CENTRUM VOOR LANDBOUWKUNDIG ONDERZOEK IN SURINAME

The International Symposium on Amazonia
Report on a Study Tour to Belem, Brazil

by

W.B.J. Jonkers and P. Schmidt

CELOS

August 1982

1. Itinerary

7^{th} July 1983 - Paramaribo - Belem
15^{th} July 1983 - Belem - Paramaribo

2. Introduction

The SBPC (Sociedade Brasileira para o Progresso da Ciencia) has a long tradition of organizing annual meetings in which the progress in virtually all fields of science is discussed. The central theme in the 35^{th} meeting, which was held in Belem from 7 till 13 July 1983, was the future of Amazonia.

In conjunction with this annual meeting, an international symposium was organized by SBPC, the Interciencia Association and FADESP (Fundacao de Ampara e Desenvolvimento do Pesquisa da Universidade Federal do Para).

This symposium was the first international scientific meeting held in Brazil that could address, in a multidisciplinary approach, the major basic issues regarding the Amazon Basin.

The symposium was meant to allow examination of the importance of the region in scientific inquiry and as stimulus for research and new discoveries; an evaluation of benefits already obtained; the impact of science in the regional development of this Basin, patrimony of the national and international scientific community.

The objectives of the symposium were:

1) To discuss and evaluate proposals and restrictions on the rational utilization of the natural resources of the Amazon Basin, so as to provide means of livelihood to populations of the region, analysing at the same time, the conversion rate of virgin areas and the likely impact on the ecology of the area;
2) To present pertinent data and gather the most qualified researchers who actively participate in this area, together with counterparts from participating regions in the Treaty of Amazonian Cooperation;
3) To encourage dialoque among agronomists, ecology experts, forest specialists and related disciplines by means of discussion and analysis of issues as they appear;
4) To contribute to the objective of the Amazon Basin development, in consonance with its preservation, indicating methodologies to look for new technologies capable of solving problems of this immense and important region;
5) To take into account results from previous national and international meeting regarding Amazon matters;
6) Through rapporteurs, provide summaries of conclusions on each subject, drawing similarities and interrelationships among the subjects submitted;
7) To publish and distribute materials resulting from the Symposium.

Scientists from all countries in the Amazone region and elsewhere, among them the authors of this report, were invited to participate in the symposium and to present a paper. The participation of dr. P. Schmidt was sponsored by MAB-UNESCO. The authors would like to express their gratitude for this financial support.

3. Scientific Programme

This scientific programme included a wide range of subjects related to land use in Amazonia. The symposium attracted much public attention. In order to enable the Brazilian public to follow the discussions, virtually all papers were presented either in Portuguese or in Spanish. These languages were understood by a large majority of the participants but not by the authors of this report. Therefore, we are not able to discuss the content of the papers in detail.

The symposium was subdivided into seven sessions, i.e., an inaugural session, a session on agriculture, soils and land use, a session on ecology, a session on forestry, a session on mineral resources, a session on hydrology and a session with amazonian perspectives as central theme.

The low frequency of the flights between Paramaribo and Belem forced the authors to arrive after the inaugural session and the session on agriculture. During the ecological session, the ecology of the rainforest as well as regeneration techniques and the use of satelite photographs were discussed. In the session on hydrology the construction of hydro-electric dams in the Amazone Basin was an important issue. The session on mineral resources made it clear to us that large-scale mining operations are being planned and implemented in Amazonia.

During the symposium, the authors presented two papers, one on forestry and one about the lake Brokopondo. These papers will be discussed in the next section.

4. Papers Presented

The papers presented by the authors of this report are included as appendices I and II. The most important of the two was the paper on forestry in which the CELOS natural regeneration system was discussed. This paper was distributed to the participants by the authors before the presentation. The authors have the impression that the paper was well-received.

In the other paper, ecological and forestry aspects of the creation of artificial lakes in Suriname were discussed. Although these subjects are not his field of research, the organizers had requested dr. Schmidt to present this paper because there is an obvious lack of knowledge in the countries of the Amazone Basin about this subject. Both papers were discussed by the Brazilian press (see Appendix III).

5. Other Activities

On 9th July, the authors visited a reception at the local Goeldi Museum, held by the Brazilian national research counsel to introduce four new books. One of those books was "Amazonia, desenvolvimento integracao ecologia" by E. Salati, H.O.R. Schubart, W. Junk and A.E. de Oliveira.

On sunday, the 10th July, the organizers of the symposium had organized a one-day trip to a large aluminium plant under construction.

This complex includes an alimina plant with a capacity of 800.000 tons per year (Alubras) and an aluminium plant with a capacity of 320.000 tons per year (Alunorte). The electricity required will by hydroelectric power station 300 km upriver. The bauxite comes from a mine 1000 km west of the complex. In the planning of the complex, some attention is given to the protection of the environment.

On the 11th July, the authors paid a short visit to dr. J. Dubois of IICA-Tropicos and CPATU/EMBRAPA. Dr. Dubois was so kind to organize a field trip for the authors for July 14th, the day after the symposium.

This excursion was to one of the estates of Santa Izabel Agro Florestal Ltda. (SIAF). This company is specialized in afforestation. In Brazil, timber companies are obliged to plant 4 seedlings for every cubic meter harvested. Many logging firms delegate their reforestation obligations to specialized firms like SIAF.

The SIAF has a couple of field stations in Amazonia. A timber company, which has to afforestate, only has to pay. It has to pay to SIAF for the land and for the establishment and maintainance of the plantations. The revenues of the thinnings and final harvest are for the timber company.

The field station near Vila de Americano was visited. Most of the area was planted with Pinus caribaea (spacing 2 x 2 m, rotation 30 years, production goal pulp and sawn timber). The performance of this species was rather poor. Virola spp. and Carapa spp., which were planted in lines in secundary forest, showed a more promising growth.

The major advantage of the Brazilian reafforestation legislation is that it is implemented, although the authors do not know to which extent. It does, however, not result necessarily in good management practices in the forest plantations. Timber companies tend to be more interested in short-term profits than in long-term benefits. These firms will therefore try to reduce the costs of their plantations. For instance, the fact that the obligations of the logging firm is to plant a certain number of seedlings and not a certain area, will encourage this firm to apply a too narrow spacing in order to reduce the number of hectares to be purchased.

6. List of Contacts

One of the most important aspects of scientific meetings is that one is able to meet collegues and scientists in related fields. The authors met the following scientists during the symposium.

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Appendix I

CENTRE FOR AGRICULTURAL RESEARCH IN SURINAME (CELOS)

ECOLOGY AND TIMBER PRODUCTION IN TROPICAL RAINFOREST IN SURINAME

By

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Paper Presented at the
International Symposium on
Amazonia, Belem, July 1983

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July 1983

1. INTRODUCTION

On various places in Amazonia man has tried to convert tropical rainforest into monocultural plantations. In Suriname there are now about 7000 ha of plantations of *Pinus* and about 2000 ha of plantations of other species.

The ecological and economical results of these plantations are not as good as expected. In Suriname the pine plantation were established for pulp and paper production. Some years after the first planting, the paper company involved backed out and the possibility to produce paper got lost. Now it is planned to make telephone poles out of these plantations, but the economical and ecological balances will probably be negative. A positive secondary aspect is that many small Wacapou (*Vouacapoua americana*) trees, which are used now for this purpose, will be saved. Not only in Suriname but in Brazil too the growth of the plantations did not meet the expectations. The discussions on Yari indicate this.

Based upon these experiences we question the feasability of the conversion of neotropical rainforests into plantation forests. Plantation forestry, which is surely well adapted to European or North American conditions, should be only put into use in places, where the original rainforest was destroyed for other reasons, say for mining operations or for farming. If tropical rainforests have to be used silviculturally and economically, other yield systems more adapted to the ecological conditions have to be developed and used. Such a system, called the CELOS-silvicultural system, is the subject of this paper.

2. THE ECOLOGICAL CONDITIONS OF THE FOREST

If one wants to develop a silvicultural system adapted to the ecological conditions of a site, the best thing to do is to look first at the natural vegetation and to decide which characteristics are essential for the productivity. These characteristics should be incorporated in the silvicultural system.
The research was carried out on two locations in Suriname both about 100 km from Paramaribo (Fig. 1). The Mapane station was established in 1967, the Kabo one in 1978. The soil of both locations is very poor (Table 1), with a high percentage of aluminium at the adsorption complex.

According to Köppen, Suriname has a wet tropical climate (Af) with an annual rainfall of 2000-2500 mm per year. Dry periods are from February till March and from August till November. Even in the dryest periods the rainfall will normally amount to 60 mm or more per month.

The forests in question are evergreen seasonal forests (cf. Beard) with a very high number of species (see also SCHULZ, 1960). Counting only the trees above 5 cm d.b.h.* on one hectare in Kabo 108 species out of 38 families were found (SCHMIDT, 1982a). This is very well demonstrated too in Fig. 2, were a small transect of the Mapane forest is given. In this transect of 30 x 10 m 54 trees above 5 cm d.b.h. are found, belonging to 31 species out of 17 families. When small trees, lianes, palms, herbs and epiphytes are included, the number of species is at least 200 per ha.

In the tropical rainforest of Suriname, trees of all sizes occur intensively mixed. The number of trees decreases gradually with increasing diameter.

*) d.b.h. = diameter at breast height (1.30 m)

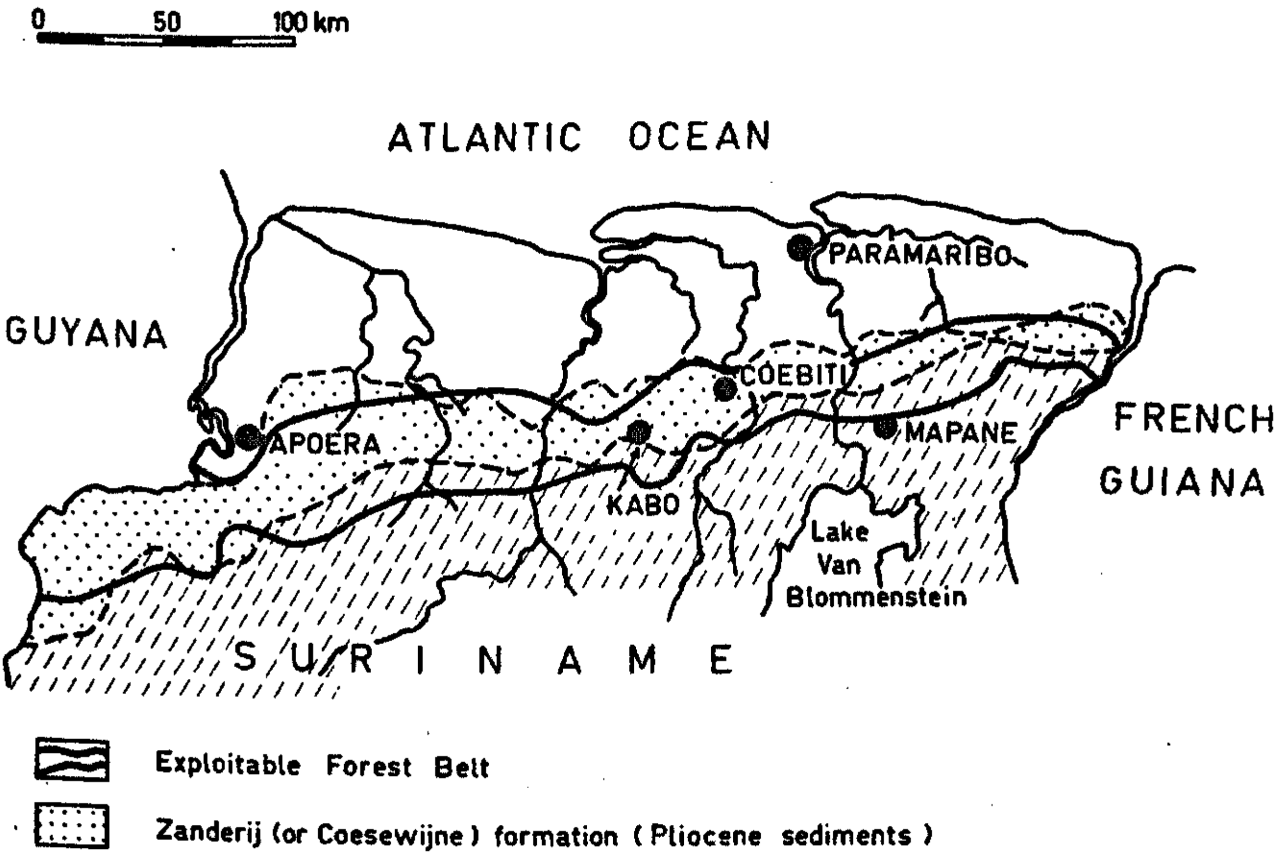


Table 1. Soils in the research areas (0-120 cm deep)

Location		Mapane[1)]	Kabo[2)]
Genesis	-	residual	sedimentary
pH/H_2O	-	3.8 - 4.6	4.2 - 4.8
Org. matter	%	2.03 - 0.28	2.09 - 0.29
CEC at pH7	me/100 gr	7.92 - 2.61	3.36 - 1.26
total bases[3)]	me/100 gr	0.73 - 0.12	0.28 - 0.07
Al	me/100 gr	1.99 - 0.87	1,02 - 0.48
Drainage	-	moderate/well	well
USDA-classification	-	orthoxic tropodult typic paludult	ultic haplorthox

1) one soil pit (de FRETES and POELS, typoscript)

2) mean of 118 samples (0-40 cm) or 28 samples (40-120 cm) (BOXMAN, in preparation)

3) K + Ca + Mg

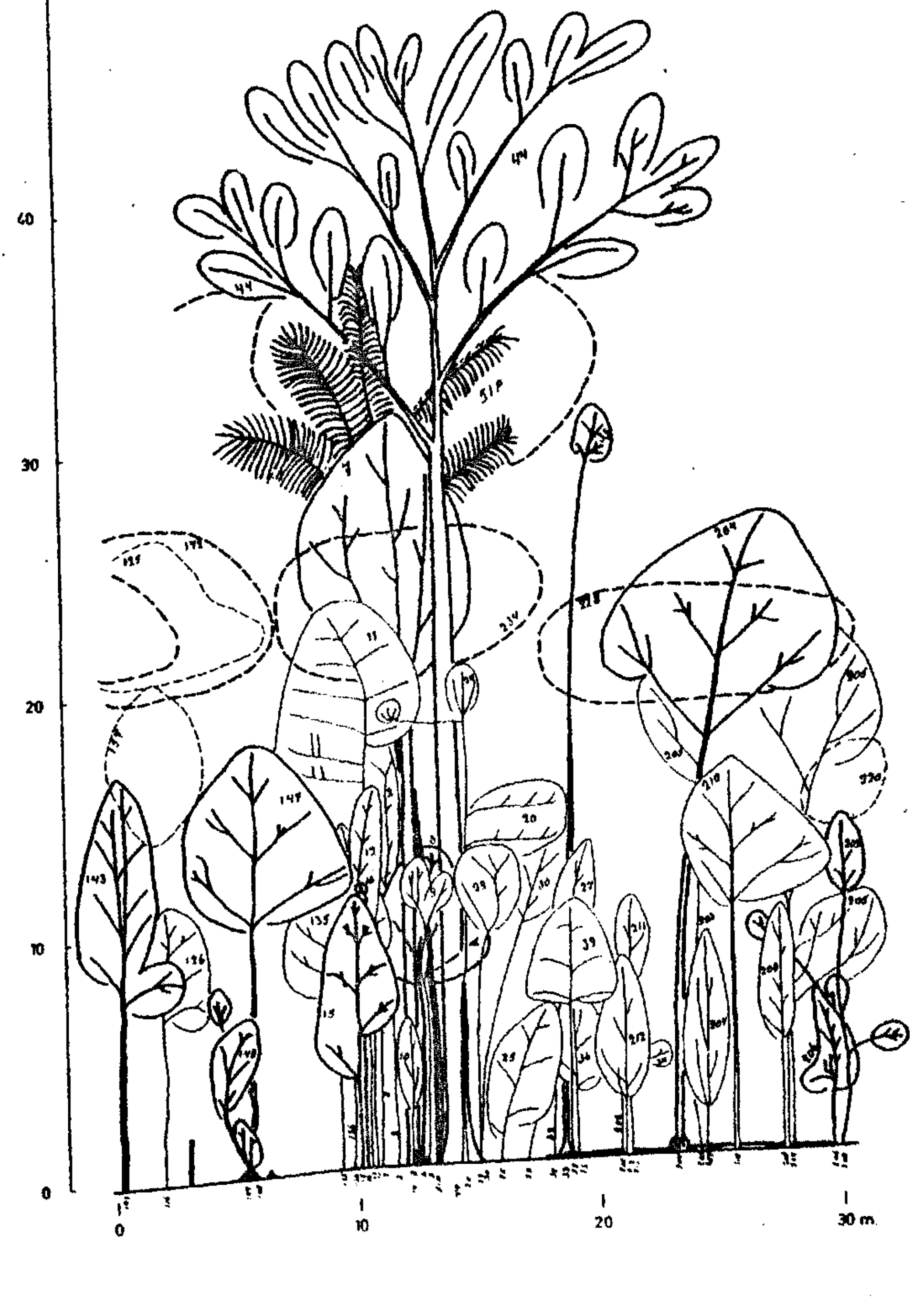


Fig. 2. Forest profile of a small (10 x 30 m) transect of the Mapane forest. Trees above 5 cm d.b.h. only.

This is also demonstrated clearly in Fig. 2, where a *Sclerolobium* of 1 m diameter and 48 m height is surrounded in the canopy by a few equally big trees, but on the forest floor by numerous small and very small trees. Although there is little known about the distribution of the roots, one can savely assume that there is a similar configuration below the ground.

The ecological consequences of these two characteristics are evident. Nearly all niches are occupied and the input of energy and nutrients is almost fully used. The gross primary production is very high, but due to the high amount of phytomass the ratio between the nett primary production and the gross primary production is very low. There are many possibilities for mutual aid and the chances for the development of pests are minimal. The amount of the living phytomass in the Kabo forest is about 480 t/ha: 16 t/ha of leaves, 118 t/ha of branches, 280 t/ha of stems and 65 t/ha of roots (see Fig. 3; OHLER, 1980; SCHMIDT, 1982). On the floor lies about 34 t/ha coarse and fine litter. An analysis of the nutrients in this system (Fig. 3) shows, that there is an abundant amount of nitrogen, that calcium and potassium are present in fair quantities and phosphorus and magnesium are scarce. The distribution of these nutrients over the various compartments of the ecosystem (Fig. 4) stresses the importance of the living phytomass: Between 70 and 90% of the amount of phosphorus, potassium, calcium and magnesium present in the ecosystem is incorporated in the living phytomass. Nitrogen is the notable exception (see OHLER, 1980; SCHMIDT, 1982).

In the Mapane forest, the average size of the trees is somewhat smaller and the total amount of phytomass is somewhat less too. The distribution of the nutrients, however, is not essential different (SCHMIDT, 1983). The ecological consequence is that the "fertility" of these forests is located in the living phytomass, not in the soil. In a silvicultural system this has to be the same. Because the nutrient capital is stored in the living phytomass, the amount of this living phytomass should always be kept at a high level.

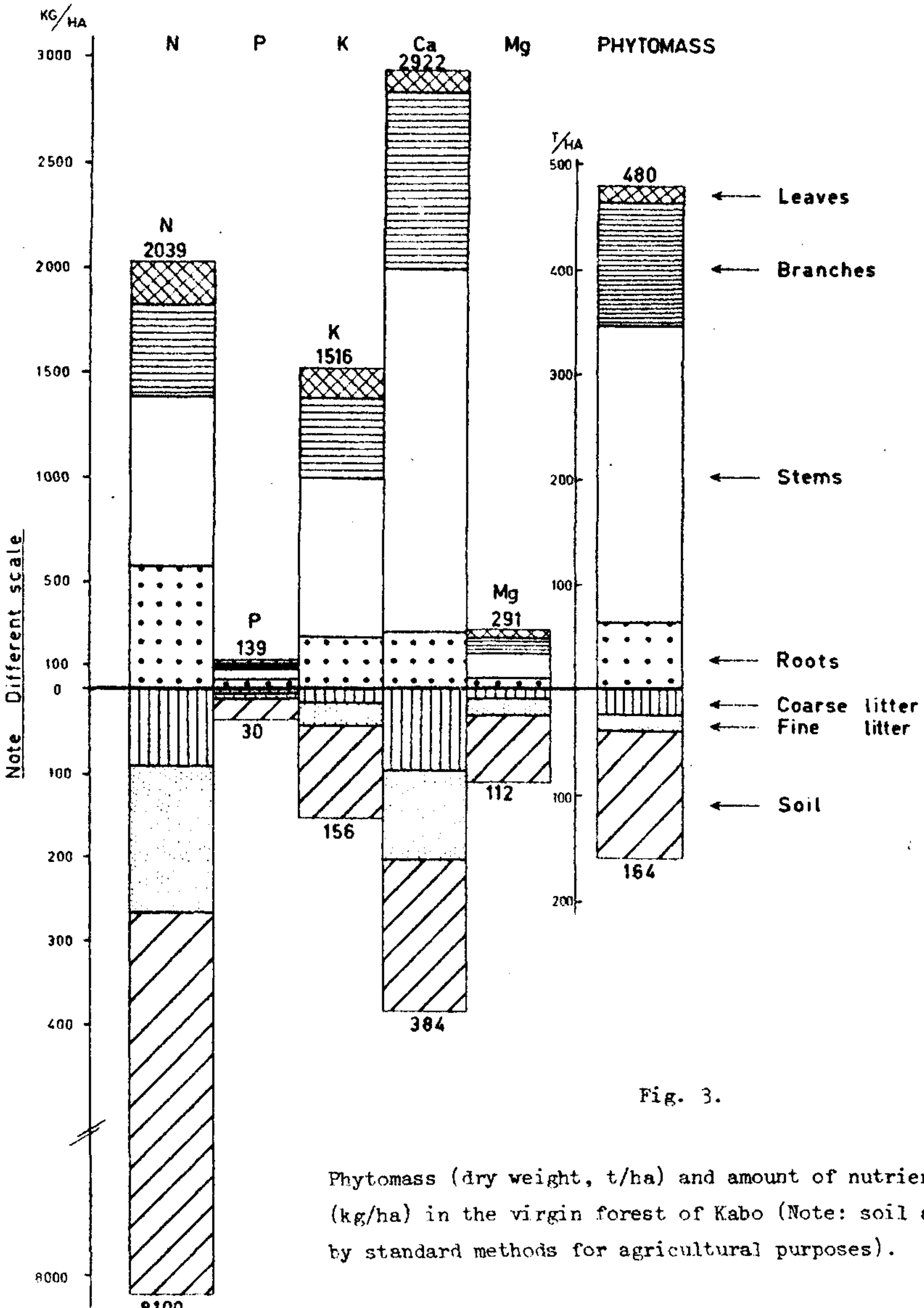


Fig. 3.

Phytomass (dry weight, t/ha) and amount of nutrients (kg/ha) in the virgin forest of Kabo (Note: soil analy by standard methods for agricultural purposes).

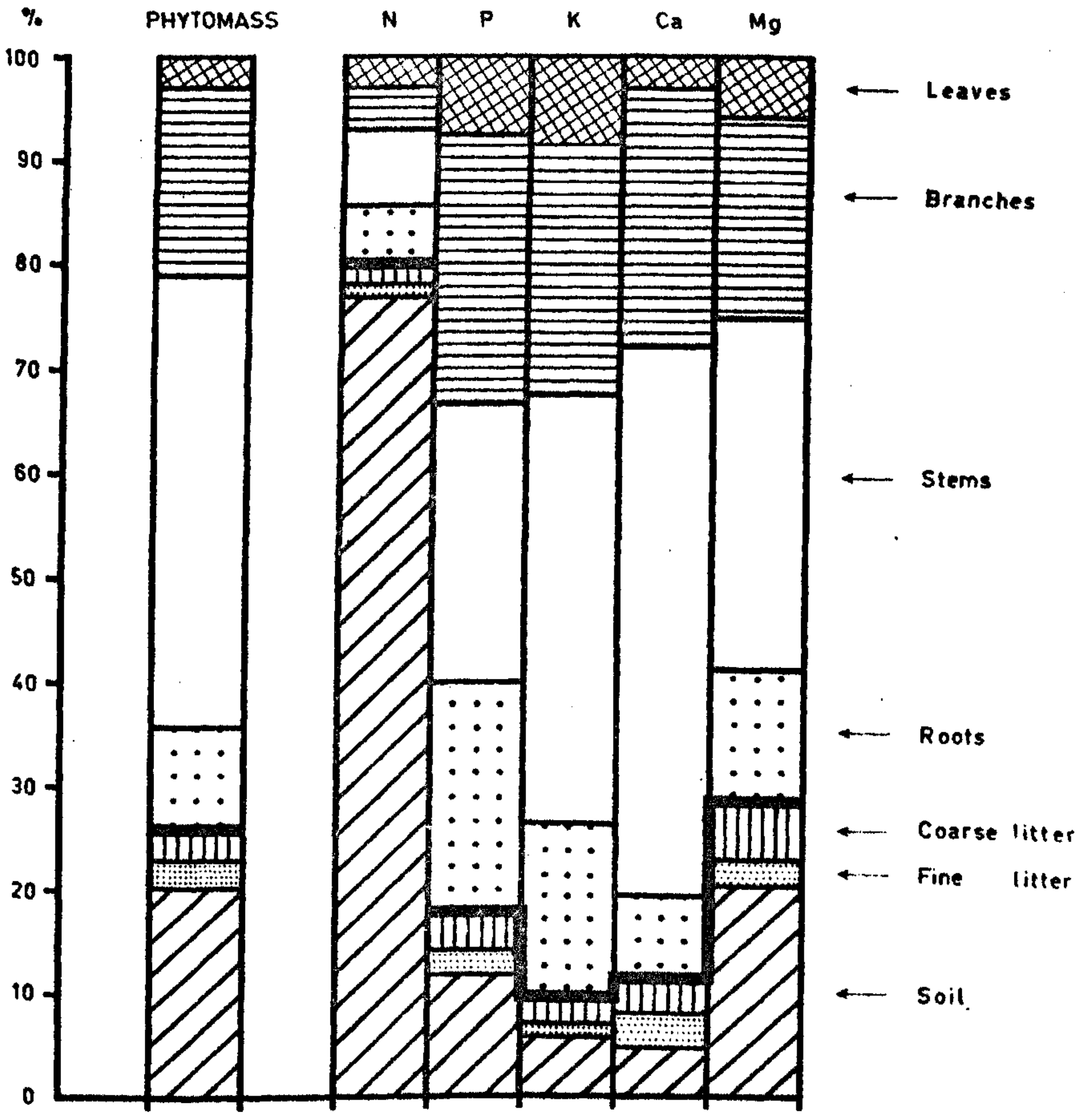


Fig. 4. Distribution of the phytomass and the nutrients over the various compartments in the virgin forest of Kabo (Note: soil analysis by standard methods for agricultural purposes).

The nutrient cycle in these systems is probably nearly closed. The research of our team into this aspect is not yet in a stage where results can be published. However, it is almost certain, that the input of minerals by rain or by the weathering of rocks is limited and that the leaching of minerals is very low as well. This means that the minerals released by the breakdown and decomposition of the litter are recycled, i.e. directly captured again and stored in the living phytomass. The compartment of the ecosystem responsible for this mechanism is the very complicated litter-soil-mycorrhiza-root symbiose (see e.g. JORDAN and HERRERA, 1981). In a silvicultural system this quality of the ecosystem should be kept intact. It is probably more efficient and surely cheaper than artificial fertilizing.

These characteristics work together in the silvigenetical processes of these forests. These processes are centered around the individual tree. As storms or other natural disasters are very uncommon in Suriname, wholesale mortality of a group of trees is a rare phenomenon in the virgin forest. Usually just one tree dies and falls down, thus creating a gap, a chablis. When this happens, light, water and nutrients become available for other trees and seedlings. In the virgin forest the created space is so small as a rule that secondary species and lianas do not get the chance to dominate. Primary species are favoured. After the space is totally used, many of these trees can fall back into a state of very slow growth and wait again for a new opportunity. In the CELOS silvicultural system, these natural silvigenetical processes are accelarated.

3. LOGGING AND SILVICULTURE

3.1. Logging

When it is deçided to use the forest for sustained timber production the forest is logged first.

A license to harvest the timber above a certain diameter limit (in Suriname 35 cm) is issued to a concessionaire. The licensee has to pay royalty over the logs extracted and is, in practise, free to take whatever he wants and to leave the rest.

The operation starts with the felling. Although the tree feller has to follow the instructions of his employer, he is the one who decides which trees to fell and which to leave. Usually, many good quality timber trees are left standing in the forest, either because the concessionary is not interested in the species at the moment, or because the feller suspects defects in the stem or finds the tree to difficult to fell or as result of mere oversight.

The extraction of the logs should be carried out as soon as possible after felling in order to avoid decay of the timber. In practise the wheeled skidder often arrives long after the first log has been felled. As the skidder operator does not know the location of the logs, he drives around in the forest looking for them. As soon as he spots one, he turns his machine, pushes the log in the right position for extraction if necessary and returns, often with just one log, to the landing on the road side. After unhooking the log, he starts searching for the next one. Usually some good quality felled timber is overlooked by the skidder driver and left to rot in the forest.

In our opinion, such an operation is not efficient. The concessionaire tries to save on management, planning and supervision. The result is that skidding costs are higher than necessary. These extra costs are likely to exceed the savings on management etc. Furthermore, part of the potential production is wasted.

The most likely impression of a visitor, walking on a skid trail shortly after logging, is one of almost complete destruction.

This impression may be justified in some (but certainly not all) Dipterocarp forests in S.E. Asia, where 40-100 m^3/ha is extracted (see e.g. FOX, 1968, MATTSON MARN and JONKERS, 1981). In Suriname, however, where the average yield seldom exceeds 20 m^3/ha, the damage is considerable, but the forest is not destroyed.

Table 2. Diameter class distribution of commercial species (tape measurements) and all species (caliper measurements) in a selectively logged 2.25 ha plot. Basal areas in m^2/ha and numbers of trees per hectare

Diameter	Number of Trees per ha		Basal Area (m^2/ha)	
Class (cm)	Commercial spp.	All spp.	Commercial spp.	All spp.
10 - 20 cm	45.1	296.4	0.81	4.69
20 - 30 cm	28.0	83.1	1.28	3.88
30 - 40 cm	19.1	52.5	1.76	4.93
40 - 50 cm	12.0	26.2	1.71	4.26
50 - 60 cm	8.0	8.9	1.79	2.04
60 - 70 cm	1.8	3.1	0.56	1.05
70 cm and above	3.1	6.7	2.20	4.36
Total	117.1	476.9	10.11	25.21

This is illustrated by the following example (Table 2 and Figures 5 and 6). Table 2 is a stand table of an experimental plot in Suriname after a harvest of 42 m^3/ha. In spite of the high logging intensity, the stand still contains almost 500 trees per hectare of 10 cm diameter and above. Figures 5 and 6 are maps of the central part of the same plot. Figure 5 shows the skid trails, cut stumps and the area under fallen trees. Figure 6 shows the crown projections after logging. It is obvious that the damage is concentrated around skid trails, and cut stumps and that the canopy is intact over approximately 70% of the area. It should be noted however, that the locations of the trees to be felled were mapped prior to logging and that this map was used by the skidder operator to locate the logs.

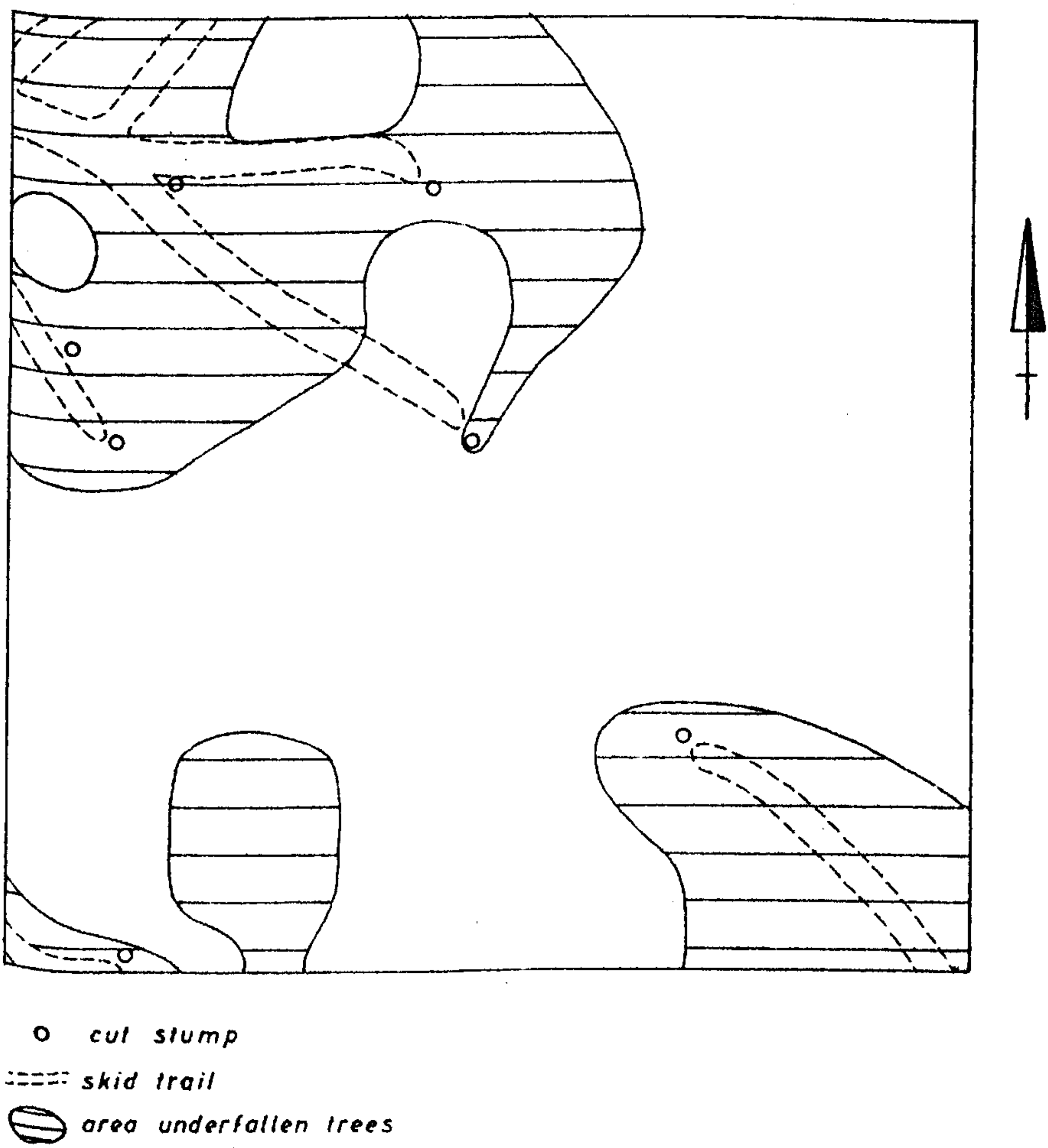


Fig. 5. Cut stumps, skid trails, and the area where the undergrowth has been destroyed by falling trees in an exploited 80 x 80 m plot.

A logging technique, which aims at increasing the efficiency of the operation as well as reducing the logging damage is currently being tried on experimental scale in Suriname (HENDRISON, 1982). Although many authors have emphasized the importance of logging damage, such an attempt to reduce it is almost unique (other examples: FOX, 1968, MATTSON MARN and JONKERS, 1981). Hendrison's experiment focusses on the extraction. It is considered easier to reduce skidder damage than damage caused by falling trees. Furthermore, skidding is by far the most costly part of the exploitation. The method includes among others mapping of terrain characteristics and trees to be felled, planning of skid trails and directional felling to facilate skidding. Results from this experiments are not yet ready for publication.

3.2. Silviculture

The rain forest is a renewable natural resource. After logging, the residual stand which still includes many individuals of commercial species* (see e.g. Table 2), keeps growing. Unfortunately, this self-renewing proces is a very slow one.

Since the 1950's, attempts are made in Suriname to increase the growth rate of the commercial species in logged forest by eliminating competing vegetation. The methods tried originally were based on the Malayan Uniform System, i.e. virtually all trees were poison-girdled in order to stimulate the increment of seedlings and saplings of commercial species. These species showed a positive response, but secondary species and lianas benefitted even more. It proved necessary to treat the stand frequently in order to keep the growth of the commercial species at an acceptable level (see SCHULZ, 1967). Although these early experiments did not result in an operational system, results were positive enough to justify a continuation of the research.

*) commercial species: species, which are suitable for sawn timber or veneer. A list is given in JONKERS, 1982.

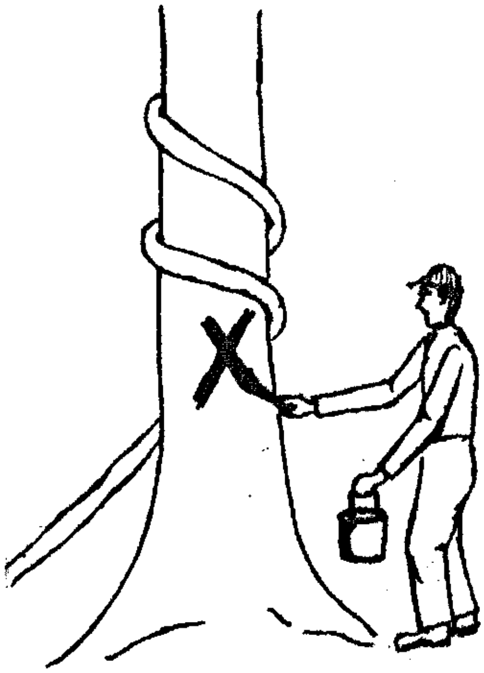
The basis for the present silvicultural technique was established in 1967. The principal aim of the treatment is to induce a faster growth of the trees of commercial species in the remaining stand, rather than to stimulate the increment of seedlings and saplings. This is achieved by eliminating competition from medium-sized and large trees without commercial potential and lianas. Furthermore, the treatment has a fertilizing effect as the nutrients stored in the killed trees and lianas become available for the remaining vegetation.

The first treatment, which is called refinement, is scheduled one to two years after logging. The instructions are purposely kept simple and can be easily understood by unskilled labourers. The treatment is carried out in four steps (see Fig. 7). First, the tree is identified by a tree spotter. Trees without commercial potential above a certain diameter limit (usually 20 cm) are marked to be eliminated. The tree spotter is accompanied by a labourer who cuts all lianas with a machete (step 2).

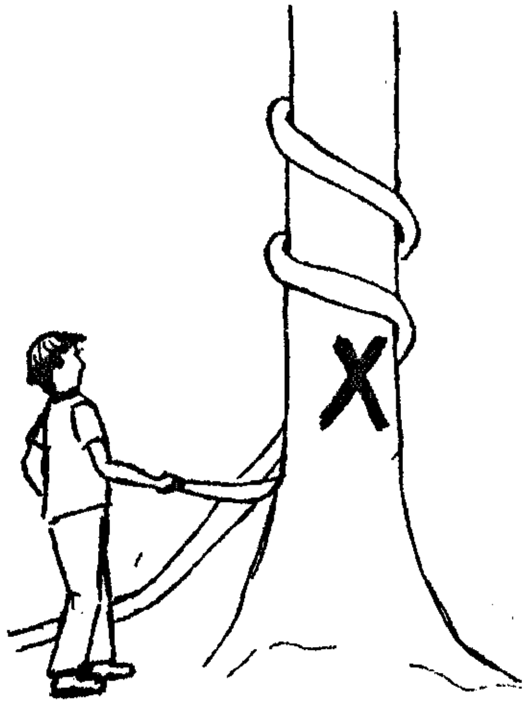
These two men are followed by the poison-girdling gang. Marked trees are frill-girdled with a small axe (step 3). This means, that overlapping cuts are made over the whole circumference of the tree, forming a kind of channel. The cuts should extend just into the sapwood and should make an angle with the vertical of about 45 degrees (see Fig. 8).

After completion of the frill-girdle, arboricide is administered to the tree (step 4). The frill-girdle is filled with arboricide first and then the bark just above the frill is covered with a film of the solution over a height of 10 cm. Up to now a 5% solution of 2, 4, 5-T in diesel oil was used. However, a recent experiment showed that the concentration can be reduced to 2½%.

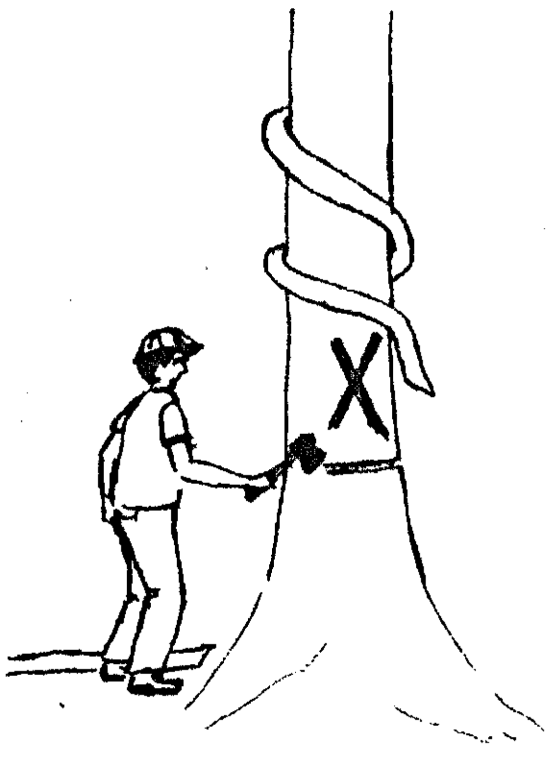
The effect of the poison-girdling is slow and lasts long.



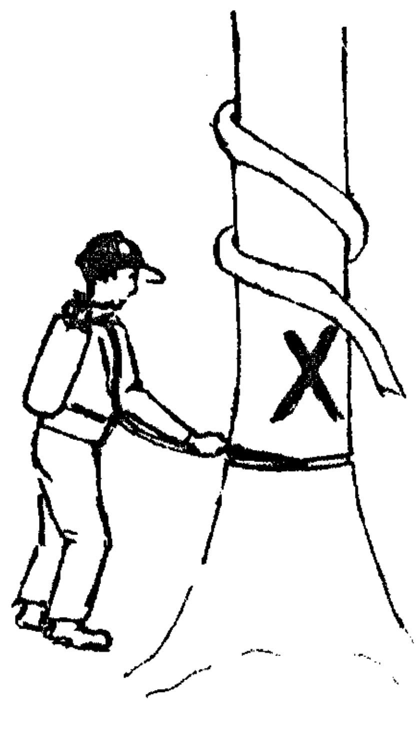
Step 1 : The trees to be poison-girdled are marked



Step 2 : Lianas are cut



Step 3 : The frill-girdle is made



Step 4 : The arboricide is administered

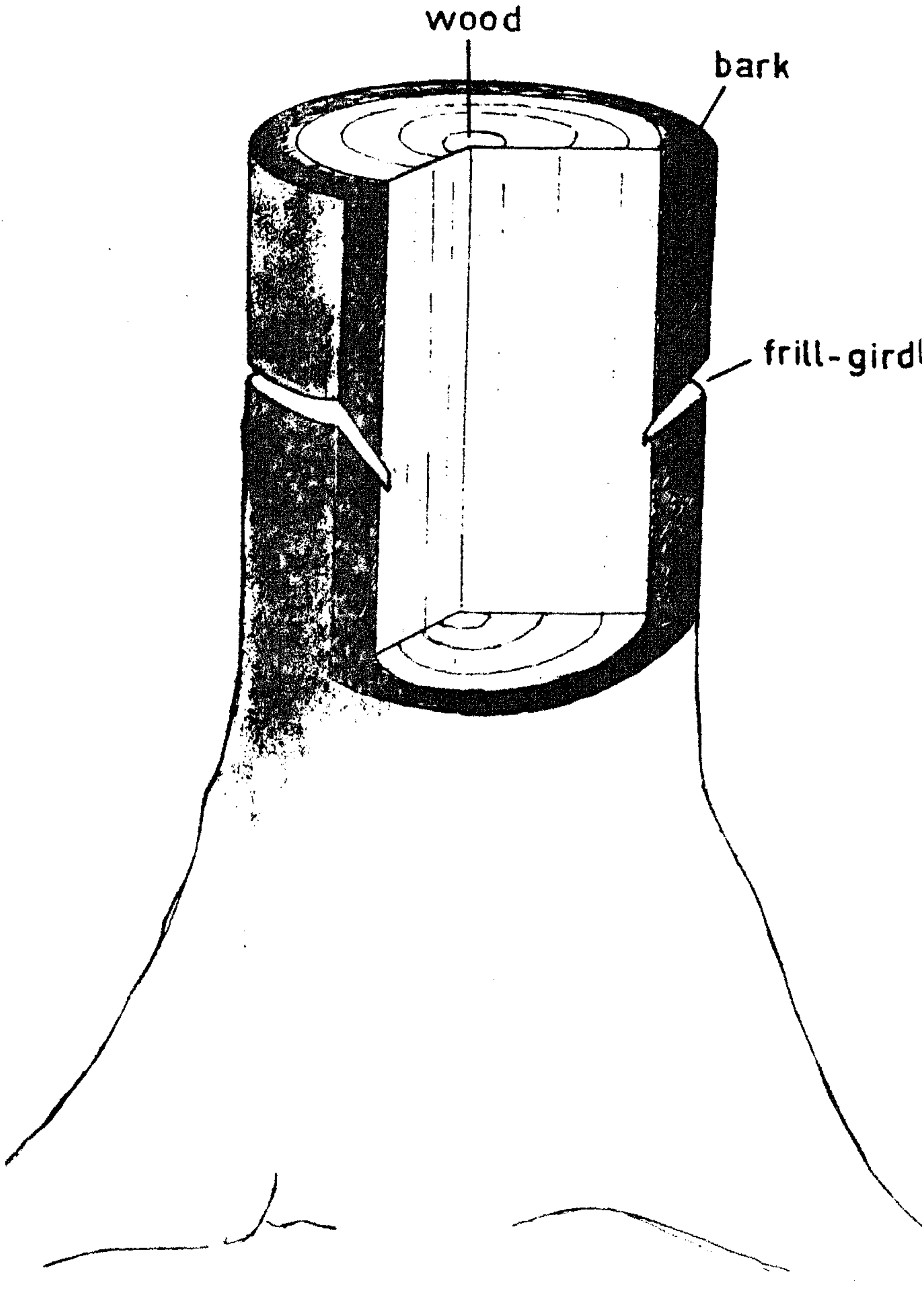


Fig. 8. A visual impression of a frill-girdle.

Although the first bare trees are recorded already after a few weeks, it takes a year before 60-70% of the poisoned trees have lost their leaves and several years before this percentage is close to 100%. The branches of such trees fall usually within a few years after it has died. The trunk remains standing as a rule until it is almost completely decayed. This may take a very long time. Even 16 years after the treatment, remnants of many poisoned trees are still standing upright in the regenerated forest. Obviously, the fertilizing effect is long lasting. Furthermore, the number of (commercial) trees killed by falling wood is small.

After treatment, the total basal area should be reduced to approximately 15 m^2/ha, i.e. about half of the pre-felling value. In the example presented in the previous section (Table 2 and Fig. 6) more than 100 trees per hectare are to be poison-girdled in order to achieve this. A comparison of Figures 6 and 9 provides a visual impression of the changes in the stand as result of the treatment.

Although the treatment worked out well in all experiments, a modification is considered at present. According to the current prescriptions, virtually all trees above 20 cm diameter are to be poison girdled in very poorly stocked parts of the forest. The experiments carried out in the 1950's show that such a destruction of the canopy results in a secondary vegetation rather than in a good regeneration of commercial species.

The present prescription often have a similar effect in large gaps created by logging. For instance, two medium sized trees in the large gap in the SE corner of Fig. 6 survived exploitation. According to the prescription, they should be poison-girdled (see Fig. 9). However, eliminating them does not serve a purpose as they do not compete with other trees and provide some shade necessary to suppress secondary species. Obviously, poison-girdling should be restricted to the vicinity of the commercial species to be liberated.

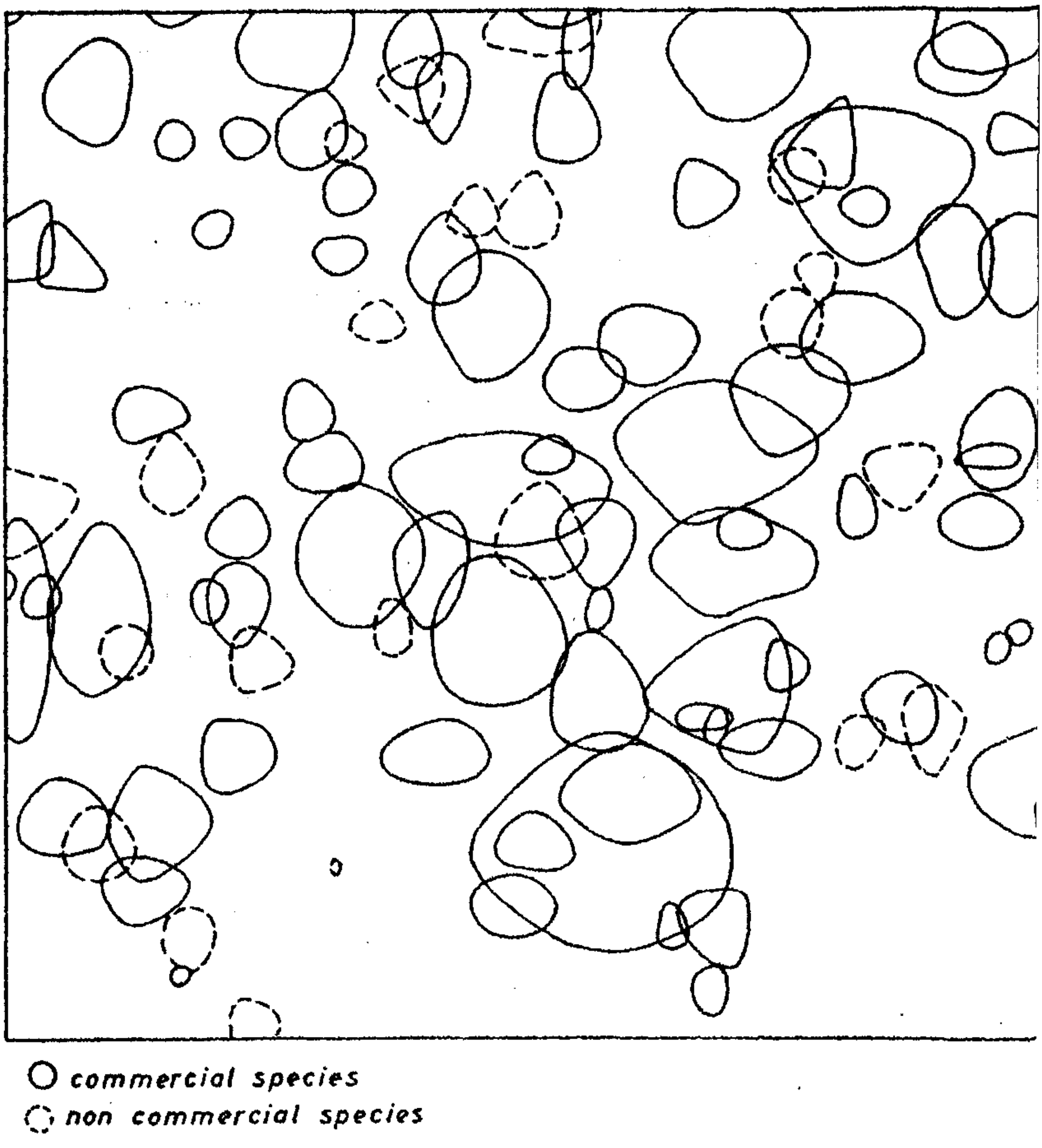


Fig. 9. Grown projections of all trees of 15 cm d.b.h. and above in an exploited 80 x 80 m plot after logging and a refinement with diameter limit 20 cm.

After treatment, the diameter increment is greatly increased (see section 5). Approximately 8 to 10 years later however, the growth rate starts to decline. According to DE GRAAF (1982) follow-up treatments are necessary after 8 and 16 years in order to keep the diameter increment at a high level. A second harvest should be possible after 20 years (DE GRAAF, 1982).
The nature of these follow-up treatments is still a subject of research. DE GRAAF (1982) suggests poison-girdling treatments down to a basal area of 10 m^2/ha (second treatment) and 15 m^2/ha (third treatment). Recent results suggest that the second treatment can be delayed by at least two years. This means that the third treatment may not be required at all.

4. ECOLOGICAL ASPECTS

The CELOS silvicultural system interferes in the ecosystem in many ways. Only the ecological effects which are considered the most important for sustained timber production are discussed in this paper.

During the harvest some trees of commercial species are removed, during the subsequent refinement many trees of non commercial species above a certain diameter level are killed. As a result of these measures but mainly due to the refinement non-commercial species why do not complete their life cycle below the diameter limit of 20 cm are likely to be eliminated completely. As nearly all species which do not produce fruits below this limit are considered commercial, the reduction in number of species is not disturbing. Only a few species run this risk (in Suriname e.g. *Parkia pendula and Sclerolobium spp.)*.

The diameter distribution of the forest changes too. The number of stems decreases more rapidly with increasing diameter than in a virgin forest and not as gradually. Above the refinement limit all the non-commercial trees are killed and above the felling limit a part of the commercial trees is removed. The remaining forests stand, however, is still an intensive mixture of big and small trees (see Fig. 9, for trees above 15 cm d.b.h.).

These changes in species number and in diameter-distribution do not seem to damage the forest in such a way, that the ultimate production level will be reduced to an inacceptable height.
By harvesting trees, the living phytomass of a forest is reduced. A calculation for the Kabo forest (Table 3; SCHMIDT, 1983) shows that with the harvested wood 3.1% of the living phytomass and 2.6% of the nutrient capital is removed from the forest. It is expected that the forest can cope with this slight reduction. But a harvest causes more damage. The non-usable parts of the felled trees and the trees damaged and killed by the felling and extraction of the usable trees amount to 7.5% of the living phytomass and to 10.9% of the nutrient capital.

Table 3. Estimated effect of a light exploitation on the phytomass and the nutrient capital of the virgin forest at Kabo, given in kg/ha and as percentage of the living phytomass (leaves + branches + stems + roots)

	Virgin Forest living phytomass	Damage by Exploitation			
		willingly killed and removed i.c. harvest		unwillingly killed not removed	
	kg/ha	kg/ha	%	kg/ha	%
Phytomass	480,000	15,000	3.1	36,000	7.5
N	2,039	43	2.1	213	10.4
P	139	3	1.9	14	9.9
K	1,516	38	2.5	158	10.4
Ca	2,922	92	3.1	341	10.8
Mg	291	7	2.5	30	10.4
Nutrients	6,907	183	2.6	756	10.9

This is about twice the amount of nutrients in the annual litter fall (leaves, branches, flowers and fruits). It should be noted that these trees and parts of trees are killed, but not removed out of the forest. No nutrients are taken away directly. The nutrient cycle, however, is accelerated. A part of these untimely released nutrients is used as fertilizer by the remaining trees, but it is possible that not all the nutrients in these extra amounts of litter can be captured again and recycled in the living phytomass. POELS (1983) found a very slight increase of the nutrient contents of a creek after a light exploitation.

A refinement will enhance the fertilizing effect and the danger for leaching. Due to the arboricide treatment 40-50% of the phytomass is killed. In the first few years after treatment leaves of the poisoned trees will fall on the forest floor, followed in the next years by twigs and branches. The stems can remain a decade and more. After a starting gift by the leaves, the fertilizing effect will be spread out over several years, dwindling gradually. The danger of leaching will be greatest in the first one or two years after treatment, when the largest amount of nutrient rich and quickly decomposing phytomass coincides with a recently damaged and not yet restored mycorrhiza-root-complex. The first impressions based upon one year of experiments in a catchment area under a refined forest are that the refinement increases the nutrient concentrations in creek water slightly (POELS, 1983).

The results of the research till now into this important aspect of the CELOS silvicultural system can be summarized as follows. No serious indications were found that due to exploitation and refinement significant amounts of nutrients will disappear out of the system. However, the way to the positive statement that the productivity is not endangered, is still a long one. Research into these aspects should be continued, as killing too many trees leads to a reduction in nutrients and productivity. This limit the silviculturist in the prescription of the treatment.

As a matter of course the silvigenetical processes of the forest are altered by a refinement. A refinement is nothing else than playing with these processes, i.e. killing undesirable trees to promote desirable trees. The natural processes are accelerated. But here nature poses a second limitation to the prescriptions of the treatment, as killing too many trees will result in a not very attractive secondary or liana forest.

5. ECONOMICAL ASPECTS

Two important aspects will be discussed now, viz. costs and benefits. Two management options are compared. The first option is doing no treatment after logging. The second one is applying the CELOS silvicultural system described in section 3.2.

No costs are involved when the forest is not treated after logging. Unfortunately, the benefits are almost negligable too. The development of selectively logged forest has been followed since 1967 in various experiments. The annual diameter increment of commercial species (20 cm diameter and more) is about 4 mm/yr and the annual mortality is close to 1.5%. This results in a very slow increase of the harvestable volume.

For example, in the stand presented in Table 2, about 37.5% of the commercial trees of harvestable size (50 cm diameter and above) is likely to die within 25 years, i.e. about 4.8 trees per hectare. In the 40-50 cm diameter class about 7.5 trees per hectare survive. These trees are expected to grow into the harvestable size class. So, the nett gain of harvestable trees is about 7.5 - 4.8 = 2.7 trees per hectare within 25 years.

When the CELOS silvicultural system is applied, both costs and benefits are higher. The first treatment is probably the most expensive one. Expenditures in two recent experiments, with a treated area of more than 200 hectares were 2.5 mandays/ha of unskilled labour, 0.3 mandays/ha of skilled labour (the tree spotter), 17 litres/ha of 2, 4, 5-T solution plus overhead costs and some minor expenses.

A second treatment has been applied over just two hectares until now. Due to inexperience of the labourers, costs were relatively high. DE GRAAF (1982) mentions 3.3 mandays/ha and 10-15 litres/ha of arboricide. In a routine treatment, 2 mandays per hectare are likely to be sufficient.

A third treatment has not been applied yet. It is expected to cost about 1 manday per hectare plus a few litres of arboricide.

The CELOS silvicultural system results in a mean annual diameter increment of 9-10 mm/yr and an annual mortality of 2%. DE GRAAF (1982) estimates the volume of trees which grows into the exploitable size class at 40 m^3/ha in twenty years.

Application of the CELOS system in the stand presented in Table 2 is expected to have the following results. About 40% of the commercial species of diameters of 50 cm or more are likely to die within 20 years, i.e. about 5.2 trees per hectare. In the 30-40 cm and 40-50 cm diameter classes about 18.7 trees per hectare are likely to survive and reach a diameter of 50 cm or more. So, the nett increase in number of harvestable trees is about 13.5 trees per hectare within 20 years, as compared with 2.7 trees per hectare in 25 years when no treatment is applied.

6. SYNTHESIS

The described silvicultural system for sustained timber production in tropical rainforests consists of two independent parts, an improved harvest technique which aims at a minimally damaged stand after exploitation and silvicultural treatments, which aim at reducing the competition among the trees of the remaining stand in order to concentrate the productivity of the ecosystem on the commercial trees. Many aspects of this system were not yet included in the research program (e.g. fauna, microclimate, out ecology). Other aspects are being studied now, but the results are not discussed here (e.g. hydrology, erosion).

However, results up to now of the research into the most critical aspects (e.g. productivity, nutrient capital and nutrient cycling, leaching, species composition and some economical studies) indicate, that the CELOS silvicultural system is economically feasible and ecologically acceptable.

7. ACKNOWLEDGEMENT

The authors are very grateful to the organizers of the International Symposium on Amazonia for the opportunaty to present this paper and to MAB-UNESCO for the financial support. Besides, the authors would like to thank all the workers of the Project LH/UvS 01 and CELOS, without whose dedication the basic work for this paper could not have been done.

LITERATURE

DE GRAAF, N.R., 1982: Sustained timber production in the rain forest of Suriname. In: Wienk, J.F. and H.A. de Wit (eds.): Management of Low Fertility Acid Soils of the American Humid Tropics. IICA, San José, Costa Rica.

FOX, J.E.D., 1968: Logging damage and the influence of climber cutting prior to logging in the lowland dipterocarp in Sabah. Mal. For. 31, 326-347.

HENDRISON, J., 1982: Harvesting Systems. In: Project LH/UvS 01, Annual Report 1981, CELOS, Paramaribo, Suriname.

JONKERS, W.B.J., 1982: Silviculture. In: Project LH/UvS 01, Annual Report 1981. CELOS, Paramaribo, Suriname.

JORDAN, C. and R. HERRERA, 1981: Tropical rain forests: Are nutrients really critical ? Nature and resources, 17 (2), 7-13.

MATTSON MARN, H. and W.B.J. JONKERS, 1981: Logging damage in tropical high forest. Forest Department, Kuching, Malaysia.

OHLER, F.M.J., 1980: Phytomass and mineral content in untouched forest. CELOS-rapporten 132, 1-43.

POELS, R.L.P., 1983: Hydrology. In: Project LH/UvS 01, Annual Report 1982. CELOS, Paramaribo, Suriname. (In press)

SCHMIDT, P., 1982: Ecology. In: Project LH/UvS 01, Annual Report 1981. CELOS, Paramaribo, Suriname.

SCHMIDT, P., 1983: Production Ecology. In: Project LH/UvS 01, Annual Report 1982. CELOS, Paramaribo, Suriname. (In press)

SCHULZ, J.P., 1960: Ecological studies on rain forest in northern Suriname. Van Eeden Fonds, Amsterdam.

SCHULZ, J.P., 1967: La regenaracion natural de la selva mesofitica tropical de Surinam despues de su aprovechamiento. CELOS bulletins no. 3, Landbouwhogeschool, Wageningen, Nederland.

Appendix II

CENTRE FOR AGRICULTURAL RESEARCH IN SURINAME

A FORESTER'S LOOK AT LAKE BROKOPONDO

By

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Paper presented at the International Symposium
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INTRODUCTION

When the organizers of this symposium invited me to report here on the lake Brokopondo in Suriname, I asked myself what can a forester tell about this lake. Reading and thinking about the lake, I found many aspects of the lake, where forestry is touched. I will comment here on some of them, but first I will outline the history of the lake.

In 1958 the Government of Suriname and Suralco (Suriname Aluminium Company, a subsidiary of Alcoa) reached an agreement to build a dam in the Suriname river somewhere near Brokopondo. In february 1964 the dam was closed. One year later, the generators were tested. Since october 1965 power is generated continually. In 1971 the spillways were used for the first time, in 1975 for the second time.

The lake has an area of about 1500 km^2, a maximum depth of about 50 m and a volume of 24 km^3. The Lake Brokopondo is one of the first man-made lakes, of which the impoudment area originally was covered with a dense tropical high rain forest. The catchment area is about 12,000 km^2 with an annual rainfall between 2000 and 3000 mm. For a great part, this catchment area is covered also with tropical rainforest growing on very poor, deeply weathered soils. The Suriname river upstreams of the lake is oligotrophic and saturated with oxygen. It has very little organic material.

The circa 5000 people living in the area before inundation were transmigrated to new villages around the lake. Nearly 10,000 animals were saved.

Waterlevel in the lake

Only in the very wet periods, the lake is really filled up. Since the closure of the dam, the spillways had to be used only twice. Nowadays only four out of the six generators can be used, because the lake does not contain enough water. This creates problems for the economical financial and energetical balances. The planning aimed in another direction.

What went wrong ? I see three probable causes: First, the lake disturbed the pattern of rainfall on the lake area. People who fish frequently on the lake, claim that the weather on the lake is much better than in the surroundings. Even when it is raining cats and dogs in areas around the lake, the fishers sit in the sun. This would mean that on 10% of the catchment area less rain would fall and more evaporation would occur. This claim, however, is not confirmed by the Meteorological Service of Suriname. They have no rain measurement on the impoudment area before inundation and comparable measurements on a small island in the lake and around the lake are too young to base statements upon.

A second cause could be leakage. I did not find anything before of against it, so I will not discuss this.

A third cause could be errors in the survey of the area. If the slopes of the upper parts of the hills are in reality much less steep as calculated, a small rise of the waterlevel in these heights would cause an enormous enlargement of the area combined with only a small enlargement of the volume. In this manner the evaporation would be enhanced very much and would predominate upon the water supply. The background of this could be a wrong estimation or a false generalization of the tree-height, par example not including the fact that trees upon hilltops are shorter than trees on the slope.

This problem is so serious that Suriname is planning to enlarge the catchment area to be south by diverting the Jai creek.

Landuse along the river

Before the dam was closed and thus some regulation of the waterflow was introduced, some areas along the river were too wet to be used. Not only in swamp areas, but also in areas where problems with aeration and reduction prohibited the use of these soils. Now at Baboenhol, a husbandry farm, 30 km north of the lake, these parts are the best pasture lands of the farm. And at Victoria, an oilpalm plantation 20 km north of the lake soils formerly too bad, are being planted now.

I can imagine very well the use of these soils for short-rotation-forestry. This provides a small compensation for the loss of fishing possibilities here. After the closure of the dam, the river ran dry and the fish died, or escaped. Nowadays the riverwater downstreams had no or nearly no oxygen for the greatest part of the year. The fishing possibilities are and will remain very low.

The waterhyacinth

Although not a forestry plant, I like to comment here on the waterhyacinth. The waterhyacinth (Eichhornia crassipes) was very scarce in the Suriname river, its normal habitat being the nutrient rich swamp areas along the coast. Soon after the closure of the dam, an explosive growth of the waterhyacinth on the lake occurred, and in 1966 about 50% of the area was covered with waterhyacinth (VAN DONSELAAR, 1968).

Based upon research in Florida (TIMMER and WELDON, 1967) Suralco feared that the waterhyacinth would evapotranspirated about 3.5 times as much as a free watersurface. Therefore, Suralco started an eradication campaign, spraying the waterhyacinth with 2-4. D-herbicides, first only by boat, later also by plane. In 1968 VAN DER WEERT and KAMERLING proved in Suriname that the evapotranspiration of the waterhyacinth was only 1.4 times the evaporation of a free watersurface, but the spraying was continued. Although Suralco succeeded in reducing the waterhyacinth fields, an eradication could not be obtained. This spraying campaign was continued till 1970, costing in total 2½ million dollars.

Around 1969/1970 some ecological change in the Lake Brokopondo occurred, resulting in the fact that the waterhyacinth is not gregarious any more and that it no longer gives problems. Unfortunately and surprisingly no research was done to clear the background of this phenomenon. One can only speculate about attacks by insects or mites, about stronger turbulence after the breakdown of the crowns and about changes in the nutrient content of the lakewater.

The last one is probably the most acceptable theory. The decomposition of the nutrient-rich leaves shortly after the closure of the dam enriched the water of the newformed lake to such a level that the waterhyacinth found very favourable growth conditions.
After some years, all the leaves were decomposed and this source of nutrients was exhausted. The nutrient-rich water of the lake was now diluted by the nutrient-poor water of the catchment area, reducing the nutrients in the lake to such a low level, that these favourable conditions ceased to exist. Perhaps, this proces was accelerated by the waterpurifying qualities of the waterhyacinth itself. These plants accumulated nutrients out of the nutrient-rich upper layers of the lake. After dying, they sank to the bottom of the lake. There the decomposition is slow. Besides, the mixing qualities of the lake in the first years after the closure of the dam were bad. Thus the liberated nutrients remained near the bottom of the lake and the upper layers were depleted of these nutrients.

The forest on the inundated area

As already mentioned before, the impoundment area of Lake Brokopondo was covered with high tropical rainforest. The Lake Brokopondo is one of the first man-made lakes with this vegetation.
Mainly for economic reasons, the forest on the impoundment area was not exploited or cleared. At present, 19 years after the closure of the dam, still many remnants of tree crowns can be seen above the watersurface of the lake. Just below this level still more stems can be found. Rotting-processes, needing oxygen, will only take place above and just below the watersurface, causing the breadown of the treeparts above the surface.

It is a very sad sight, those dead crowns above surfaced of the lake. Any forester looking at those trees will put the question "was the decision not to cut these forests the right one and can these trees still be used?"

An answer to the second question is given by a FAO report of 1979. They advise strongly that a feasiblity study should be made of pontoon logging on the Brokopondo Lake. Some stems could still be used as saw timber. Besides, the salvaged wood would make an excellent quality of charcoal (SCHULZ, 1968). The problem will be the technology. Hydraulic cutters and saws for such salvage operations have been developed for Canadian Pinus, not for very hard Amazonian Vouacapoua americana stems. But perhaps, it will only be necessary to pull these shallow rooted trees out of the soil and the lake water. Unfortunately up till now the advise to make a feasibility study has not resulted in any action.

The first and more important question "should the forest in the impoundment area be exploited or clearcut before inundation" requires more attention.

A decision to exploit or to cut the forest in the impoundment area before inundation should be based upon ecological, economical or political considerations.

An advisory committee (see ANONYMUS, 1981) on the Lake Kabalebo, a planned Lake in West Suriname, came to the conclusion that clearing these forests would have a negative effect on the fish reproduction in the lake and very slight positive effects on the water quality and the growth of aquatic weeds (see Table 1). Other ecological variables like public health and the protection of the installations would not be affected. The total ecological impact of clearing the forest on the impoundment area is slightly positive. It is very probable that these ecological considerations do apply in other regions. They are, however, not strong enough to justify the enormous costs of a clearing.

The same committee (see ANONYMUS, 1981) found that the costs of selective cuttings for timber production would outweigh the earnings by 30%. The prospects for pulp production are not good, because no technology is available in Suriname and the export can only be done in small vessels. For charcoal, the amount of wood available in the forest in the Kabalebo region is too small to make a charcoal industry feasible. For an integrated multi-purpose forest industry the purposes are equally bad. Clearing for other reasons (fisheries, recreation etc.) would also bring no benefits. So the committee advised to do nothing in these forests in the Kabalebo area.

These consideration do not need to be valid for other regions: the Kabalebo forests have only a small volume of wood, about 140 m^3/ha, of which is about 16 m^3/ha commercial wood. Centers of population are far away and the wages in Suriname are very high. For other lakes new calculations should be made and the outcome could easily point out in another direction.

Surprisingly or on second thought perhaps not so, this committee has not dealt with political considerations. These political considerations are the most important ones and can easily put aside ecological or economical ones.
Among those political considerations, I consider the protection of the tropical rainforest as the most important one. If large areas are to be inundated and also destroyed, the constraint to protect the remaining areas becomes greater. These remaining forests should not be logged, nor be turned over into pulp or charcoal. All these products could easily be get out of the impoundment area before the inundation. If a lake has to be made and hence the forest has to be destroyed, all the usable products of these forests should be exploited first, even at higher costs, to protect the remaining forest.

At Lake Brokopondo it was not done and the remaining inundated dead trees should be seen as even so many warning fingers for future lakes.

Table 1. Integrated impact matrix as a basis for deciding on a possible clearing plan

Source: ANONYMUS 1981

Aspects:	No clearing Effects on variables: Ecological	 Economic	Complete pre-impoundment clearing Effects on variables: Ecological	 Economic	Selective pre-impoundment clearing Effects on variables Ecological	 Economic	Post-impoundment clearing Effects on variables Ecological	 Economic
Ecological								
Water quality	0	0	+1	-	0	-	0	-
Aquatic weeds	0	0	+1 -1	-	0	-	0	-
Public health	0	0	0	-	0	-	0	-
Hydro-power installations	0	0	0	-	0	-	0	-
Fish reproduction	+	0	-	-	-1	-	-1	-
Economic								
Timber production	0	0	0	-	0	-	0	-
Pulp-chips manufacturing	0	0	0	-	0	-2	0	-
Charcoal manufacturing	0	0	-	-	-1	-2	0	-
Fisheries	0	0	0	-	0	-	0	-
Tourism and recreation	0	0	0	-	0	-	0	-
Utilization of drawdown area	0	0	-	-	-	-	0	-
Water transportation	0	0	0	-	0	-	0	-

1. Marginal effects only
2. Volumes insufficient for economic production
3. To be investigated for its economic benefits; required information obtainable after impoundment

Explanation of signs:

0 = zero effect, neutral or no relationship
\+ = beneficial impact
\- = negative impact

LITERATURE

ANONYMUS 1981: Environmental impact of the Kabalebo project, Final Report, Volume V Clearing of the impoudment areas. Paramribo, Ministry of Development. 37 p.

DONSELAAR, J. van, 1968: Water and marsh plants in the artificial Brokopondo Lake (Suriname, South America) during the first three years of its existence.

FAO 1979: Mission report: Logging and draining the Kabalebo and Brokopondo reservoir. TCP/SUR/8802.

SCHULZ, J.P., 1976: Notes on the Brokopondo dam of Suriname after 1968.

TIMMER and WELDON, 1967 in the Hyacinth Control Journal, June 1967 (not seen).

WEERT, R. van der and KAMERLING, G.E. Evaporatie van de waterhyacinth. Landbouwproefstation, Paramaribo, Intern rapport 211, 1-49.

Some comments by the Brazilian newspaper O'Liberal

(13th July 1983)

CELOS — Partindo da constatação dos resultados negativos até agora obtidos pelo homem nas tentativas de homogeneizar uma floresta tropical úmida, **Pieter Schimidt**, por sua vez, relata os resultados conseguidos até o momento com experiência realizada no Suriname pelo Centro for Agricultural reserarch un Suriname (Celos), visando a produção de madeira comercial na floresta tropical úmida no Suriname, o qual tem como principal base a utilização de áreas já desmatadas e o remanejamento de florestas, bem como a eliminação da competição entre as árvores de forma a que as mortas sirvam no enriquecimento de nutrinetes no solo.

Apesar de terem sido observados efeitos negativos como a rápida lixiviação do solo, por exemplo, outros aspectos considerados positivos nas pesquisas levaram Pieter a seguinte conclusão:

"De qualquer maneira, os resultados das pesquisas até agora, dentro dos aspectos mais críticos (produtividade, ciclo de nutrição, composição de espécies e alguns estudos econômicos), indicam que o Celos sivilcultural sistema é economicamente exequível e ecologicamente aceitável".