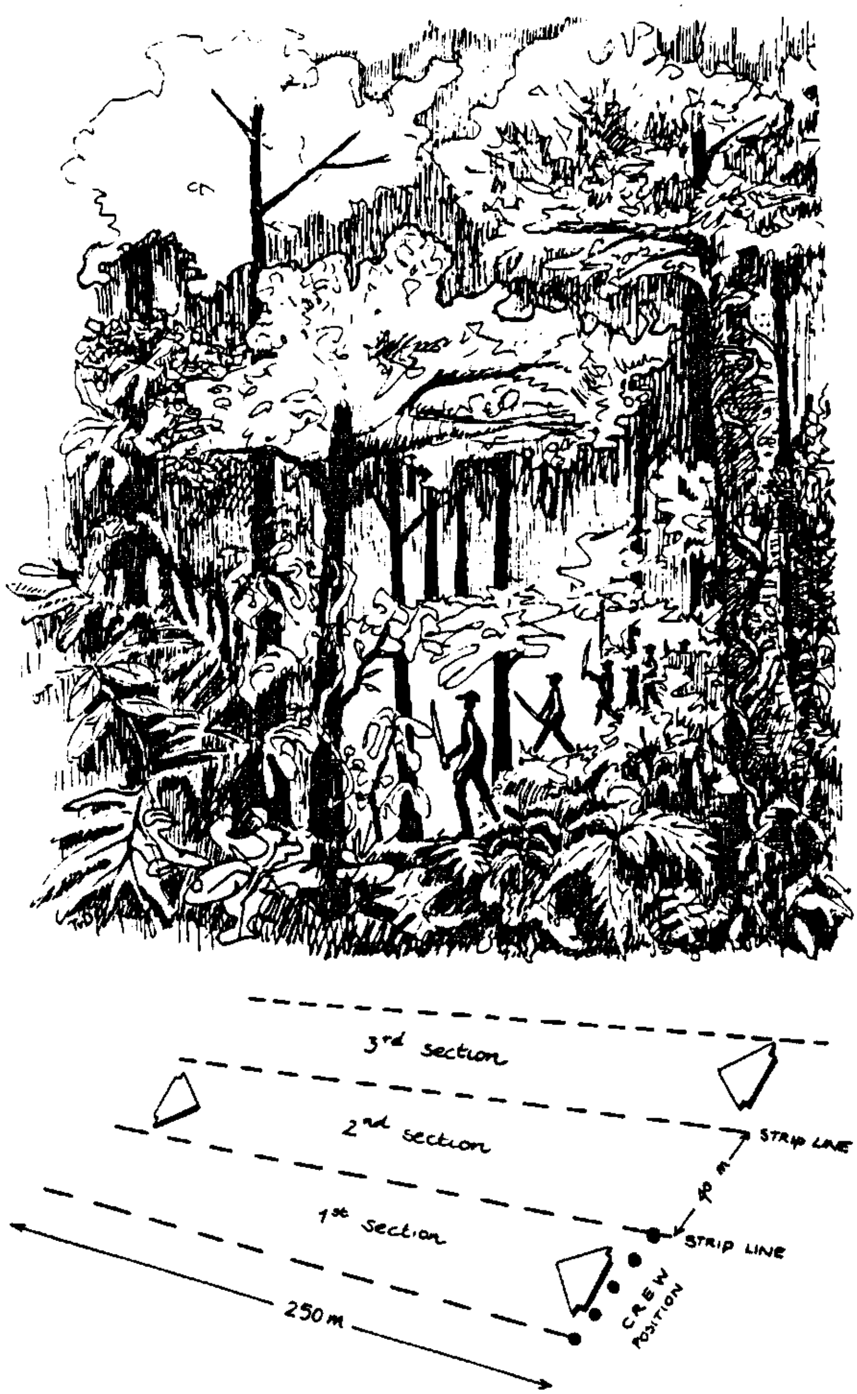
For the prospecting the following procedure is executed:

1. A crew of five tree spotters starts in the first section from a position along the north-south boundary. The crew members are spaced 10 m apart with a foreman in the middle (see Figure 4).
2. At a signal from the foreman, the crew moves in an east-west direction across the unit. It is important that the tree spotters move slowly and at the same speed. While walking, tree spotter number one signals picket distances marked on the east-west boundary to the foreman and to the tree spotter number five who cuts a new (temporary) line and marks the distances with pickets.
3. When a commercial tree is observed, the spotter signals the crew to halt. The tree is identified, numbered and the height and diameter assessed. Stems should be checked for rot, which in many cases can be done by hitting the tree trunk with an axe and listening to the sound. Trees with serious visible defects are recorded as rejects and marked with a blue cross indicating that they should not be felled.
4. Tree dimensions are recorded on a form (see Figure 6). The crew identifies trees in the forest by their vernacular name, and is recorded in code. The crew assesses the tree diameter in centimetres at the reference height of 1.30 m or 1 metre above the buttresses, and the length of the usable bole in metres, in most cases the tree section between the butt and the first branches.
5. The data are given to the foreman who first repeats (in order to avoid errors) and then records the information. Tree location and number, together with relevant topographic information (such as creeks, gullies, rock outcrops, steepness of slopes and possibly already existing main skid roads) are recorded on a predesigned map (1 piece of paper size A3 for one inventory unit

of 10 ha, see Figure 5). The occurrence of lianas on an enumerated tree is also recorded (to be cut by the sampling team, see 2.2.2).

6. On reaching the unit boundary, the crew moves to the next 40 x 250 m section, and the procedure is repeated in the opposite direction (west-east).

Figure 4: Prospecting method.



An experienced crew can cover approximately 20-25 ha within a day. Data on trees and topography are recorded simultaneously. The information presented on the hand-made maps could in the future be processed and stored in a computer data base, from which up-to-date maps and lists can be produced.

Some *practical points*:

1. Tree species and dimensions are best recorded in codes on waterproof sheets (e.g. "Rite-in-the-rain" paper) by the foreman (see Figure 6).
2. Selected trees can be marked with pre-numbered yellow or orange plastic labels fixed to their trunks with thumb-tacks. Each Inventory Unit of 10 ha should be numbered separately. Labels should be numbered from 1 till 100.
3. Tree diameter and height of the usable bole are assessed, but periodic checks with calliper and clinometer are recommended.
4. Trees for future silvicultural functions, e.g. seed trees, have to be clearly marked with a special painted sign so that extra care is taken to protect them from felling damage. Selection of seed trees is done by the foreman, who uses silvicultural criteria, like (good) quality and length of the bole, rareness and market value of the species. It should be observed that in the office extra seed trees may be indicated on the map, which afterwards have to be marked in the field (see section 2.3.2).
5. Identification of defective trees is very important. These trees are not felled but may be eliminated during silvicultural treatment.

2.2.2. Sampling for silvicultural treatment

This second prospecting consists of 3 activities which can be combined in one cruising (for reasons of transport efficiency the group executing these activities could work immediately behind the prospecting group):

- cutting of lianas and woody climbers on harvestable trees;
- sampling of advance growth;
- sampling of all tree species in order to estimate basal area.

The first activity is an essential part of CHS. In order to restrict felling damage, lianas and woody climbers on harvestable trees need to be cut during the prospecting phase, preferably one year before felling activities so that they rot before trees are felled. The cutting of lianas and woody climbers should be executed in all Inventory Units in the whole area to be logged. Only thick lianas (minimum dbh 5 cm) have to be cut.

The samplings are part of the CSS but should be executed before starting the harvesting activities, because shortly after logging the forest is difficult to enter. The samplings may take place in only one inventory section of 40 x 250 m in each inventory unit of 400 x 250 m. The selected inventory section should seem roughly representative for the whole inventory unit.

For the sampling of advance growth of desirable species a lower limit of 10 cm dbh is used while all desirable species are grouped together. Recording should be done with an angled calliper. Sampling methods should permit estimation of the diameter distribution, and not only of total basal area. Therefore a subdivision into diameter classes of 5 cm is necessary (10-14.9, 15-19.9, etc.).
Also a sampling of the total tree population is needed, which can be done simultaneously in one 40 x 250 m turn. Silvicultural treatment is decided on the basis of these sampling data (see 3.1.4 and Appendix 4).

2.2.3. Establishment of permanent sample plots

Visual inspection is not very helpful for estimating present standing volumes, and it is useless for assessing increments. A simple inventory technique, using permanent sample plots is essential, especially for the CSS. Therefore it is strongly recommended to use a series of permanent sample plots to monitor developments in the managed forest. Under normal Surinamese conditions 2 one-hectare plots per compartment of 100-400 ha is thought to be sufficient.

In the plots all commercial trees with diameter larger than 15 cm are measured (approximately 100 trees/ha). The plot is marked with plastic pickets so that it can be measured again after 8-10 years. A team of 6 men can establish and record a one-hectare plot in 2 days of fieldwork. A new recording requires 1 day's team work. If executed in the proposed way, this activity costs about 0.12 man-days per managed hectare. This activity is also part of CSS but should be executed before logging activities start.

2.3. Harvesting planning

2.3.1. Compartment and site selection

A management compartment is a harvesting and silvicultural entity with regards to sustained management. However, the decision as to which compartments are suitable for the CMS is based on prospecting and soil surveys. On basis of site quality and commercial timber stocking, some parts of a management unit may not be considered suitable for sustained management.

Some parts in a compartment may have a protective function, for instance marsh and freshwater swamp forest, or may be excluded from production for other reasons. These parts should be indicated on the map.

2.3.2. Assessment of allowable cut

The prospecting data are sufficiently accurate to estimate the standing volume of commercial species in cubic metres, that is the potential available gross volume. Per inventory unit of approximately 10 ha an estimate should be made of the potentially harvestable quantity. Certain parts may be that densely stocked with commercial harvestable trees, that the exploitation will largely exceed the required level of 30 m^3/ha. In that case a selection of trees to be harvested should be made.

This selection is primary made in the office, using the tree location map and the other information from the prospecting, recorded on the special form. The selection should *not* be based on the idea of creaming the forest, i.e. felling as much as possible of the most desired species. *The interest should be focused on the stand that remains after logging.*

This may imply that harvestable, but still relatively small trees of most desired species may be left in the forest to be harvested in the next felling cycle. In general it is recommended to cut few quantities of harvestable trees in the diameter classes between 35 and 50 cm, as trees of this size of many commercial species generally show good volume increment.It may also imply that trees of relatively rare, but desired species are left in the forest as seed-trees and that out of a concentration of harvestable trees on a small area, a selection is made.

As a result of this selection procedure and the skid trail design (see 2.3.3) a definitive map is made (see Fig. 5). The selection made in the office may be confirmed by a *field-visit* in which plastic labels are quitted of trees which on second view are not selected for harvesting.

2.3.3. Skid trail design

Prior to harvesting a skid trail system has to be established. The road system gives access to the management unit and connects the management compartments to each other and to landings and camp areas. For each compartment apart a skid trail system is designed.
In conventional trail systems, the skid trails are long with many curves and creek crossings and trail sections with low bearing capacity. These factors influence skidding production because the round trip time increases and the payload is reduced. At the same time a lot of damage is done to the remaining stand and the soil.

In the CHS a skid trail system should, therefore, be designed in accordance with road and harvesting plans, management compartment map (scale 1:5000), and topographic and prospecting data. The planning procedure starts at the office where each management compartment is treated as a harvesting unit.

The *main or primary trails* are part of the infrastructure of a management compartment and provide access to the compartment for machines. These trails *should be located permanently on high, well-drained and trafficable ground* as derived or assessed from mapped data. Of course, steep slopes should be avoided. The service life of primary trails is not restricted to one harvest only: each felling cycle (20-25 years) they should be used.

The *spacing* of main trails is largely determined by terrain conditions, the harvestable stock, and the density of the road system. Spacing should be as wide as possible but *should not exceed 100 m* because the maximum distance for winching logs is approximately 40-50 m. This is also an economic distance for crawlers in presorting operations. The maximum slope for a (primary or secondary) skid road is 4-5%.

In addition to office design, *field checks* are needed to determine the final location. The trail design is worked out on maps for use by the trail-opening and harvesting crews.
Main trails should be aligned in the forest ("stripped or cutlassed") prior to opening in order to ensure that the planned lay-out really is established in the field.

Branch or secondary trails are projected towards the harvestable trees as identified from the tree location map. These trails are not permanent and their routes may vary from harvest to harvest. As they form the shortest connection between stumps and main trails their service life is generally restricted to a few days. Because of the low traffic intensity, trails could be made on soils less favourable for skidder movements. Relatively bad sections should be clearly indicated on the map so that harvesting in the wet season can be avoided or at least restricted.

Branch trails need not be aligned for a trained skidding crew which is able to use a tree location map to search for logs. The trail lay-out as mapped is then sufficient basis on which to decide whether a branch trail to the stump area has to be opened or whether logs can be winched to the main trail.

2.3.4. Operational planning

All pre-harvesting and harvesting activities need to be set out in a plan of operations or harvest plan. This plan should also include production estimates and indicate the way harvesting and long-distance transport is arranged.

Important factors in the operational planning are:

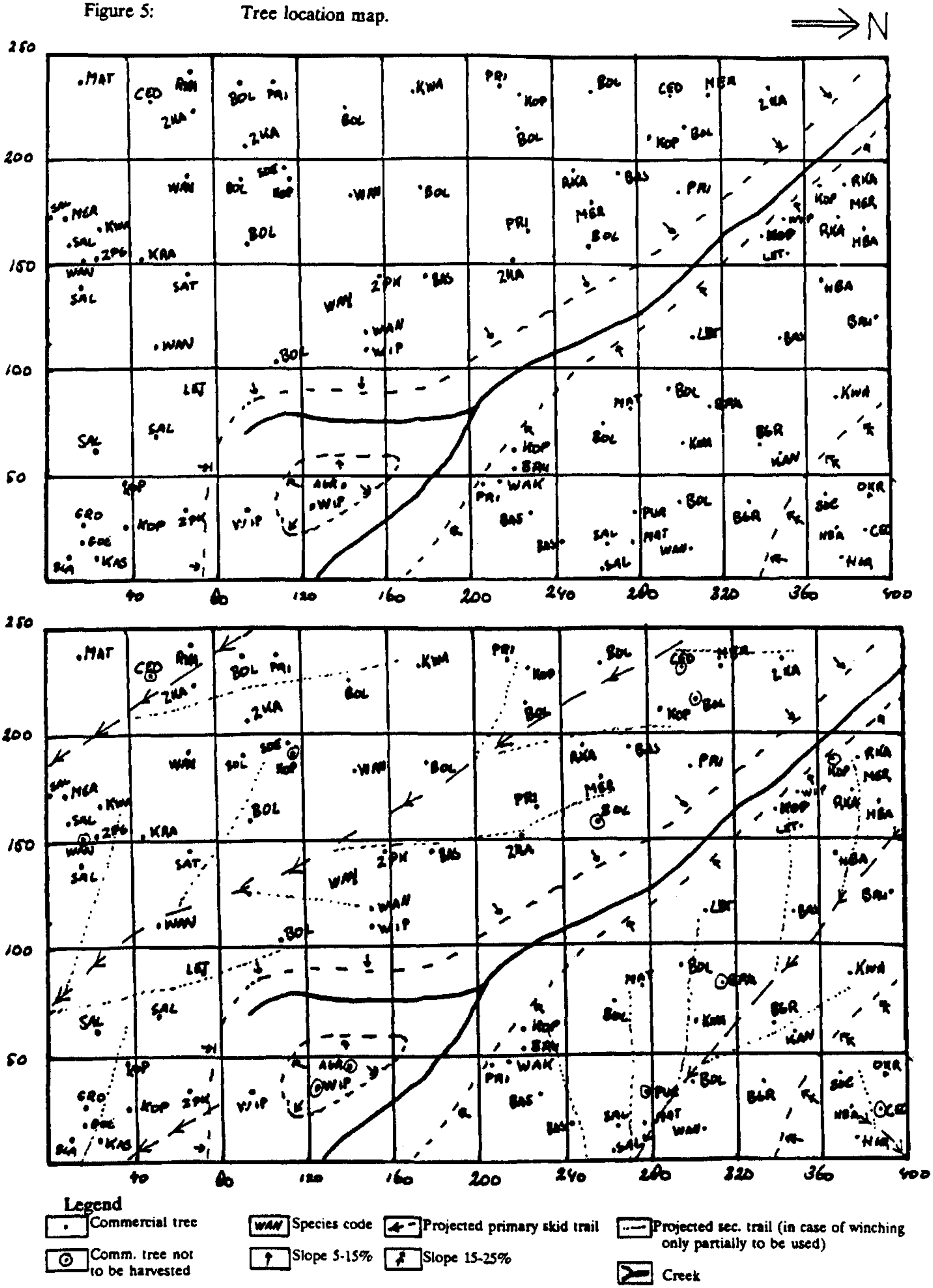
- technical skill of the workers;
- development of procedures for recording of all activities;
- harvestable volumes (m^3 per ha);
- tree dimensions;
- skidding distances;
- labour and machinery inputs;
- felling and skidding outputs.

Logging production of a management compartment can be assessed by means of production diagrams.

2.4. CHS: Logging operations

Careful logging should be economically feasible and ecologically acceptable. When the objective of maximizing short-term profits per area unit is replaced by sustained production, management policy has to be changed and logging methods modified. These modifications are not drastic. The same equipment as in conventional logging can be used for clean and efficient logging and to restrict damage to the remaining stand.

Figure 5: Tree location map.



2.4.1. Trail opening

Trails are opened prior to harvesting primarily to restrict logging damage, but also to improve logging efficiency. Projected (main) trails have to be aligned and are opened up in two possible ways:

1. by crawler tractor (bulldozer);
2. manually with the aid of powersaws.

2.4.1.1. Crawler tractor (bulldozer)

The best method is opening up the trails by the crawler tractor (bulldozer) which is also used for road construction. Some *practical points*:

1. Do not dozer big trees, as this produces big gaps in the trail;
2. Totnal with of the trail should not exceed the over-tyre width of the skidder plus one meter, that is generally not more than 4 m.
3. Sometimes the organic layer and remnants of cleared vegetation improve trafficability. In that case do not dozer the forest floor;
4. Avoid places with a soft soil. If this is impossible, dozer the top layer in order to improve trafficability.
5. Some parts of the main trail system are susceptible to disturbance. The idea behind damage-controlled skidding is to use the main trails again in future harvests. As long as old trails can be repaired, new ones should not be opened. *Stabilization* of parts of the main trails susceptible to disturbance, can be done in two ways:

   - by a top layer of gravel;
   - by dry compaction done with an unloaded wheeled skidder traversing opened trails four to six times until maximum compaction is obtained. This treatment, which will improve trafficability, is also recommended for the repair of damaged trails after deep ruts have been filled with gravel or sand.
6. Creek valleys are very susceptible to soil damage, and are a source of problems affecting skidding efficiency and damage prevention. Therefore, *bridging creeks* with movable aluminium culverts or hollow trees covered with a soil bed is essential.
7. Given the risk of *bark and root damage*, harvestable trees along primary trails should be felled and not reserved for future production. Such trees should be added to the felling list if not already selected by the prospecting crew.

2.4.1.2. Manually with the aid of powersaws

Trails can also be opened manually with the aid of powersaws. This method has some positive points for damage control, but it is labour intensive and expensive (especially when costs of labour are relatively high). In Suriname it should only be used if a crawler tractor is not available. A light-weight powersaw may be used to clear a trail by felling trees above 15 cm dbh, whereas lower vegetation can be dozered by a wheeled skidder. To avoid puncturing skidder tyres, stumps need to be cut flat to the ground.

2.4.2. Felling operations

The felling technique has to be adapted to control gap forming and damage to future harvestable trees as much as possible. Felling can be carried out carefully at little extra cost and an orderly felling pattern makes skidding more efficient and consequently less expensive.

Figure 6: Filling up of the recording form.

a. *Filling up during prospecting phase*

Recording form
Date of Prospecting 20 Feb 1990

Inventory unit number: 10
Compartment number: 3

Tree no.	Species Code	DBH (cm)	Length of Bole (m)	Date of felling	Log no.	D-top (cm)	D-bottom (cm)	Length of Log (m)	Notes/ Quality	Date of skidding	Skid trip no.	Date of transport	Trip no.
31	KOP	85	16										
32	WAN	76	17										
33	BGR	90	20										
34	CED	51	8										

b. *Filling up during felling phase*

Recording form
Date of Prospecting 20 Feb 1990

Inventory unit number: 10
Compartment number: 3

Tree no.	Species Code	DBH (cm)	Length of Bole (m)	Date of felling	Log no.	D-top (cm)	D-bottom (cm)	Length of Log (m)	Notes/ Quality	Date of skidding	Skid trip no.	Date of transport	Trip no.
31	KOP	85	16	10 Jan 91	827	75	84	8	B lianas				
					828	74	63	7	B lianas				
32	WAN	76	17	10 Jan 91	829	66	74	8	B				
					830	65	57	9	B				
33	BGR	90	20	10 Jan 91	831	78	88	6	A				
					832	77	69	7	A				
					833	68	59	8	A				
34	CED	51	8	10 Jan 91	834	40	49	7	B				

c. *Filling up during skidding phase*

Recording form
Date of Prospecting 20 Feb 1990

Inventory unit number: 10
Compartment number: 3

Tree no.	Species Code	DBH (cm)	Length of Bole (m)	Date of felling	Log no.	D-top (cm)	D-bottom (cm)	Length of Log (m)	Notes/ Quality	Date of skidding	Skid trip no.	Date of transport	Trip no.
31	KOP	85	16	10 Jan 91	827	75	84	8	B lianas	17 Jan 91	1		
					828	74	63	7	B lianas	17 Jan 91	2		
32	WAN	76	17	10 Jan 91	829	66	74	8	B	17 Jan 91	3		
					830	65	57	9	B	17 Jan 91	4		
33	BGR	90	20	10 Jan 91	831	78	88	6	A	17 Jan 91	5		
					832	77	69	7	A	17 Jan 91	6		
					833	68	59	8	A	17 Jan 91	7		
34	CED	51	8	10 Jan 91	834	40	49	7	B	17 Jan 91	7		

d. *Filling up during transport phase*

Recording form
Date of Prospecting 20 Feb 1990

Inventory unit number: 10
Compartment number: 3

Tree no.	Species Code	DBH (cm)	Length of Bole (m)	Date of felling	Log no.	D-top (cm)	D-bottom (cm)	Length of Log (m)	Notes/ Quality	Date of skidding	Skid trip no.	Date of transport	Trip no.
31	KOP	85	16	10 Jan 91	827	75	84	8	B lianas	17 Jan 91	1	21 Jan 91	4
					828	74	63	7	B lianas	17 Jan 91	2	21 Jan 91	4
32	WAN	76	17	10 Jan 91	829	66	74	8	B	17 Jan 91	3	21 Jan 91	4
					830	65	57	9	B	17 Jan 91	4	21 Jan 91	4
33	BGR	90	20	10 Jan 91	831	78	88	6	A	17 Jan 91	5	21 Jan 91	5
					832	77	69	7	A	17 Jan 91	6	21 Jan 91	5
					833	68	59	8	A	17 Jan 91	7	21 Jan 91	5
34	CED	51	8	10 Jan 91	834	40	49	7	B	17 Jan 91	7	21 Jan 91	5

2.4.2.1. Organization

CHS is based on prospecting with tree location mapping to facilitate work organization and the search for harvestable trees. Management compartments are felled sequentially as stipulated in the management plan. Within a compartment, inventory units of 10 ha are systematically felled one by one, for example, by starting in the top section and continuing in the one direction towards the roadside landing of the compartment. For safety reasons only one crew is assigned per compartment.

The time between felling and terrain and long-distance transport of logs should be as short as possible, in order to avoid biological deterioration of the logs or other risks. At the other hand felling and skidding need to be well coordinated so that sufficient stock is felled to ensure that the skidder can operate continuously. Therefore, it is recommended to *maintain a stock of a few weeks*.

2.4.2.2. Crew and equipment

The felling crew consists of three men, one of them a senior operator who leads the team. All members can handle a powersaw. In this way felling production and work quality can be improved, fatigue and accidents are prevented and motivation and involvement of all workers are stimulated. The senior operator (or foreman) is responsible for felling and recording.

A good *felling equipment* is relatively cheap. At the other hand, the felling is very important for the entire harvesting process. Both arguments justify the investment of the following equipment, of which each crew should dispose:

* 2 powersaws
* spare chains and bars
* maintenance tools
* wedges and hammer.

All equipment should be well maintained. As to the powersaws, it can be observed that in Suriname the dimensions of the trees allow the use of medium-weight powersaws of approximately 8 kg.

For the *safety* of the crew the following articles are essential:

* safety clothing and shoes
* helmets
* gloves
* ear and eye protectors.

These articles are presently available throughout the world and are well adapted to tropical climatic conditions. In training sessions the necessity of the use of these articles should be explained and emphasized to the labourers.

2.4.2.3. Method

Felling is executed in a predefined sequence, starting for instance, in a logging compartment in the northern section of an inventory unit.

1. First underbrush and lianas are removed and flight paths are cut;
2. Then the felling direction is determined with care. This direction is determined by the following factors:

   * first priority for safety;
   * shape and size of the tree crowns;
   * the occurrence of lianas linking crowns of neighbouring trees;
   * possibility of application of directional felling (see 2.3.2.4);
   * wind direction;
   * natural lean of the tree.

   Based on the judgement of the foreman, the felling direction is determined.

3. Felling is done by making the notch and the back cut with a powersaw. A hinge approximately 3 cm thick is left in the tree to direct the fall (also see Fig. 7);
4. The felled tree is topped, limbed and bucked, numbered, measured and recorded (see 2.4.2.5). In order to facilitate winching, the length of the logs should preferably be between 7 and 10 m and their weight should preferably not exceed 6.5 tonnes. Each section of the trunk is numbered on the bottom with a metal disk which remains visible throughout the harvesting process.

The following points are important to *restrict felling damage*:

1. Use wedges for efficient and safe work, and to direct the lay of (especially smaller) trees;
2. Fell smaller (harvestable) trees first so that they are not damaged by larger ones;
3. Avoid wood waste by making the felling cut as close as possible to the ground and also by careful bucking and topping of the trees. In this way the felled volume can be increased by 2-5% ;
4. Avoid complete covering of logs by branches and leaves, so that the logs can easily be located by the skidding team;
5. Transport logs timely, if there is a risk of damage from other felled trees;
6. Special incentives should ensure quality work. For instance, every quarter a special prize might be awarded to the labourer who performed the best quality work.

2.4.2.4. Directional felling

Directional felling means predetermining the lay of the felled tree on the ground. The felling direction should be an angle of 30° to 60° to the adjacent trail, with the thicker part of the stem towards the trail (*herring bone felling*). In this way logs are positioned for transport to the trail, and damage to the remaining trees is restricted. However, because also other factors influence the felling direction (see 2.3.2.3) a perfect herring bone felling pattern is hardly ever reached.

A high level of training is required to execute directional felling safely and effectively. The directional felling method can best be explained by describing basic functions of the felling notch (Figure 7a). The notch, composed of a (horizontal) undercut and an oblique cut, is sawn to direct the fall of a tree and to prevent splitting of the butt. A tree with a straight trunk and symmetrical crown can be fully directed by the notch. A second cut (back cut) opposite the notch is needed to induce the fall. A medium sized tree (35-50 cm dbh) with a regular crown, but with a trunk against the required lay can be directed in the desired position by inserting a lever or wedge in the back cut and lifting the butt.

Larger trees have to be handled in another way because of the limited lifting capacity of a manually operated lever. A large tree with heavy crown often cannot be directed against its lean, and has to be directed to fall at an angle at one or other side of the lean thus influencing the lay to a certain extent. A tapered hinge needs to be maintained as holding wood to pull the tree in the desired lay (Fig. 7b). The holding wood is in opposite direction to the lean and its shape is determined by the angle between the lean and the lay. Large buttresses should be cut prior to the horizontal undercut.

Directing a tree is facilitated by wedges - one, two or three, depending on the tree diameter and the lean of the trunk - which are placed into the back cut (Fig. 7c and d). While the back cut is being sawn by the operator, his assistant gradually hammers a wedge to keep it open, thus preventing pinching of the saw bar. When the back cut has been made, the saw bar is removed and hammering of the wedges is continued until the tree is forced over (Fig. 7d).

2.4.2.5. Registration of felling

The same recording form as applied in the prospecting phase can be used in order to register felling production (see Fig. 6). A copy of the recording form with the prospecting information is taken into the field, while the original remains in the office.

Depending on the length of the bole, trees are topped and bucked into one, two or three sections or logs, each of which is numbered with a disk. Rejected logs are also measured for statistical reasons and the reason for rejecting is registered. The top and bottom diameter of a log are measured with a calliper and the log length with a tape.

Log quality is coded as follows:

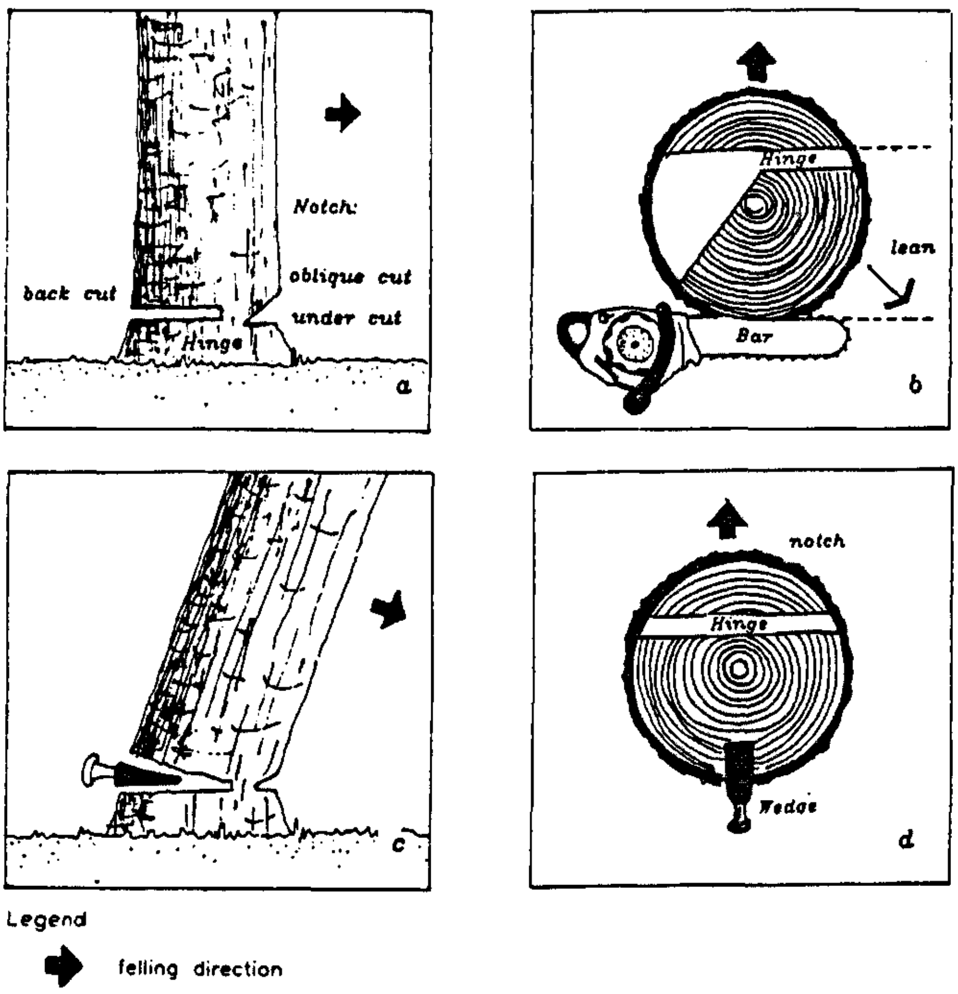
A = first quality;
B = second quality;
C = reject because of natural defects;
D = reject because of felling defects.

The occurrence of buttresses is recorded as:

1 = significant buttresses.

In case of no or small buttresses nothing is noted down.

Figure 7: Directional felling: making a felling cut (a and b) and inserting a wedge (c and d).



2.4.3. Collection of logs by crawler tractor

2.4.3.1. Organization

The best method to transport the logs from the stump area to the landing is by a combined operation. In this operation logs are collected and transported to the skid trail by 1 crawler tractor (if possible by using its winch), and transported further by 2 skidders. These operations are executed simultaneously.

2.4.3.2. Crew and equipment

For the crawler tractor - equipped with a winch - a three-man crew is needed, comprising an operator and two assistants. As in felling, job rotation is strongly recommended in order to cope with the heavy work and to maintain the crew's motivation. It is not easy to achieve job rotation because senior operators prefer to stay on their machines and leave the preparatory ground work to the choker men. Special training is needed for job flexibility.

Crews need to learn how to work carefully and how to use the power of both the crawler tractor and its winch to prevent damage instead of inducing it. Conventional working methods concentrate on rapid log transport, and machine power is often misused in order to achieve this target. Winching aims at avoiding travelling through the stand, but more manual labour is needed to pull out a winch line to the logs. It is obviously more convenient for the assistants if the skidder enters the stump area. *Taking a step back to more manual labour is rather a mental than physical barrier for conventional operators.*

2.4.3.3. Method

In principle, the crawler has to stay on the trail to winch logs from the stumps to the track. Winching is pulling logs over some distance while the machine on which the winch is mounted, remains stationary. Only when winching is hampered by large obstacles may the machine change position or be driven closer to the stump area. There are no special provisions to protect valuable trees in the stump area. In the CHS individual tree protection is not considered to be an adequate strategy.

The use of hydraulic winches is perfectly possible. Two men are able to pull out the line easily to a distance of 50 m. Winching efficiency and damage control are increased by:

1. a good trail network (see 2.2.2). This facilitates winching because it provides the shortest distance with the stump area;
2. an appropriate felling pattern (see 2.3.2);
3. by resetting the winch line in case of hang-ups (logs blocked by obstacles);
4. reducing the length of the logs to 7-10 m.
5. improving the skill of the winching crew.

When these conditions are fulfilled, winching can be used on approximately *40 % of the felled trees.*

The winch is located at the rear of the machine and has two main components:

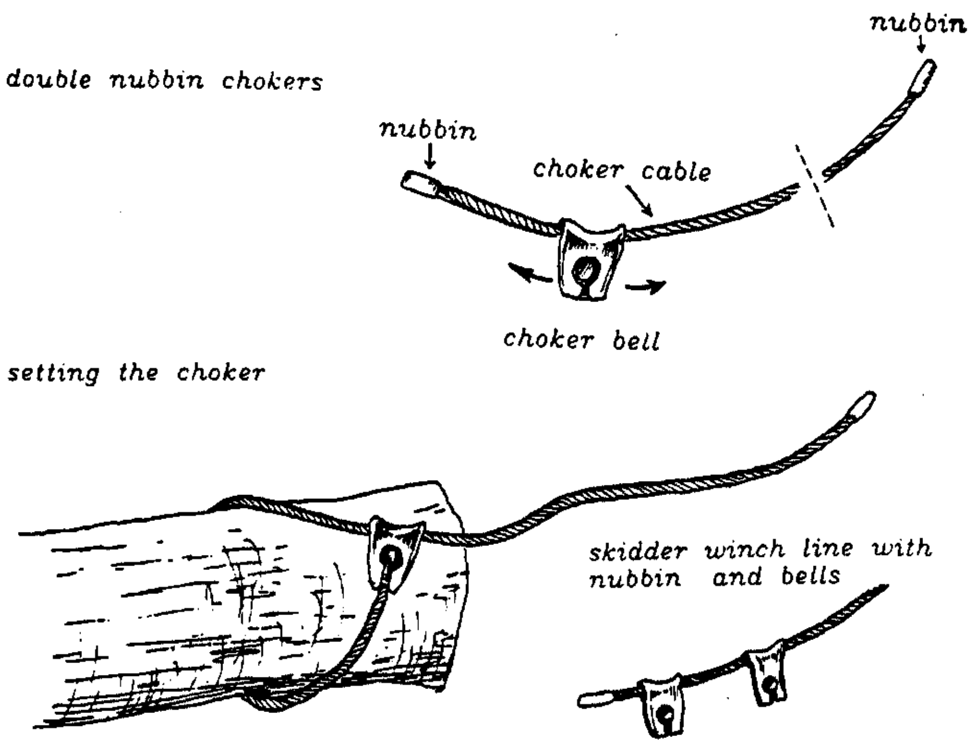
- the drum, which is powered by the engine (through a power take-off) and hydraulically controlled, is used to pull in and wind up the winch line;
- the winch line, a cable of 50 m in length and 16 mm in diameter. The line can be unwinded by hand when the engine is out of gear. The line has a nubbin on the end with some choker bells (see Fig. 8). In this way no pull hook is necessary (approximately 3.5 kg). This fact makes the winch line easier to handle. The chokers can be connected to one of the bells.

For the following reasons it is not recommended to use thicker cables than 16 mm in diameter:

- There is a risk of overloading the winch components;
- A thicker cable is heavy to handle. In principle, a cable with a diameter of 16 mm can be pulled out by one assistant only. This makes job rotation possible;
- A thinner cable is more flexible for winding on the winch drum without frequent jamming;

Under normal conditions the pulling capacity of the winch is not a limiting factor. The problems of winching very heavy logs were related more to their dimensions than their weight. Sizeable logs are very difficult to handle, both in choking and in guiding, while the chance of being blocked by trees and small obstacles increases. A log of approximately 10 tonnes (110 cm dbh and 11 m length) is, from a physical point of view, the maximum load that can be handled, but in such a case the cycle time is already uneconomically long. The maximum allowable load for winching is therefore approximately 6.5 tonnes.

Figure 8: Choker cables.



2.4.3.4. Winching cycle

A winching cycle consists of the following operations:

1. *Pulling out the winch line*. Generally one person can reach a log within a distance of 40 m in approximately a minute. At greater distance the line becomes heavier and considerable force is required to pull it out.
2. *Setting the chokers to the logs*. The most suitable type of choker is the choker with patent bell and double nubbin, which allows rapid connection to the log and winch line (see Fig. 8). Choker length was 4-6 m and diameter 16 mm. A set of 4-6 chokers is convenient. Occasionally, two small logs can be winched in one work cycle. While one assistant follows a log during winching, the second worker sets another choker, thus saving time.
3. *Hooking the winch line to the chokers*.
4. *Winching the log to the trail*. Many obstacles can block a moving log, causing a "hang-up". Whenever this happens, the assistant who follows the log, has to signal the operator to slacken the winch line. The choker is then reset so that the log can roll or slide away from the obstacle. Workers are able to release logs from obstacles simply without using tools other than cutlasses (machetes) and chokers.

5. *Unhooking the winch line*. When a log arrives at the trail, the winch line is slackened and unlocked by the setter who has guided the log.
6. *Decking the log*. The last action is the positioning and grouping of logs along the skid trail for further transport to the landing. When a log is winched from a favourable lay, further handling is often not necessary. For a log lying at more than 45° to the trail, the crawler has to manoeuvre the log until it is in a transport position.

For a standard load of 4 tonnes transported over a distance of 20-30 m the cycle time is approximately 6 min, corresponding with a theoretical production of 40 m^3/hour. Transport a distance of 30-50 m of a standard log takes approximately 7.1 minutes.

2.4.4. Skidding

If logs are properly collected and bunched (stored) along the trails, further transport with wheeled skidders is a relatively simple operation. Presorted and prechoked logs can be conveniently connected to the winch line of the skidder. In this stage, skidding production is determined by the quality of the trail system rather than by skid-operator's skill. For prevailing conditions in Suriname's Forestry Belt, the standard load for maximum travelling speed of the skidder is approximately 5 tons. Cost control of skidding is largely determined by the quality of the trails and justifies maintaining them in good condition.

Along the trails no special provisions are taken to protect individual valuable trees, except for cutting harvestable trees near the trails that may be damaged. In the CHS individual tree protection is not considered to be an adequate strategy.

On the recording form log numbers as well as trip numbers are recorded for administrative purposes. The same procedure is repeated for the transport phase, when the logs are loaded on a truck or boat for transport to a sawmill (see Fig. 6).

2.5. Administration

An important task of the administration of the management unit is to process the information on the recording forms, filled up during prospecting, felling, skidding and transport. After each phase the recording forms are copied. The original is stored for administrative purposes, while a copy is carried into the field to be filled up during the subsequent phase (see Fig. 6). By analyzing the information it can easily be checked if:

- all trees prospected as harvestable, were really felled;
- during the felling operations a lot of harvestable wood is lost;
- all felled trees really were transported to the landing;
- the quantity of wood transported by truck or boat to the sawmill or other wood processing industry, corresponds with the quantity brought to the landing.

Of course the administration also has other tasks, for instance personnel management and management of the CSS schemes.

3. CELOS SILVICULTURAL SYSTEM (CSS)

3.1. CSS: Its silvicultural philosophy

As was explained in 1.2.5.2, the CSS is based on the concept of "biomass dependent site quality", which implies that the interventions in the forest should not kill a too large part of the biomass. Another principle of the CSS is that the least possible should be done to reach an economically satisfactory production. The increment - the biological growth - is canalized in a commercial production of timber, but without destructing the ecosystem.

Simple harvesting of timber in a polycyclic system, leaving the forest to regenerate without further silvicultural assistance is not a satisfactory approach. In the long term such a management system is not feasible, because production of saleable timber per hectare is economically too low (in Suriname approximately 0.2 m^3/ha/yr). Therefore, silvicultural treatment to attain higher yields per hectare is essential. The silvicultural treatments should be easy to apply and to organize, mainly with low- or unqualified personnel.

The main objectives of the silvicultural treatments are:

1. Promotion of volume increment of desirable species;
2. Regeneration of desirable species and recruitment of saplings into the higher diameter classes;
3. Balancing of the ecology of the stand to safeguard sustained yield.

3.1.1. Volume increment of desirable species

In the CSS the silvicultural treatments applied in conditions comparable to the Mapane region in Suriname, may result in increments of desirable species of approximately 2 m^3/ha/yr, which means a tenfold increase compared to a situation without silvicultural interference.

A basic question is the selection of species to be favoured by the system. It is logic to start with the species accepted by the wood processing industry, because the general public is already used to them. The CSS uses a list of 49 species belonging to 20 taxonomic families (see appendix 1). This is a rather progressive list. The timber market is generally more conservative. In future, however, shortages in supply of tropical timber can be expected and possibly the timber market will (have to) accept more species. When applied to other regions, the Celos-list should be adapted to the local ecological and economic situation.

It should be observed that the goal of the silvicultural treatments should not be to eradicate undesirable species, but to reduce their proportion in the stand, and to ensure that individuals of these species do not become unduly competitive.

3.1.2. Regeneration of desirable species

A minimum regeneration is required to maintain a fairly stable stand table. In the experiments carried out in Suriname, in spite of all upward shifts of trees in the diameter classes, the total number of trees of desirable species in the lowest class was not diminished under optimal treatment schemes, but increasing, be it very slowly. It was also observed that individuals of desired species, liberated by the silvicultural treatments, flowered longer and more abundantly than individuals in untreated stands. In order to achieve seed dispersal for natural regeneration, it is preferable to prevent the natural allies of the forester, the forest animals that disperse the seeds, from being hunted.

3.1.3. Balancing the ecology

Balancing the ecology of the stand is a very complex matter, with many unknown long-term effects. The fauna, both large and small, are essential not only to seed dispersal and other aspects of regeneration, but also to the litter decomposition and soil processes. Working as closely as possible to the natural processes, and maintaining the forest in as natural a state as possible, is some guarantee for a good ecological balance.
In general it can be stated that monkeys, bats and other seed-dispersing animals are important, if not indispensable, for the dispersal of seeds of many tree species. So conservation of these animals is an important silvicultural item.

As to monkeys, for instance, it seems to be likely that spider monkeys (Ateles paniscus paniscus Linnaeus 1758) - a species on which an extensive study was executed - are the principal factor in the realization of locally high densities for commercial species like *Virola melinonii*, *Tetragastris* spp. and *Protium* spp. The spider monkey is largely restricted to the undisturbed, most heterogeneous high forest. In the Voltzberg region in Suriname, it occurs almost exclusively in mesophytic lowland rain forest. In liana forest, low forest and "rocksavanna" it probably does not enter. It infrequently enters edge habitats, probably because these offer little food. It is found primarily in the upper levels of the canopy and in emergents. The understorey is rarely used, and the lower extreme of its vertical range appears to be 12 meters.

If species like the spider monkey can survive in large areas under CMS management is unknown. More long-term research is needed to understand the consequences of CMS treatments for the ecological balance. Possible degrading effects caused by eradication of tree or animal species could not be detected easily on the relatively small experimental areas in Suriname, as the surrounding ecosystem, still largely intact, had a compensating influence.

With the now available information three (provisional) solutions can be proposed:

- The allocation of large areas (several thousands of hectares) for nature conservation;
- Protection of the population of certain tree and liana species important for the dispersing animals;
- Deliberately leaving pockets of untreated forest.

The first item is part of the national and regional planning, which were treated in Section 1.7.1, the other two items will be treated below.

Commercially undesirable species should not be eradicated, at least not before it is known whether they are essential to the forest ecosystem. An example of commercially undesirable species which are important to the ecosystem are species which bear fruits in periods of relative fruit scarcity (in Surinam July - September). Seed dispersing animals like rodents, monkeys and bats disperse the seeds of part of the commercial species. In order to survive during the period of relative seed scarcity, species that bear their fruits at that moment are important to the seed dispersing animals (to what extent is unknown). In Suriname some of these tree species, which may be considered as *key-species*, are: hoogland konkoni oedoe (*Gustavia hexapetala*), hoogland oemanbarklak (*Lecythis corrugata*), rode jakanta (*Dendrobangia boliviana*), kaneelpisi (*Licaria guianensis*) and lika oedoe (*Antonia ovata*).

For the same reason it may also be important to preserve part of the liana population. Efforts to improve efficiency of climber cutting operations which are part of the CSS treatments, other than some minor changes in field organization, should not be pursued. At the other hand, the climber cutting operations that are executed on harvestable trees one year before logging operations, should be as effective as possible in order to reduce damage to the remaining stand.
Most of the above mentioned key-species do not qualify for arboricide-girdling in the first refinement because they are too small. In the second refinement in which the diameter-limit for arboricide-girdling is lower, it is necessary to preserve at least part of the trees of these species.

Deliberately leaving pockets of untreated forest (*forest-for-zero-management*) can help prevent loss of species (see also Section 1.7.2). An area of approximately 1.000 ha per management unit of approximately 22.500 ha is proposed. A group of spider monkeys (roughly 15-20 individuals needs about 250 ha of undisturbed forest, so the proposed area is sufficient to maintain several groups. But there remain some open questions: Is such an area sufficient to avoid in-breeding on the long term ? Can there be sufficient contacts between groups living in different management units ?

3.1.4. Silvicultural effects of the treatments

An exploitation should take away about 5 to 10 stems/ha depending on size, with a total volume of 20-30 m^3/ha. Thus the basal area (=the sum of the areas of all stem-sections at 1.30 m height) of the originally undisturbed forest is reduced from about 31 m^2/ha to 28 m^2/ha. Growth conditions of the remaining population of commercial species are not improved greatly by this light exploitation, and therefore a refinement should follow.

In a felling cycle of approximately 20-25 years, the best is to introduce 3 refinements, but 2 may also be possible. Growth and mortality rates in the experiments in Suriname are such that it is theoretically possible to log the stand again 20 years after the first harvest. In practical forest management, however, it is preferable to make allowance for delays in treatment and other eventualities by planning a 25-year felling cycle.

3.1.4.1. First refinement

The first refinement is scheduled for the second year after felling. Treatment immediately after felling is not recommended because access to recently logged forest is obstructed by large amounts of fresh logging debris. It is recommended to delay the treatment until one year after felling, when passage is easier.

Refinement is the elimination, usually by arboricide-girdling, of undesirable trees above a certain limit, mostly of non-commercial species, but also badly damaged or hollow trees of commercial species, without future. It also includes cutting of lianas above a certain diameter limit.

In the first refinement the *exact diameter limit for refinement* is determined using the diameter or basal area distribution of the listed commercial species and of all species. The limit is placed where basal area of all species remaining under the said limit, plus the basal area of the commercial trees remaining above the limit, result in the target total basal area. The total basal area should be reduced from 28 m^2/ha to approximately 12 m^2/ha (maximum to be left alive: 16 m^2). In general this means that the diameter limit for arboricide-girdling should be placed between 20 and 30 cm. This implies that more than half of the tree biomass is killed. The refinement should not be more drastic, as this may result in excessive growth of weeds, lianas and secondary species, and probably in leaching-out of nutrients. At the other hand, if more than 16 m^2 of the basal area is left alive, the impulse given to the remaining stand is to weak to induce good growth.

Refinement is relatively simply to organize, and a uniform treatment, though not resulting in uniform forest conditions. It is important to realize that the biomass killed remains in the forest. Felling the undesirable trees would do much more damage to the remaining vegetation than this killing on the stump.

As a result of decreased competition and a large increase in nutrients and water available, the average girth increment of the remaining stand increases considerably and the commercial species have a good chance to come back and produce. Annual increment was raised above 2 m^3/ha in a trial plot of 16 ha in Suriname, monitored for six years, from 1976 to 1982. See also Fig. 9 and 10.

This treatment has proved to give good results, but according to Jonkers it is too drastic for poorly stocked parts of the stand. He proposes three alternatives, of which the effects could not be proved in the field during sufficient time (due to political circumstances):

1. Treatment 40/20-10. The lower diameter limit of 20 cm for non-commercial species is to be used in the vicinity of commercial trees larger than 20 cm dbh (at a distance less than 10 m) and the upper limit of 40 cm applies elsewhere.
2. Treatment 20-C. All trees of non-desirable species of more than 20 cm dbh and seen to be competing for light with commercial trees larger than 20 cm dbh are eliminated.
3. Treatment SR 18. All trees of non-desirable species of more than 30 cm dbh are eliminated. This is more or less the treatment De Graaf proposes.

Treatment 20-C and SR 18 are much milder and cheaper than treatment 40/20-10, but may result in less favourable growth rates.

3.1.4.2. Second refinement

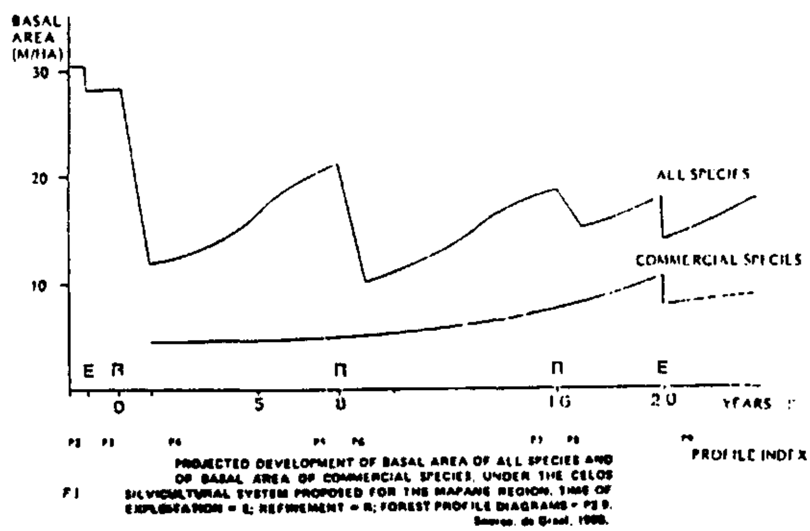
After 8-10 years the girth (and volume) increment slows down, because competition reaches high levels again:

- Basal area has increased from about 12 to about 20 m^2/ha. This implies that the living biomass and the leave area index have increased considerably, so the competition for light is heavy again;
- Most of the nutrients from the biomass killed in the first refinement, have been released (and absorbed by the living biomass), so the competition for nutrients (and sometimes water) is also heavy again.

So a second refinement is needed. The second refinement is carried out especially to relieve saplings and small trees of commercial species from competition. Because these are very vulnerable to felling damage in the second exploitation an increase in numbers is most desirable to achieve a more balanced diameter distribution. Therefore a treatment is proposed to arboricide-girdle all non-commercial trees larger than a certain diameter limit (generally between 5 or 10 cm dbh, depending on the outcome of an inventory). Also lianas with a diameter larger than 5 cm have to be cut. The result of the treatment should be a reduction of basal area from approximately 20 to 10 m^2/ha. *However, at least part of the population of key-species should be kept alive (see 3.1.3).*

The diameter limit for arboricide-girdling is again determined at the office, but should be lower now than in the first refinement, because there are only small quantities of big trees left in the stand (commercial species) and there is a relative abundance of trees in the lower diameter classes. So a larger part of the total basal area is concentrated in relatively small trees.

Figure 9: Projected development of basal area.



According to Jonkers this approach leads to the eradication of most non-commercial species and virtually complete elimination of the canopy in poorly stocked parts of the stand and he considered this as undesirable. De Graaf, however, observes that where intermediate or even small trees of desirable species are absent in areas of say more than a hectare, consideration could be given to leaving these areas untreated, but this should be done only if this does not disorganize the field work. A reason to treat such areas may be that treatment will stimulate recruitment of new individuals of desirable species. Without refinement, recruitment depends on slow natural processes.

According to Jonkers field surveys might still be necessary to develop an alternative for the second refinement which should also be a type of thinning in order to eliminate:

- commercial trees with stems which are too poor to contribute to future yields;
- commercial trees which grow very slowly. Characteristic features to identify these trees are the presence of many well developed, undissected lichens on the tree trunk or the presence of large epiphytic Bromeliaceae on the stem. Other yet unknown characteristics might exist.

3.1.4.3. Third silvicultural treatment

The third silvicultural treatment is best scheduled after year 16 after logging and a few years before the second harvest. This is a light treatment, which has not yet been applied in the experiments in Suriname. According to de Graaf it should have approximately the same character as the second refinement, but most emphasis is placed on liana-cutting. Jonkers also proposes to cut lianas, to execute other measures to reduce (future) logging damage and competition of palms. In this refinement, arboricide-girdling should be restricted to palms and small trees for the safety of the loggers.

3.2. Advantages of CSS

The CSS has several important advantages, apart from improved increment and regeneration, especially when the system is compared with plantation systems:

1. By retaining much of the original all-aged structure of the forest, many management options are kept open;
2. Forest managed in the CSS method is not very vulnerable to neglect. Neglect (e.g. not executing a planned refinement) reduces, of course, the increment of valuable timber, but it does not endanger the structure of the forest. In neglected plantations, however, the trees may easily be smothered in weeds, even at an advanced age;
3. There is little risk of forest fire because there is little dry slash, as even heavily refined forest remains damp and cannot be set on fire easily;
4. Pests and diseases are "calculated risks" as in the original forest. This means that these phenomenons may occur, but not on a large scale and not affecting many species at the same time;
5. Restricted changes in vegetation are less destructive to the fauna and flora than the radical treatments to obtain uniform plantations;
6. The nutrient store in the biomass, and the filtering function of the forest are only partly disturbed by the treatments prescribed, and so the forest ecosystem remains capable to replenish the nutrient store by absorbing the small quantities of nutrients which are present in raindrops;
7. Changes in evapotranspiration and hydrology are small;
8. Many non-woody forest products still can be harvested and produced as in forest without silvicultural treatment. Important species, producing these products might be included in the list of commercial species.

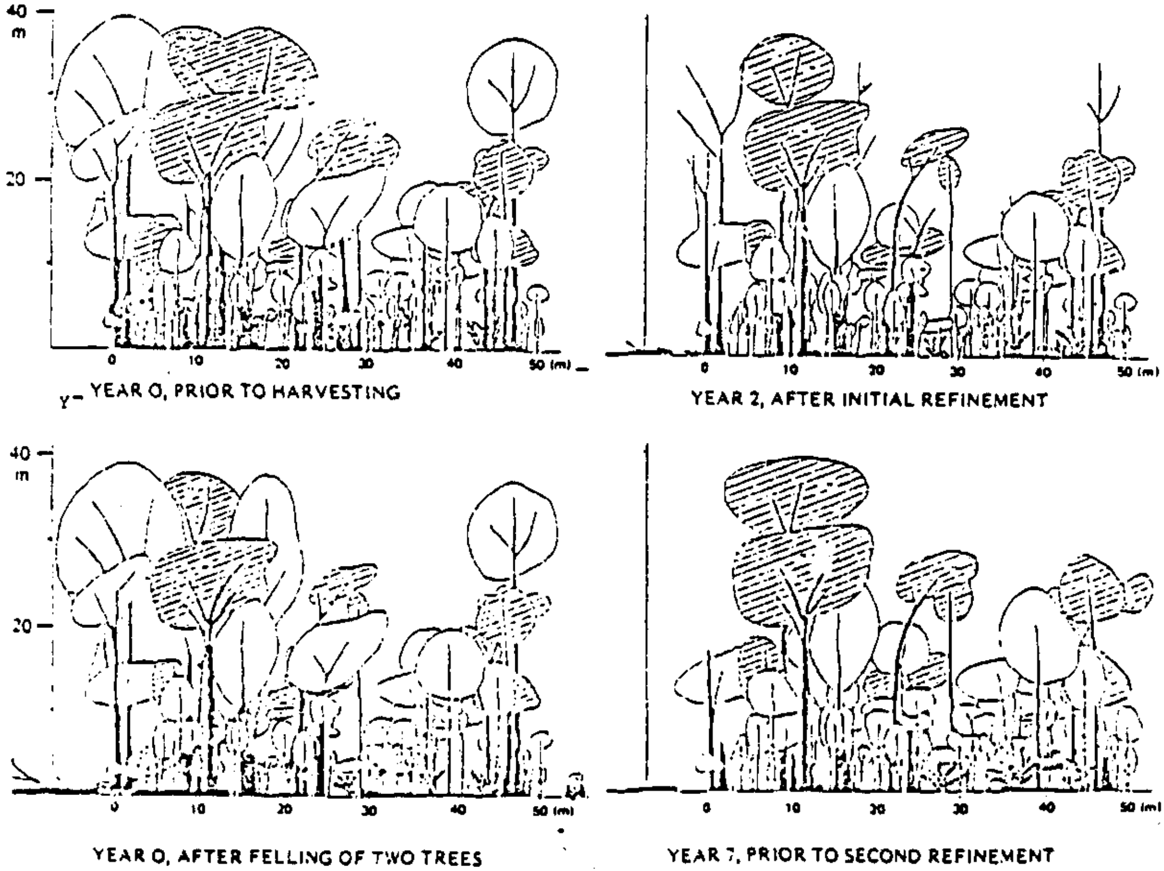
3.3. CSS: List of operations

As was stated before, silvicultural treatment immediately after felling is not recommended because access to recently logged forest is obstructed by large amounts of fresh logging debris. Therefore, the activities of the Celos Silvicultural System start approximately one year after felling.

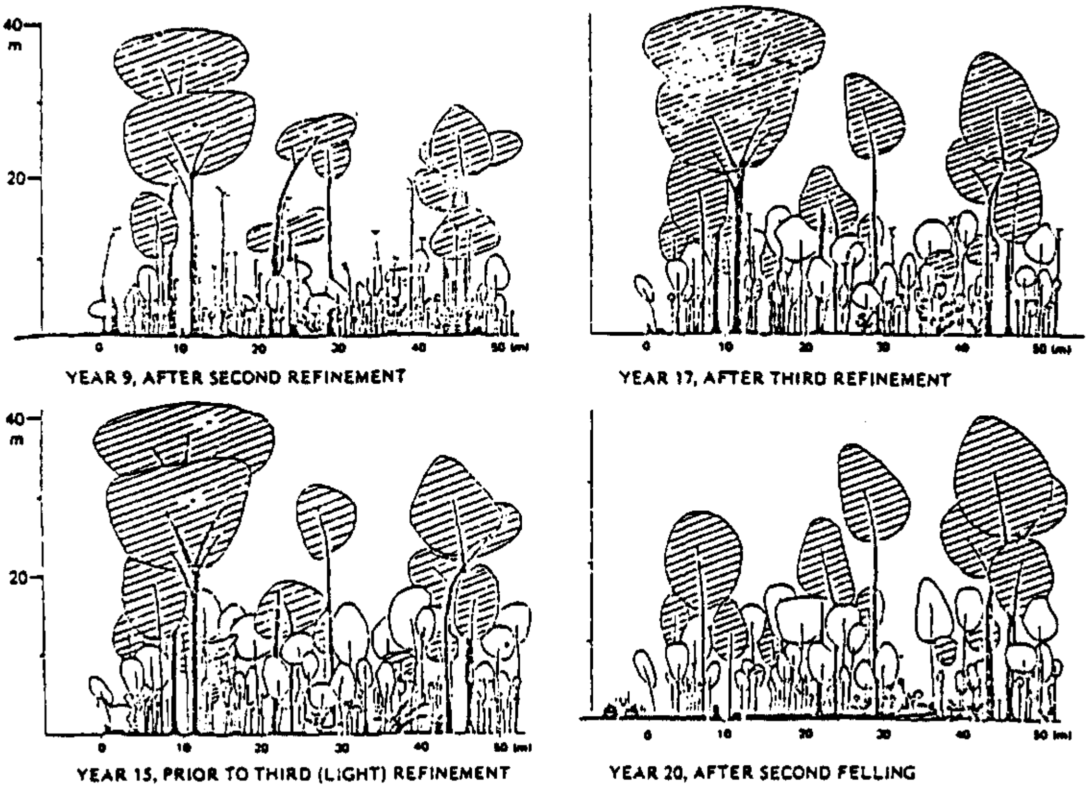
3.3.1. Sampling to determine diameter distribution and total basal area

This sampling cannot be combined with that carried out to estimate advance growth of desirable species and total tree population, as long as logging damage is unpredictable. See for procedure to follow section 2.2.2. If logging damage is predictable, this sampling is not necessary. The estimated number of man-days is 0.13/ha.

Figure 10: Hypothetic forest profile diagrams.



HYPOTHETIC FOREST PROFILE DIAGRAMS FOR THE FIRST FELLING CYCLE UNDER CMS. YEAR 0 – 7.



HYPOTHETIC FOREST PROFILE DIAGRAMS FOR THE FIRST FELLING CYCLE UNDER CMS. YEARS 9 – 20.

Source: De Graaf, 1986

3.3.2. Additional line cutting

After one year the lines around each Inventory Unit of 10 ha will still be visible, but the temporary lines cut during prospecting will be almost invisible. New lines are cut to form east-west strips 100 m wide and 250 m long. Thus each Inventory Unit of 400 x 250 m is divided into four parts of 250 x 100 m (see Fig. 11). The estimated number of man-days per hectare required is approximately 0.15. The strips should not be too wide for inexperienced labour. The north-south lines can be demarcated more clearly by a conspicuous line, for example those laid out by the portable distance measuring device used by the French Forest Service (Topochaix). This saves much line clearing, and also reduces problems in administration of tasks performed. On this device the length of the thin rope that is pulled out, is indicated. It is rather an expensive device. Thick, coloured rope might also be used, but this might rather often be stolen.

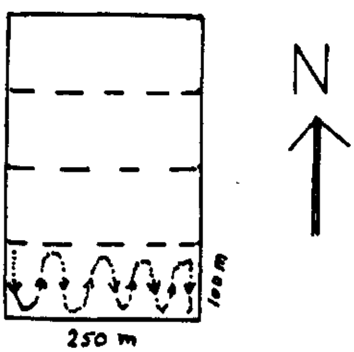
3.3.3. First refinement

3.3.3.1. Marking of the trees and liana cutting

Marking of the trees and liana cutting should be carried out by two tree spotters and three liana cutters. The treespotters mark the trees, while the labourers cut all lianas of more than 2 cm in diameter with a machete (see Fig. 12). The men work east-west and west-east direction, in a zigzag through the strip (see Fig. 11).

The bark of trees to be killed should be marked with (preferably blue) paint and not with slashes, because these are not conspicuous enough in many species, especially after several weeks. Prescriptions should be kept simple (list of non-desirable species with vernacular names and minimum diameter) as long as the consequences have not been tested sufficiently for more complicated instructions. Once the diameter limit is determined in the office (see 3.1.4) all trees of non-desirable species with diameter larger than the limit set for refinement, should be marked.

Figure 11: Route to be followed during a refinement.



The following points are important:

1. A tree should not be marked for arboricide-girdling if there is even the slightest doubt that it is a non-commercial species.
2. Most errors made originate from inaccurate diameter assessment. Measurements are often necessary to determine whether or not a tree should be arboricide-girdled. The best way is to use rulers or marks on the cutlasses, because callipers are too large and cumbersome, and tape measurements take too long.

Woody climbers are numerous, many fairly inconspicuous and those which are easily seen often grow in intricate tangles in which individual plants are hard to identify. This makes climber cutting a tedious and difficult job. At the other hand, it is not recommended to reach a 100% efficiency in killing woody climbers, because they also fulfil important functions for seed-dispersing animals.

3.3.3.2. Frilling and spraying

The marking-team is followed by the arboricide-girdling gang, who frill-girdle marked trees at a convenient height with a light, short-handled axe. The gang consists of three men cutting and two men doing the arboricide spraying. Also here, *job rotation* is recommended.

For a good execution of the activity the following points are important:

1. Frill-girdling is done by making overlapping cuts over the whole circumference of the tree, forming a kind of collar (Fig. 12, step 3). The cuts should extend just into the sapwood making an angle with the vertical of about 45°. However, sections of fluted or buttressed stems which cannot be reached with the axe are not cut. The frill should be located as near to the roots as feasible, because the arboricide is meant to be active in the root system.
2. After completion of the frill-girdle, the arboricide is administered (Fig. 12, step 4) with a low-pressure knapsack sprayer. This is modified by removing a small rotating component of the sprayer nozzle, so that the arboricide is applied as a jet rather than a spray.
3. The frill-girdle is filled carefully and 10 cm of bark immediately above it is coated with a film of arboricide. If the stem has been incompletely frill-girdled, uncut sections are treated to a height of at least 40 cm above the frill-girdle.
4. Overflow of the frill-girdle should be avoided.
5. The band of arboricide above the frill-girdle facilitates orientation during this part of the operation and makes supervision easier because it is almost as conspicuous as paint marks, remaining visible for months.
6. Spilling of arboricide on the forest floor should be avoided. In general, instructions for handling and storage of the arboricide and waste oil should be provided and enforced. Special restrictions are to apply near watercourses and other sensitive areas.
7. The best arboricide to be used is a 2.5% solution of 2,4-D in diesel or water.
8. The total input per hectare for a 20 cm refinement is three man-days, plus 0.4 litres of (pure) 2,4-D and 16.6 litres of diesel oil, plus overhead costs and some minor expenses.

A possibility to avoid the use of arboricide is ring-barking twice. More time is needed for the trees to die, but in a trial in Suriname, after two years more than 70% of the twice ring-barked trees were almost dead and non had recovered. Because of the short recording period, it may be premature to recommend twice ring-barking as an alternative to arboricide-girdling, but it is surely worth the effort to do experiments with this technique.

Still another possibility is a combination of ring-barking twice species that die rapidly after this treatment and applying arboricide to persistent species. In this case practice will show the species on which to apply arboricide. Whatever technique is chosen, for safety reasons the result of the technique should be that treated trees should have died off and fallen before the next silvicultural treatment is applied.

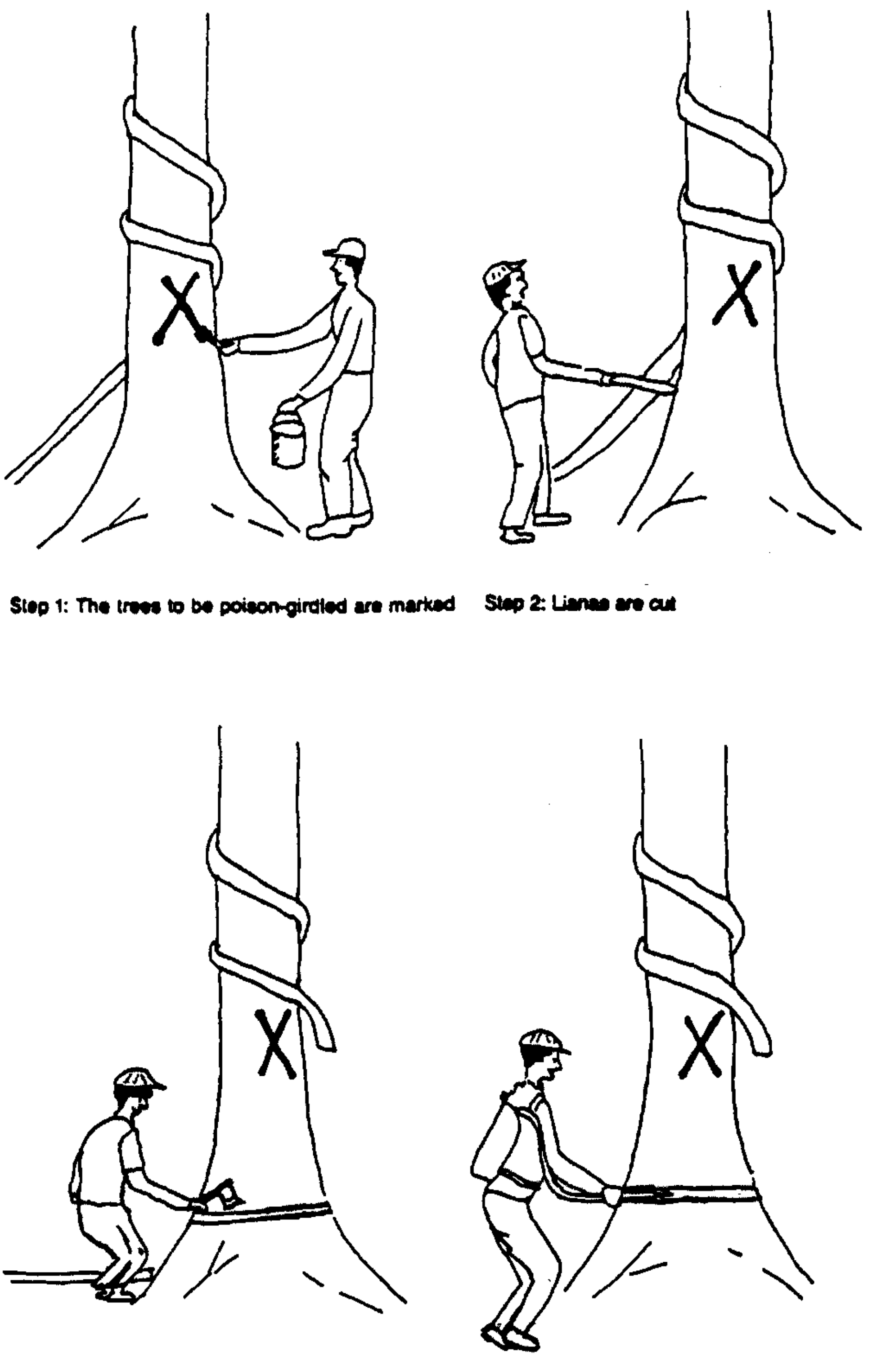
3.3.4. Second recording of permanent sample plots

The whole procedure that was described in 2.2.3 is repeated after 8-10 years in order to check:

- if increment of the trees of commercial species has been satisfactory;
- if new trees of commercial species have surpassed the diameter limit for registration;
- the development of the basal area.

If basal area is already above 20 m^2/ha, the second refinement should be executed.
A team of 6 men can record a one-hectare plot in one day of fieldwork. This activity is estimated to take 0.06 man-days per hectare of managed forest.

Figure 12: Refinement technique.



3.3.5. Second refinement

Before this activity can start the following preparatory activities are necessary:

- opening up the forest again (see 2.1);
- sampling to determine diameter distribution and total basal area (see 2.2.2);
- additional line cutting (see 3.3.2).

The lower limit for arboricide-girdling is determined at the office (see 3.1.4.2). The procedure to follow in the field is the same as in the first refinement (see 3.3.3). This activity including the preparatory activities will take about 3 man-days/ha. The refinement itself will take less time than the first refinement, as there will be few large undesirable trees. The amount of arboricide used will also be less, about 10 litres of mixture/ha.

3.3.6. Third recording of sample plots

In year 16 after logging a third recording of the sample plots is needed. See 3.3.4.

3.3.7. Third refinement

As was discussed in 3.1.4.3, unfortunately, the third refinement was never carried out in the experimental plots in Suriname. Probably the best way is to follow the same procedure as prescribed for the second refinement (see 3.3.5). The exact character of this refinement should be determined by evaluating the stands, using the data obtained from the permanent plots and from the samples.

3.3.8. Second logging

Between year 20 and 25 the second logging may take place. In principle the whole cycle of activities starts anew, but most activities will take less time, as the infrastructure already exists and the stands already contain a higher proportion of trees of commercial species.

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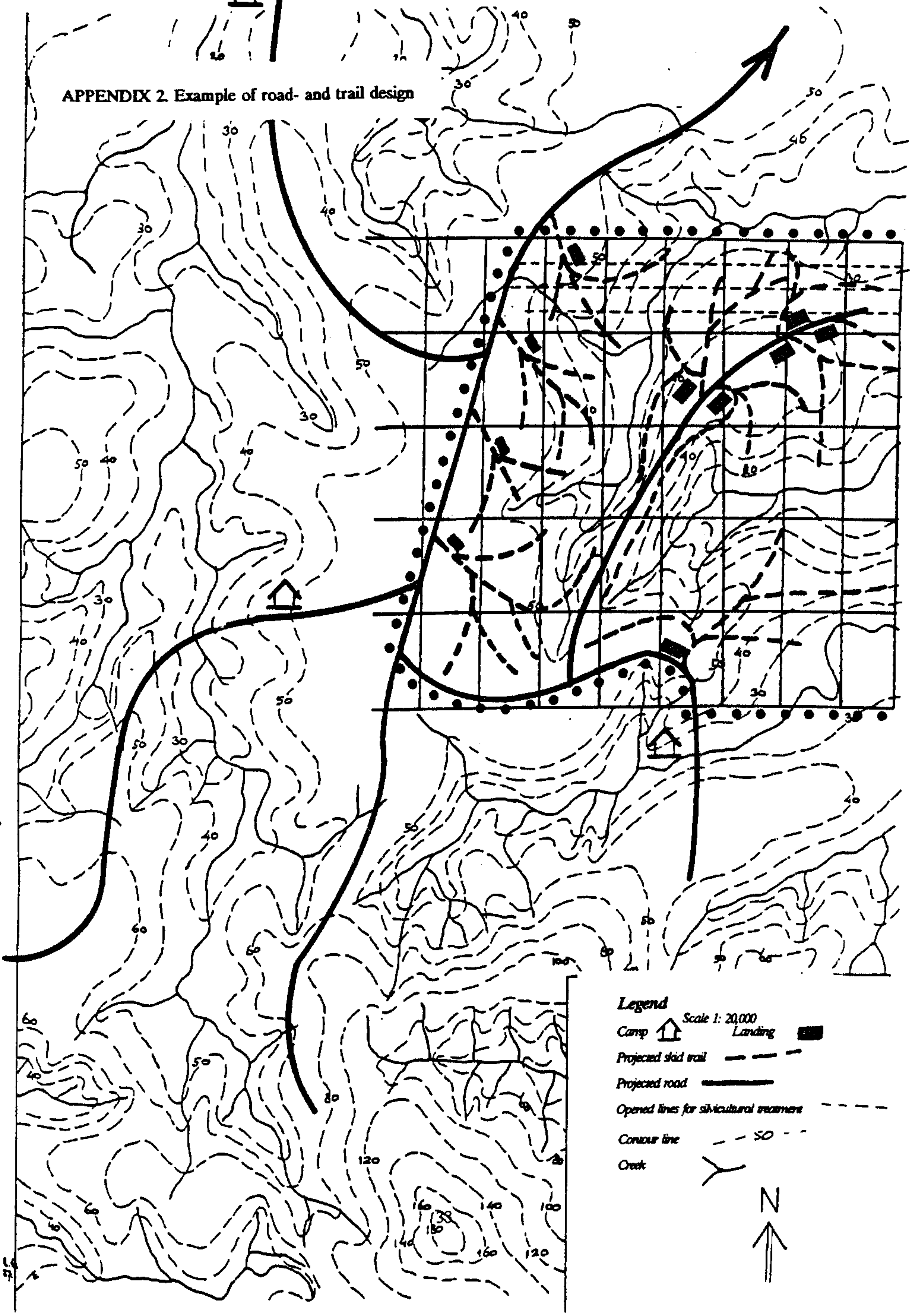
APPENDIX 1. CELOS-list of commercial species

Family	Scientific name	Vernacular name	Trade name
Anacardiaceae	*Loxopterygium sagotii*	slangenhout	
Annonaceae	*Xylopia aromatica; X. nitida*	pegrekoepisi	
Araliaceae	*Schefflera decaphylla* (syn.: *S. paraensis*)	morototo	
	Schefflera morototoni (syn.: *Didymopanax morototoni*)	kassavehout	morototo
Bignoniaceae	*Jacaranda copaia*	goebaja	futui
	Tabebuia serratifolia	groenhart	tabebuia
Burseraceae	*Protium insigne*	grootbladige tingimoni	kurokai
	Protium neglectum	harde bast tingimoni	kurokai
	Tetragastris altissima	rode sali	
	Tetragastris hostmannii	tingimonisali	
	Trattinickia burserifolia; T. rhoifolia	ajawatingimoni	
Goupiaceae	*Goupia glabra*	kopi	goupie
Guttiferae	*Platonia insignis; Rheedia benthamiana*	pakoeli	pakuri
	Symphonia globulifera	mataki	manni
Humiriaceae	*Humeria balsamifera*	blakaberi	tauroniro
Lauraceae	*Licaria canella* (syn.: *L. cayennensis*)	kaneelhart	
	Nectandra grandis	zwarte grootbladige pisi	louro preto
	Ocotea globifera	wanapisi	louro preto
	Ocotea glomerata	zwarte kleinbladige pisi	louro preto
	Ocotea petalanthera	witte pisi	louro preto
	Ocotea rubra	wana	red louro
Lecythidaceae	*Lecythis zabucajo* (syn.: *L. davisii*)	kwatapatoe	
Leguminosae	*Andira coriacea; A. inermis; A. surinamensis*	rode kabbes	angelin
	Dicorynia guianensis	basralokus	angelique
	Diplotropis purpurea	zwarte kabbes	tatabu
	Dipterix odorata; D. punctata	tonka	tonka
	Hymenaea courbaril	rode lokus	courbaril
	Mora excelsa	mora	mora
	Parkia nitida	agrobigi	
	Peltogyne paniculata; P. venosa	purperhart	purpleheart
	Platymiscium trinitatis; P. ulei	koenatepi	
	Vouacapoua americana	bruinhart	wacapou
Meliaceae	*Carapa procera*	krapa	andiroba
	Cedrela odorata	ceder	cedar
Moraceae	*Brosimum paraense*	satijnhout	satiné
	Brosimum guianense (syn.: *Piratinera guianensis*)	letterhout	snakewood
Myristicaceae	*Virola melinonii*	hoogland baboen	baboen
	Virola surinamensis	laagland baboen	baboen
Rutaceae	*Fagara pentandra*	pritijari	
Sapotaceae	*Manilkara bidentata*	bolletri	balata
	Micropholis guyanensis var. *commixta*	zwart riemhout	
	Micropholis guyanensis var. *guyanensis*	wit riemhout	
Simaroubaceae	*Simarouba amara*	soemaroeba	simarouba
Sterculiaceae	*Sterculia excelsa; S. pruriens*	okerhout	sterculia
Vochysiaceae	*Qualea albiflora*	hoogland gronfoeloe	gronfoeloe
	Qualea coerulea	laagland gronfoeloe	gronfoeloe
	Qualea rosea	bergi gronfoeloe	gronfoeloe
	Vochysia guianensis	wiswiskwari	kwarie
	Vochysia tomentosa	wanakwari	kwarie

Source: de Graaf (1986); Jonkers (1987).

APPENDIX 2. Example of road- and trail design



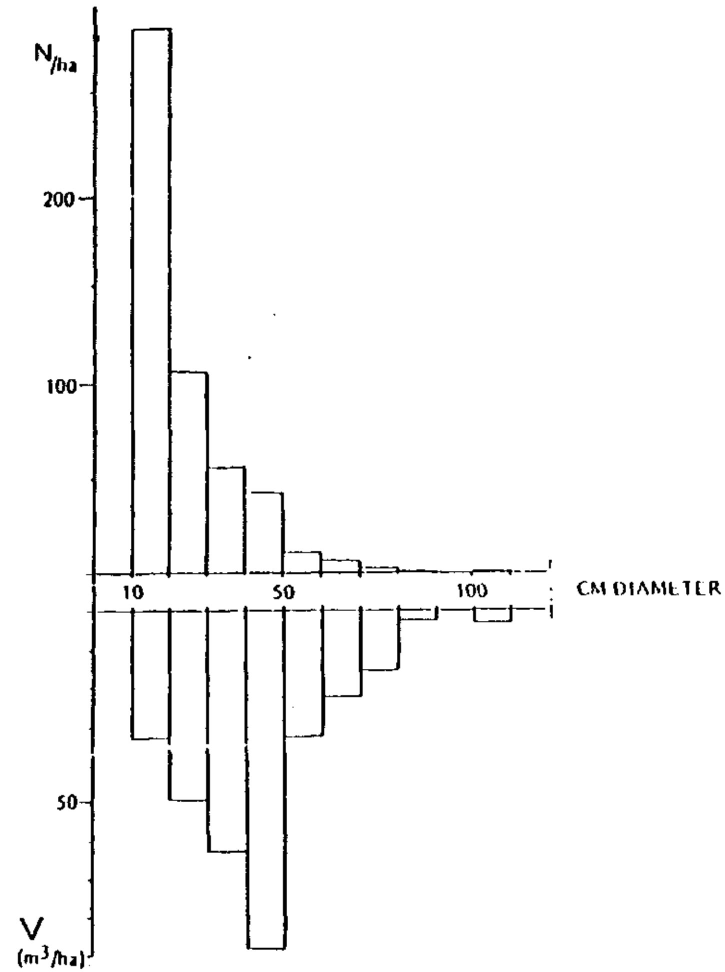
Species and volume harvested in the Weyerhaeuser pulpwood sample, Mapane, 1969. (after 's Lands Bosbeheer, 1971)

Local name	Volume (m^3/ha)	Botanical name
		Anacardiaceae
boskasjoe	0.20	*Anacardium giganteum; A. spruceanum*
slangenhout	0.46	*Loxopterygium sagotii*
weti oedoe	0.52	*Tapirira guianensis*
thyrsodium	0.02	*Thyrsodium guianensis; T. schomburgkianum*
		Annonaceae
pegrekoepisi	0.42	*Xylopia aromatica; X. longifolia; X. nitida*
		Apocynaceae
kromantikopi	0.10	*Aspidosperma album; A. megalocarpon*
pera (mapa)	0.10	*Couma guianensis*
bergibita	0.04	*Peissospermum sericeum*
mapa (sokosoko)	0.30	*Macoubea guianensis; Parahancornia amapa*
		Araliaceae
kasavehout (morototo)	0.12	*Didymopanax morototoni; Schefflera paraënsis*
		Bignoniaceae
goebaja	1.20	*Jacaranda copaia*
groenhart	1.68	*Tabebuia capitata; T. serratifolia*
		Bombacaceae
boskatoen	0.70	*Bombax crassum; B. globosum; B. nervosum*
		Boraginaceae
bostafelboom	0.26	*Cordia panicularis; C. sagotii*
		Burseraceae
tingimon	7.30	*Protium aracouchini; P. heptaphyllum; P. hostmannii; P. insigne; P. neglectum; P. polybotryum; P. sagotianum*
rode sali	10.32	*Tetragastris altissima*
sali	1.62	*Tetragastris hostmannii; T. panamensis*
awaloe pisi	0.30	*Trattinickia burserifolia; T. demerarae; T. rhoifolia*
		Caricaceae
awara oedoe	0.06	*Jacaratia spinosa*
		Caryocaraceae
sawari	1.12	*Caryocar glabrum*
		Celastraceae
kopi	5.94	*Goupia glabra*
sowtmeti oedoe	0.12	*Maytenus myrsinoides*
		Combretaceae
djiendja oedoe	2.71	*Buchenavia capitata*
kalebashout	0.06	*Terminalia amazonia*
bosamandel	0.24	*Terminalia dichotoma; T. lucida*
		Ebenaceae
blakaoema	0.60	*Diospyros guianensis; D. melinonii; D. sp.*
		Elaeocarpaceae
rafroenjanjan	1.48	*Sloanea eichleri; S. grandiflora*
boskoeswe	0.12	*Sloanea sp.*
		Euphorbiaceae
manbébé	0.02	*Alchorneopsis trimera*
fomang	6.64	*Chaetocarpus schomburgkianus*
tabakabron	0.14	*Croton matourensis*
witte foengoe	1.52	*Drypetes variabilis*
hevea	0.02	*Hevea guianensis*
merki oedoe	0.36	*Sapium klotzschianum; S. obtusilobium*
kototiki	0.18	*Mabea sp.*
		Flacourtiaceae
bita oedoe	0.04	*Homalium guianense; H. racemosum*
kaaiman oedoe	0.62	*Laetia procera*
		Guttiferae
laksiri	0.20	*Caraipa densifolia; C. richardiana*
pakoeli (geelhart)	0.28	*Platonia insignis; Rheedia benthamiana; R. macrophylla*
mataki	1.60	*Symphonia globulifera*
bosmangro	0.02	*Tovomita choisyana; T. schomburgkii; T. secunda*
		Humiriaceae
bofroe oedoe	0.14	*Sacoglottis cydonioides; S. guianensis*
		Icacinaceae
iakanta	1.28	*Poraqueiba guianensis; Dendrobangia boliviana*

Local name	Volume (m^3/ha)	Botanical name
		Lauraceae
pisi	0.64	*Aniba taubertiana; Endlicheria endlicheriopsis; E. multiflora; E. pyriformis; Nectandra kunthiana; N. pisi; Ocotea neesiana; O. puberula; O. splendens; O. wachenheimii*
kaneel pisi	0.04	*Licaria guianensis*
zwarte pisi	1.52	*Nectandra grandis; Ocotea glomerata*
witte pisi	1.42	*Ocotea globifera; O. petalanthera*
zilver pisi	0.06	*Ocotea guianensis*
wana pisi	3.22	*Ocotea sp.*
wana	0.40	*Ocotea rubra*
kaneelhart	0.02	*Licaria canella; L. cayennensis*
		Lecythidaceae
ingipipa	17.42	*Couratari fagifolia; C. pulchra; C. stellata*
boskalebas	0.04	*Couroupita guianensis*
tité oedoe	7.26	*Eschweilera chartacea; E. poiteaui; E. stellata*
hgl. oemabarklak	2.78	*Eschweilera corrugata*
hgl. manbarklak	7.81	*Eschweilera odora*
kwatapatoe	1.14	*Lecythis davisii*
		Leguminosae-A (Mimosaceae)
tamarin prokoni	0.56	*Enterolobium schomburgkii; Pithecellobium pedicellare*
swietiboontje	2.22	*Inga spp. (about 21 species)*
prokoni	2.62	*Inga alba; I. pezizifera*
agrobigi	0.60	*Parkia nitida*
kwatakama	0.64	*Parkia pendula; P. ulei*
pikinmisiki	8.00	*Piptadenia suaveolens*
bostamarinde	1.90	*Pithecellobium corymbosum; P. racemosum*
sopo oedoe	0.60	*Pithecellobium jupunba*
		Leguminosae-B (Papilionaceae)
rode kabbes	0.58	*Andira coriacea; A. inermis; A. surinamensis*
aroemata	0.02	*Clathrotropis brachypetala*
hoepelhout	0.34	*Copaifera guianensis*
basralokus	4.22	*Dicorynia guianensis*
zwarte kabbes	0.28	*Diplotropis purpurea*
tonka	0.34	*Dipteryx odorata; D. punctata*
walaba	14.32	*Eperua falcata*
makakabbes	0.50	*Hymenolobium flavum*
bosmahoni	0.36	*Martiodendron parviflorum*
hgl. kokriki	0.30	*Ormosia coccinea*
purperhart	0.68	*Peltogyne pubescens; P. venosa*
koenatepi	0.50	*Platymuscium trinitatis; P. ulei*
hgl. bébé	0.04	*Pterocarpus rohrii; P. santalinoides*
rode djedoe	2.42	*Sclerolobium albiflorum*

Local name	Volume (m^3/ha)	Botanical name
savanne djedoe	0.20	*Sclerolobium guianense*
zwarte djedoe	1.64	*Sclerolobium micropetalum*
djadidja	2.62	*Sclerolobium melinonii*
bergibébé	1.98	*Swartzia benthamiana*
gandoe	0.30	*Swartzia tomentosa*
ijzerhart	0.02	*Swartzia prouacensis*
gele kabbes	0.60	*Vatairea guianensis; V. speciosa*
bruinhart	1.33	*Vouacapoua americana*
jongo kabbes	0.55	*Vataireopsis sp.*
		Linaceae
pakira oedoe	0.10	*Hebepetalum humiriifolium*
		Loganiaceae
lika oedoe	0.48	*Antonia ovata*
		Melastomataceae
spikri oedoe	0.56	*Mouriria crassifolia*
		Meliaceae
krapa	4.08	*Carapa guianensis; C. procera*
ceder	0.02	*Cedrela odorata*
doifisiri	0.78	*Guarea guara*
sorosali	0.14	*Trichilia roraimana; T. surinamensis*
		Moraceae
kaw oedoe	0.74	*Bagassa tiliaefolia*
satijnhout	0.04	*Brosimum paraënse*
bospapaja	1.18	*Cecropia palmata; C. surinamensis*
manbospapaja	0.46	*Cecropia sciadophylla*
manletterhout	2.30	*Perebea laurifolia*
letterhout	0.50	*Piratinera guianensis; P. scabridula; P. velutina*
granboesipapaja	0.66	*Pourouma aspera; P. laevis; P. mollis*
takina (takini)	0.02	*Helicostylis sp.*
olie oedoe	0.10	*Trymatococcus amazonicus*
		Myristicaceae
broedoe oedoe	2.00	*Iryanthera sagotiana*
hgl. baboen	3.40	*Virola melinonii; V. sebifera*
		Myrtaceae
rode bosguave	0.06	*Aulomyrcia hostmanniana*
boskers	0.10	*Eugenia coffeifolia; E. patrisii*
		Nyctaginaceae
njamsi oedoe	0.16	*Torrubia olfersiana*
prasara oedoe	0.02	*Torrubia sp.*
		Olacaceae
patakoe wana	0.12	*Chaunochiton kappleri*
alata oedoe	0.20	*Minquartia guianensis*

Local name	Volume (m^3/ha)	Botanical name
		Rosaceae
hgl. anaura	1.36	*Couepia caryophylloides; C. versicolor*
kwepi	0.62	*Licania apetala*
rode kwepi	0.20	*Excellodendron barbatum*
santi oedoe	1.70	*Licania ovalifolia*
zwarte foengoe	0.30	*Licania micrantha*
foengoe	0.22	*Parinari campestris*
		Rubiaceae
moeténé (dede oedoe)	0.12	*Capirona surinamensis*
boskoffie	0.02	*Coussarea paniculata*
		Sapindaceae
Zwarte pintolokus	0.22	*Talisia sp.*
		Sapotaceae
batambali	0.02	*Ecclinusa guianensis*
bolletri	0.10	*Manilkara bidentata*
wit riemhout	4.54	*Micropholis guianensis*
zwart riemhout	1.64	*Micropholis guianensis; Pouteria engleri*
pintobolletri	1.74	*Pouteria cladantha; P. robusta*
zwarte pintobolletri	0.10	*Pouteria spp.*
djoebolletri	0.04	*Pouteria spp.*
kwasiba	2.43	*Pouteria spp.*
jan snijder	0.77	*Pouteria guianensis*
kimboto	0.06	*Pouteria ptychandra; P. surinamensis*
apra oedoe	1.54	*Pouteria sagotiana; P. gonggrijpii*
		Simaroubaceae
soemaroeba	0.20	*Simarouba amara*
		Sterculiaceae
okro oedoe	3.68	*Sterculia excelsa; S. pruriens*
		Tiliaceae
kankan oedoe	1.20	*Apeiba echinata*
fokofoko oedoe	0.18	*Apeiba tibourbou*
katoen oedoe	0.54	*Lueheopsis flavescens; L. rugosa*
		Ulmaceae
kwaskwas oedoe	0.10	*Ampelocera edentula*
		Violaceae
taja oedoe	0.02	*Paipairola guianensis*
unknown	0.30	
		Vochysiaceae
hgl. gronfoeloe	2.14	*Qualea albiflora*
gronfoeloe	0.48	*Qualea couruleu*
gujavekwari	1.04	*Qualea dinizii*
wiswiskwari	1.40	*Vochysia guianensis*
wanakwari	0.20	*Vochysia tomentosa*
mawsikwari	0.76	*Vochysia sp.?*
Total	194.42	



STEM–DIAMETER DISTRIBUTIO (N) AND VOLUME DISTRIBUTION (V) IN MESOPHYTIC FOREST IN SURINAME.

APPENDIX 4. Example of determination of basal area and diameter limit for refinement

1. Introduction

Table 1 of this appendix belongs to a relatively poor forest that was selectively logged some 20 years ago and then abandoned. Now it is going to be logged again and afterwards treated according to the Celos Silvicultural System.

The logging has two important consequences for our calculations:

- the trees of the commercial species with diameters larger than 35 cm are extracted, with a maximum extracted basal area of 3 m^2/ha; In this example we do not reach that limit;
- there will be damage to the remaining stand: if the Celos Harvesting System is used, this damage will be approximately 12% of the number of trees. As the proportion of small damaged trees - which contribute less to the total basal area - will be higher, the effect on the remaining basal area will be somewhat less, say 10%. So the reduction factor to be applied in the calculations is 0.9.

2. Basal area

In table 1 of this appendix the quantities of trees per hectare is given for all species grouped together and for all commercial species grouped together. Also the basal area per diameter class is presented. This can be calculated using the following formula:

$$BA = N * 1/4 * \pi * d_m^2$$

whereby:

BA = total basal area of all trees in one diameter class
N = quantity of trees in the diameter class
d_m = the mean diameter within the diameter class

For the diameter class 5.0-9.9 of table 1 this formula results in:

$$BA = 775 * 1/4 * 3.14 * ((0.05+0.099)/2)^2 = 3.41 \ m^2$$

In the same way the basal areas for the other diameter classes can be calculated.

Table 1 also presents information on the diameter class 5.0-9.9 cm. Under normal management circumstances these trees are not measured, because this would take a lot of time and the result will in many circumstances not vary much from 3.5 m^2/ha for all species together. However, in the calculations one has to keep in mind that trees up to 9.9 cm diameter have approximately 3.5 m^2 of basal area.

3. Limit for refinement

The procedure to determine the limit for refinement is a process of "trial and error". First we try a diameter for refinement of 25 cm. What basal area (BA) would result because of this refinement, taking also into account the logging damage and the extraction of trees of commercial species?

$$BA_{total} = 0.9 * \quad [(\text{BA of all species with dbh} < 25 \text{ cm}) + (\text{BA of comm. species with } 25 \text{ cm} \leq \text{dbh} < 35 \text{ cm})]$$

This results in:

$$BA_{total} = 0.9*[(3.41+1.85+2.95+2.39) + (0.64+0.69)] = 10.74 \ m^2.$$

This is too low, because 12 m^2 is the target. So now we try a diameter for refinement of 30 cm:

$$BA_{total} = 0.9 * [(\text{BA of all species with dbh} < 30 \text{ cm}) + (\text{BA of comm. species with } 30 \text{ cm} \leq \text{dbh} < 35 \text{ cm})]$$

This results in:

$$BA_{total} = 0.9 * [(3.41+1.85+2.95+2.39+2.10) + (0.69)] = 12.05 \text{ m}^2$$

which is almost exactly our target basal area, so for this stand a refinement with a diameter limit of 30 cm is proposed.

Observation:
In order to limit the loss of nutrients and the damage caused to the remaining stand the harvested volume should not surpass 30 m^3, which means roughly 3 m^2 of basal area. If a stand is rich in commercial, harvestable trees, the total basal area of the commercial trees with diameter larger than 35 cm will surpass 3 m^2. This surpassing quantity (total basal area of trees of commercial species with diameter larger than 35 cm, minus 3 m^2) should be taken into consideration in the calculations. The formula is then as follows:

$$BA_{total} = 0.9 * [(\text{BA of all species with dbh} < L_{ref}) + (\text{BA of comm. species with dbh} \geq L_{ref}) - 3 \text{ m}^2]$$

whereby:
L_{ref} = Limit for refinement

Table 1: Number of trees and basal area per diameter class of all species and of commercial species at Sarwa, Suriname. (1968)

	All species		Commercial species	
Diameter class (cm dbh)	N/ha	Basal area (m²/ha)	N/ha	Basal area (m²/ha)
5.0- 9.9	775	3.41	40	0.18
10.0- 14.9	150	1.85	20	0.25
15.0- 19.9	123	2.95	22	0.54
20.0- 24.9	60	2.39	18	0.69
25.0- 29.9	35.6	2.10	10.8	0.64
30.0- 34.9	32.6	2.67	8.4	0.69
35.0- 39.9	21.2	2.34	4.8	0.53
40.0- 44.9	17.4	2.47	4.6	0.67
45.0- 49.9	10.8	1.89	2.4	0.42
50.0- 54.9	4.4	0.94	0.8	0.17
55.0- 59.9	4.8	1.23	1.2	0.32
60.0- 64.9	2.6	0.81	1.2	0.37
65.0- 69.9	1.6	0.56	0.4	0.14
70.0- 74.9	0.6	0.25	0	0
75.0- 79.9	0.2	0.09	0.2	0.09
80.0- 84.9	0.4	0.20	0.2	0.10
85.0- 89.9	0.2	0.12	0	0
90.0- 94.9	0	0	0	0
95.0- 99.9	0	0	0	0
100.0-104.9	0.2	0.16	0	0
105.0-109.9	0.2	0.18	0	0
>45.0	26.0	6.45	6.4	1.61
>25.0	132.8	16.03	35.0	4.13
>15.0	315.8	21.37	75.0	5.36
>5.0	1 240.8	26.62	135.0	5.78