2 History of use and management of forests in Suriname

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2.1 Introduction

Suriname became a colony of the Netherlands in the second half of the 17th Century with the main objective to develop a settlement of Dutch planters. Until the end of the 18th century, the colony was prosperous and able to produce cotton, coffee, and especially sugar for the European markets (Buddingh 1995). As in most Caribbean countries, the agricultural system was based on the labour of African Slaves, employed on large plantations along the navigable sections of the Suriname River, the Commewijne River, and the Marowijne River (Fig 1.3). The colony ruled itself without much input of the mother country. Actually, most of the plantation owners were living in The Netherlands and could afford to employ estate managers to run their possessions in Suriname.

Exports of agricultural products, generating essential revenues for the colonial government, decreased substantially even before the abolition of slavery in 1863. Before the turn of the 18th century the mother country had to finance the budget deficits of the local government. After 1863 the plantation system could only temporarily survive with contract labour from India, and a few decades later from Indonesia. The colony remained agrarian, but no longer was a significant exporter of selected products. The Asian immigrants changed the pattern towards a more diverse production system with rice as the main crop. With the decline of the plantation economy, a more stable local market was developed with a higher level of self sufficiency for food crops.

Suriname's economy made a remarkable move when bauxite became the main export commodity during and after the Second World War. The mining industry became the corner stone of the economy, especially after the construction of a hydropower plant and an aluminium factory in 1959-1960. The second source of revenues for the government was the development aid from The Netherlands that increased impressively after Suriname's independence in 1975. Until 1984 the substantial amount of approximately

one billion USD had been invested in the development of infrastructure, agriculture and forestry. Since the early 1990s oil exploration and processing, and gold mining became two new sources of revenue for the country. During the last two decades the trade and industrial activities increased and became more diverse and this can be considered a moderate achievement of the development aims of 1975.

Since the first attempts of the government around 1904 to regulate the forest sector, it progressed with ups and downs. Until the 1940s the forest sector was weakly developed, but grew since 1947, after the re-establishment of the Forest Service and the founding of the Bruynzeel Wood Company, but far less than was aimed at. The present contribution of the forest-based industry to export, gross domestic products and employment is less than 3 %.

Forest management development in Suriname can be characterized by five periods, which are not sharply and somewhat arbitrarily marked (Table 2.1). The transfer from one period to the next was mainly determined by initiatives of the forest management and research organisations, and not by a change of government policy or by the implementation of new strategies. The development plans since 1950 were predominantly influenced by the views of forestry experts from The Netherlands and from international agencies such as FAO, but also often substantially modified by governmental policy makers and politicians. Professional foresters in civil service, such as the academic staff of the Surinam Forest Service, were often key innovators while the government itself remained for a long time an observer who set the constraints for forest legislation.

Table 2.1. Review of the development of use and management of forests in Suriname

No	Period	Management concept	Main forestry activities
1	Before 1900	selective unmanaged forest use	collecting non-timber forest products; logging in private timber estates
2	1904-1947	conversion of natural forest to uneven-aged stands; plantations of indigenous tree species	first Forest Service establishing experimental plantations and testing timber harvesting; private logging along navigable rivers; boom in the balata trade
3	1948-1977	selective logging with management plans; monocyclic regeneration and open as well as strip planting	new Forest Service starting forest inventories, opening up the Forest Belt, and establishing Caribbean pine plantations and natural regeneration experiments; extension of private logging to the Forest Belt; establishing of the BSH integrated forest industry; mechanisation of timber harvesting
4	1978-1990	sustainable forest management based on ongoing CELOS forest management research (four publications on CMS)	forest management research; private logging in managed concessions; further progress in forestry training on operational, college, and academic level
5	1990-present	ecologically based forest management with RIL; polycyclic harvesting and natural regeneration based on CMS; certified forest operations and products	enforcement of the Forest Management Act; establishing SBB; formulating a National Forest Policy; introducing RIL and forest certification; international timber companies starting logging and wood processing

2.2 Selective unmanaged forest use (before 1900)

Early records on forest exploitation in Suriname refer to the harvesting of "Letterhout" by Amerindians who used it as currency in trade with colonists from Europe. It was reported that already in 1650 Letterwood (or Captain's Letterwood, *Brosimum guianense* (Aubl.) Huber, basionym *Piratinera guianensis* Aubl.) was purchased by sailors from the Dutch Province of Zeeland (Photo 2.1). This valuable commodity was very much in demand for the manufacturing of letterheads for printing offices (Gordijn 1977). Not much else is known about these early days of forest exploitation.

For about two centuries (1700-1900) the vast forestland of Suriname merely was used for selectively harvesting marketable non-timber products, while some timber was harvested in accessible forests, usually located along navigable rivers.

A number of planters were also harvesting timber on the so called 'Houtplantages' in addition to their main tasks on the agricultural plantations. These timber estates were private enterprises often close to the agricultural plantations and also based on slave labour (Kappler 1883). Their number decreased rapidly after the abolition of slavery in 1863, but a few remained until the turn of the century (Plasschaert 1910). The average size of a timber estate was around 3000 ha. All labour, including the sawing of logs into boards, was done manually. The capacity of the timber estates could hardly meet the demand for construction timber in the capital town of Paramaribo and on the agricultural settlements. Due to lack of animal and machine power for log transport, the sites closest to the river were rapidly depleted and, already in that period, the colony was confronted with deficits of desired timber species for construction wood. Berkhout (1917) reported heavily exploited forests adjacent to the agricultural estates along the main rivers. But replanting of logged-over areas was not practised.

Photo 2.1. Sometimes a keen observer sees an apparently rotten stem on the forest floor, lying there for perhaps half a century or more, which upon inspection proves to be a piece of core-wood of Letterwood, hidden in a mantle of decayed sapwood. Letterwood *Brosimum guianense,* Moraceae, is a very durable, dense and heavy wood. Local varieties show an attractive pattern of blots. It was one of the first export products of Suriname and it was gathered by hand. (Photo J.Franco)

The demand for wood products was, for a substantial part, satisfied by timber imports from the USA. Sailing ships sent to Suriname to collect agricultural products carried sawn wood as ballast; that was cheaper than locally processed boards. Buildings in the old residential quarters of Paramaribo were partly constructed from American pitch-pine lumber (*Pinus palustris* and *P. elliottii*, mainly).

2.3 Introduction of forest management (1904 – 1947)

Already before the turn of the century the most important forest product was balata or bullet-wood gum, from the bolletri (*Manilkara bidentata*). The collecting of balata was more profitable than timber exploitation and could be done with far lower investments than those required for logging. The Balata Ordinance of 1914 included prescriptions for tree tapping and gum preparation, and stipulations to maintain the required harvesting cycle, in order to protect the bolletri from overexploitation. With the continued recession of the plantation agriculture, the balata business offered jobs to thousands of workers ("balata bleeders") in the first two decades of the 20th century. After a peak export in 1913 the significance of the balata industry gradually declined until it ceased to exist in the early 1970s, but the bullet-tree is still protected and its restricted felling is subjected to special regulations in the Forest Management Act of 1992.

Photo 2.2. *Virola* spp. (Baboen) stems are pulled over a little dam, which separates two water basins with permanent different water levels. Coesewijne, Suriname, 1982. (Photo P. Schmidt)

Photo 2.3. *Virola* spp. (Baboen) stems are selected and combined into a raft for transport to the sawmil. Coesewijne, Suriname, 1982. (Photo P. Schmidt)

The colonial government had been neglecting the extensive forest land of Suriname as a sustainable source of income for a long time. The focus was too much on plantation agriculture, while forests were considered as an obstacle that had to be cleared for agrarian development. Even after the re-establishment of the Forest Service in 1947, it took almost half a century to change this approach and to gain public awareness for sustainable forest use and biodiversity conservation. After the first attempt, in 1905 (Berkhout 1917), to make the tropical rain forest of Suriname more productive as a source of quality timber, forest management concepts changed, but were not based on national forest policy objectives. Just recently, in 2003, the government of Suriname has formulated for the first time a consistent forest land use policy (see Section 2.5.2).

The colonial government in Suriname had the idea that forest plantations could be established in the same way as teak plantations on the island of Java in the Dutch East Indies

(Indonesia). Teak (*Tectona grandis*) stands had already established semi-naturally before the time of the Dutch colonization of Java. An area of nearly a million hectares of teak stands were successfully brought under permanent management in the nineteenth and twentieth centuries (Dawkins & Philip 1998). This plantation management concept, so successful on Java, was adapted for Suriname.

The starting point was the visit by Prof. Berkhout to the country, in 1903, to advise the government on developing a productive forest sector. As a result, a few years later a forest management department was founded and named 'Boschwezen'(Forest Service). Berkhout (1903) opposed the idea that the tropical rain forest has the potential to regenerate rapidly without human interference. In his opinion the significance of maintaining a cutting cycle was vital in order to develop a sustainable forest management system. He proposed a cutting cycle of 50 years in combination with replanting schemes in the logged-over forests.

In 1905 the pristine forest along the railway to the Lawa goldfields was selected for timber production. This was the first time in Suriname that a forest management unit was established. The system of Berkhout was tested on a practical scale in an experimental area of 10 000 ha, divided in annual coupes of 200 ha compartments to attain a felling rotation of 50 years. A gradual conversion to a two-storey forest was envisaged with an age difference of 50 years between the upper and middle storey. Natural regeneration was to be stimulated by manual liberation of commercial trees, while additional planting was considered to fill gaps in the forest cover (Berkhout 1917; Gonggrijp 1925).

The proposed management system was inspired by the selection forest concept, developed by the forestry schools of Switzerland (Knuchel 1947) as an alternative for clear felling. Yet, Berkhout regarded clear felling of the natural forest and conversion to forest plantations of commercial timber species the best option for Suriname. A parallel might be seen in the management of the production forests on the heavily populated island of Java, where the teak was nearly all planted with a taungya agroforestry system. In scarcely populated Suriname, however, the taungya system was not suitable, because it brought no tangible incentives for local farmers as they did not need to compete for forestland. Thus, in Suriname, additional funds were needed to establish timber stands by planting. Hence, a natural regeneration system was thought to be cheaper, but the first timber harvest (logging) could only be profitable if this could be done in a rational way so that the silvicultural measures could be paid from the revenues of logging.

This forest exploitation experiment was unsuccessful for reasons of mismanagement and wrong estimates of logging costs, as was reported by Plasschaert (1910). The experiments were suspended because of lack of funds to proceed. The expected revenues from the model forest exploitation were never made and around 1926 the Forest Service was disbanded for financial reasons. A remedy could have been, according to Plasschaert (1910), to switch to machine skidding. Pfeiffer (1929), however, rejected that option, because a far higher volume of at least 60 $m^3.ha^{-1}$ was considered essential for an economic harvest with machine skidding. Such volumes were commonly harvested in the Philippines and the Dutch East Indies, where the experiences with mechanised logging originated from, but the forest in Suriname was much poorer in commercial volume.

2.4 The activities of the Suriname Forest Service (1947 - 1977)

When the Suriname Forest Service (LBB) was re-established in 1947 there was high expectation regarding the possibilities of expanding forest production and creating a forest-based industry. The key to success would be the introduction of wise forest management accompanied by public investments in forest infrastructure. In spite of a promising start and dynamic initiatives of the Forest Service for a period of approximately 30 years, the results were not very impressive. The only forest industry that could meet international standards was that of the Bruynzeel Wood Company Inc (BSH) that was established around 1947. BSH grew rapidly and became for years the local market leader and the most important supplier of plywood and quality hardwood lumber to Caribbean countries. The local forest and sawmill business expanded in the wake of BSH, but was not able to establish a modern logging and wood-processing industry, until recently when a few new companies entered the forest sector (see section 2.5).

The re-established Forest Service had to start all over again, after a period of 22 years of unsupervised forest use. Most of the forest infrastructure was gone and field personnel such as forest guards were employed elsewhere. The forestry experiments from the previous period had not been maintained and were not measured or guarded anymore. One of the oldest plantations (the 'Gonggrijp Forest') was largely occupied by local people and converted to agricultural land. Gonggrijp, who worked in Suriname as Conservator of Forests from 1907 to 1923, returned to the country in 1947 to assist the colonial government to prepare a forest policy and to help with the re-establishment of the Forest Service. His findings were published in a comprehensive handbook on post-war forestry in Suriname (Gonggrijp & Burger 1948). The envisaged forest management system was in fact a modification of the system that was earlier proposed by Berkhout (1917) comprising replanting of exploited forest with valuable tree species. Emphasis was put on the planting of the well-known commercial hardwoods in open areas or logged-over stands.

Gonggrijp's concept of replanting has never been applied on a practical scale, because experiments with small plantations of commercial hardwood had indicated, already in an early stage, the slow juvenile growth of most indigenous tree species. His predictions on future yields were far too optimistic and were not supported by convincing field research.

At that time the idea arose to develop the most accessible pristine forest region as a forestry zone. Heinsdijk (1950) used the term Forest Belt, referring to the economically accessible dry land forests of Suriname behind the wide old coastal plain (Fig. 1.3). The hinterland further south was seen as inaccessible for sustainable forest use, because of terrain difficulties, extremely poor soils, and lower stocks of commercial species. According to professional foresters it would be better to develop a forest management system that could sustain the production of useful timber from the relatively restricted (1.5 million hectares) Forest Belt.

At that time the Suriname Forest Service had not yet made a choice for a specific forest management system, but opted for a more flexible strategy involving a number of forest

use and regeneration schemes. The most important activities and achievements of the Forest Service were:

- The Forest Belt of Suriname was opened up by a network of sandy and gravelled roads, which were first constructed from the Suriname River in eastern direction to the Commewijne River, to compensate for the depleted areas along these navigable rivers.
- An extensive forest inventory was carried out in the Forest Belt and part of that area was allocated for managed timber concessions.
- Enrichment planting experiments were continued on a small scale as a means to recover logged-over stands.
- Forest research was carried out, including experiments with monocyclic natural regeneration of logged-over forest as a means to recover the stock of commercial hardwood species.
- Pine (*Pinus caribaea*) plantations were established on cleared forest land to supply the local market with utility and industrial wood.
- Forest guards, rangers and technicians were educated successfully in an own training centre.
- Two governmental mills were established, one in Central Suriname at the Saramacca River (Photo 2.4), and one in Western Suriname at the Corantijn River, in 1973 and 1975, respectively. The first one had to test modern processing techniques and the second to produce sleepers for the new railway and construction timber for the developments in Western Suriname.

The exploration and subsequent layout of the Forest Belt formed the basis for the development of a local forest and wood-processing industry. The Forest Belt became the major region for timber harvesting and forestry in general, including the establishment of tree plantations. A system for managing forest concessions was introduced and legally enforced by the Timber Ordinance and the Special Concession Ordinance of 1947. The Forest Service was given responsibility for implementing the Ordinances. A substantial number of concessions were granted as forest units subjected to regular management. The regular management concept (Bhadran 1965) comprised the use of a management plan designed by the Forest Service, including a manual for road construction, inventory, harvesting and recording of timber production. A forest unit was divided into cutting compartments in anticipation of a felling cycle of 30-35 years, as a rotation cut was considered achievable in less than 40 years.

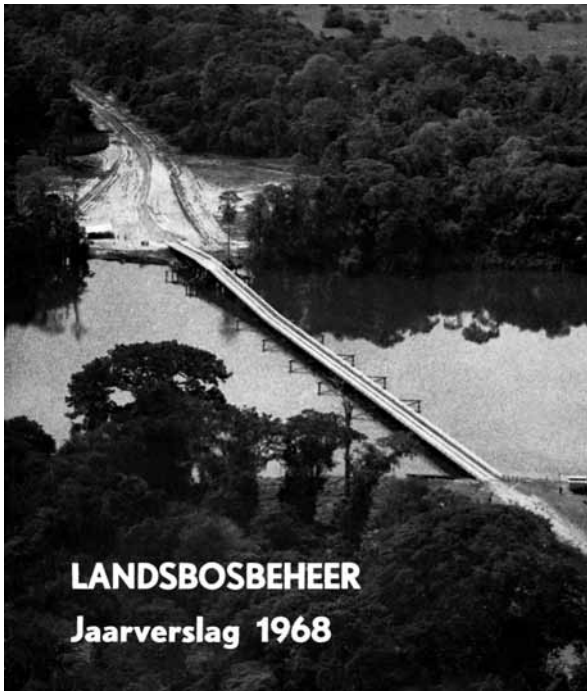

Photo 2.4. The wooden bridge over the Saramacca river, completed in 1968. (Photo Dienst's Lands Bosbeheer)

The extensive swamp forests along the coast of Suriname contained a considerable volume of plywood logs of *Virola surinamensis* Warb. (Myristicaceae). Due to a very dry year (1964) large parts of these swamp forests were destroyed by fire, often inclusive of the peat layer. This was a great set-back for the forest industry that had developed systems for exploiting the swamp forests (see Photos 2.5 & 2.6).

Photo 2.5. and Photo 2.6. Extensive stands of *Virola surinamensis* (Roland.) Warb. (Myristicaceae), in the coastal swamps were opened up by small canals. In the early days these canals were sprung with dynamite, but later they were dug out with machines. (Photo J.H.A. Boerboom)

2.5 Further developments in forest use and management after 1977

2.5.1 The deterioration of the forest sector and the Suriname Forest Service

When Suriname became independent in 1975 the Forest Service was still an active organization and a role model for the Caribbean region. But the brain drain of the early 1970s had also affected the forest sector. Already at that time there were problems in recruiting managerial and skilled staff at all levels and, as a consequence, the Forest Service had to end or suspend a number of its activities. The situation worsened the next decade after a military coup in 1980 that had its impact on the stability and democratic status of the country. A complete decline of the Forest Service and the logging industry resulted from the inland war that started in 1986.

Around 1977 the Forest Service stopped with the expansion of the Caribbean pine plantations, because of disappointing growth results and the excessive costs of stand management and weed control (Fraser et al. 1977). Tree plantation establishment on the poor tropical soils turned out to be very unattractive both in an economical and ecological sense. The objective now became to maintain the existing estates of almost 9000 ha and to search for a more efficient management system focusing more and more on the natural regeneration of logged-over forests. A governmental firm, the BOSMIJ, was set up to manage and utilise the pine stands.

Already before the 1977 the road building activities had been assigned to private contractors, while the training of rangers had been transferred to the Institute for Natural Resource and Engineering Studies (NATIN). Research activities were suspended and only the main tasks of forest management, production control and timber inspection were still carried out.

The inland war in the late 1980s heavily hit both public institutions and private logging enterprises, which lost a considerable amount of equipment and almost their complete infrastructure. The Forest Service lost practically all the 24 forest guard stations and related assets and became almost non-existent in the early 1990s. Various attempts to reanimate the Forest Service failed, mainly because of the weakness of governmental departments at that time. A radical solution was the establishment of a new forestry venture in 1999, the Foundation for Forest Management and Production Control (SBB), which took over the management and inspection tasks from the Forest Service.

The wood-processing industry was directly impacted by the corrosion of the logging ventures and the chaos in accessible production forests. Especially the larger companies, such as the Bruynzeel Wood Company, came into great troubles not only because of the reduced supply of raw material, but also due to the financial crisis in the country and therefore the lack of funds to reconstruct the damaged infrastructure. Further decline of Bruynzeel was also due to weakness of the management and the inability to renovate the company so that it could compete with other ventures from the region. Slowly, but steadily, BSH was moving towards bankruptcy.

2.5.2 Developments in forest policy and management control

The promulgation in 1992 of the Forest Management Act (FMA), which had been strongly modified since the first draft of 1974, gave the government a more powerful tool than the Timber Ordinance of 1947 to manage Suriname's forests and to supervise forest use and nature conservation. But even after a period of almost 20 years of preparation, successive governments failed to effectuate the FMA and to reorganise the Suriname Forest Service.

The FMA stipulates that timber concessions larger than 5000 ha should be managed according to a management plan designed by the concessionaire. The management plan has to be submitted to the forest authority (at that time the Forest Service) for approval. The FMA includes stipulations regarding the layout of a forest management unit, the felling cycle, the allowable annual coupe, and the maximal per ha harvest of commercial species. Yet, it took another decade before forest production could be controlled effectively by the newly assigned governmental foundation SBB.

Another major achievement was the increase of the royalty on timber harvesting from USD 50 cents to USD 6.00 per m^3. As a result of the development of SBB, the forest sector could finally again contribute to the government's budget, something that had not happened since the balata boom of 70 years earlier. In addition, concessionaires were better guided and controlled and new actions were taken to improve forest management. Furthermore, the new organisation took initiatives to promote forest and

timber certification. The first company (Suma Lumber Inc.) was certified in 2008 while presently two other ventures are in a preparatory stage for certification (Houtwereld 2008).

The Forest Service had not only survived, but got new drive after the inspection tasks had been delegated to SBB, and it reorganised the nature conservation and training departments. Further developments could lead to an integration of SBB and the Forest Service in a new forest and nature conservation authority 'BOSNAS', similar to that of Guyana. A concept to adjust the FMA has meanwhile been presented to the government. This recent initiative from SBB got support from international agencies as FAO and ITTO, who have also sponsored capacity building projects for the forest sector of Suriname.

A milestone in Suriname's forestry history was the formulation of a national forest policy (NFP) that addresses modern forest management subjects as well as community forestry and gender issues (SBB 2003). Moreover, the NFP was a backing for the new SBB and a firm commitment of the government to proceed with policy reforms.
Meanwhile a new institute, The National Institute for Environment and Development in Suriname (NIMOS), was established and also statutory involved in the forest environment. A forest sector impact assessment was conducted in 2003, including a sector study and a design of guidelines for forest land assessments (NIMOS 2003).

2.5.3 International companies

Three Asian companies got huge timber concessions in 1994 under the conditions that they would establish modern logging and wood-processing industries. These ventures went bankrupt within a few years leaving behind one middle-sized sawmill and a number of badly managed forest units with a poor infrastructure.

Currently six Chinese companies are active in Suriname's forest sector, mainly in sawmilling and small-scale traditional logging. One wood-manufacturing firm, and one plywood mill are relatively successful on the local market, but the foreign companies have contributed little to modern forest management in Suriname, accept one that has employed a trained unit to perform reduced-impact logging with the intention to prepare forest and timber certification.

2.5.4 State of the art in 2009

The activities of the successive forest management organisations ("Forest Services") were decisive for forestry development in Suriname: A century of governmental ruling of the forest sector has been followed up in the past decade by a transitional phase, in which other interest groups got involved in the management of forests.

The forest sector of Suriname is clearly in an advanced state of recovery and improvement. Most important is that public as well as private organisations are taking their responsibility to further developing the sector and its supporting institutions. Almost all interest groups and stakeholders are organised in one way or another and structural consultations have been accepted as an effective tool to rule the forest sector.

The private sector is represented by the General Suriname Timber Association (ASHU) and by the Timber Sector Platform (Platform Houtsector Suriname, PHS), which have regular meetings with SBB and private organisations from the sector. This new phenomenon of consultation has also to do with public awareness on issues of sustainable forest management, biodiversity conservation, and management of natural resources. It is an encouraging development and the first time in Suriname's history that the government gets effective feedback from the society through its representing bodies.

The Foundation for Forest management and Production Control (SBB) has become a respected organisation, which has reached remarkable achievements with regard to the quality of its inspection and extension tasks. It presently employs about 130 persons, including academic, college and lower technical staff. SBB promotes sustainable forest management, not only by implementing regulations and control, but also by guiding and training logging operators including those from forest communities.

Forest legislation is in need of revision, because since the enforcement of the Forest Management Act of 1992 social-economic circumstances and forest management practices changed substantially. The concession stipulations need to be reviewed and a project is in preparation to adapt the forest charges system in such a way that the revenues for the government are increased and at the same time incentives are introduced for sustainable and efficient forest operations.

In spite of the promising projected policy, forest legislation and forest management reforms, the logging and wood-processing industries are yet far from modern. The only integrated forest industry, BSH, has disappeared again, while little improvements were achieved in the sawmilling sector. Since the financial crises of 2008, export of timber declined by approximately 20 % and investments in new ventures came almost to a complete stop. Yet, in the last quarter of 2009 there were indications that this negative trend started to recover. A number of temporarily closed forest enterprises started again with logging and timber trade, while local lumber prices increased with a mere 5 %.

2.6 Research developments since 1950

The history of forest management and forest research is strongly linked with the development of the Suriname Forest Service, which once was a role-model institution in the region, able to execute a variety of tasks and activities. Already in the 1950s it understood the importance of having reliable silvicultural systems available in order to manage permanent forest estates. Various experiments were started on the soils of the wet coastal zone (Photo 2.5 & 2.6) as well as on the soils more inland under high-dryland tropical rain forest. Both plantations (open planting as well as enrichment planting) and natural regeneration were tried. The goal was to raise the volume production per hectare of useful timber. Logically, the natural forest types with a relatively high proportion of usable timber volumes got early attention. Schulz, Boerboom and De Graaf played pioneer roles in developing a forest management system adapted to the special features of the tropical rain forest of Suriname. Their research contributed to the design of the CELOS Management System (CMS).

2.6.1 The ecological studies of Schulz

The investigations of Schulz (1960) largely concentrated on forest ecology with due attention to forest regeneration. One of his conclusions was that the ecology of tropical rain forest is probably too complex to allow a reliable prediction of effects of regeneration treatments, even after extensive research. Schulz was strongly influenced by the research of Dawkins (1958) in Uganda, who recommended a monocyclic regeneration system to transform the uneven-aged mixed tropical rainforest into an even-aged stand, largely consisting of valuable tree species. The aim was to increase not only the increment, but also the number of the current commercial timber species. This commercialisation of lesser known species became a hot issue in wood technology research (Japing & Japing 1960; Vink 1965).

Schulz stated that most species regenerate regularly in the high-dryland forest of Suriname, and that this uneven-aged forest has more or less an exponential diameter distribution for a great number of species, with a decreasing number of the large-diameter trees. It was already clear that regeneration takes place mainly in (natural) gaps caused by falling trees, with a dynamic equilibrium between recruitment and mortality of trees.

In his first publication Schulz (1960) did not opt for one specific silvicultural system for Suriname. He made reservations in a later paper about introducing a monocyclic system as designed for Africa (Schulz 1967). However, the risk of excessive logging damage in a polycyclic system is less in Suriname. This is, amongst others, because of the relatively small tree crowns, a factor in favour of polycyclic management systems.

2.6.2 Silvicultural research of Boerboom

The concept of the accessible and manageable Forest Belt had been introduced already in the 1950s, with the idea to establish a sustainable and productive forest management zone. It was already known at that time that after harvesting the relatively small volume of valuable timber per ha, the extremely slow re-growth of these attractive species would not generate a next comparable harvest within a few decades. The required felling cycle of probably 80 years or more would imply a costly maintenance of the forest infrastructure and would require the allocation of a relative vast area of forestland to harvest sufficient volume. Tree planting systems turned out to be uneconomical, while controlled natural regeneration could be an option.

The need for a higher number of trees of valuable species meant that a drastic change in the volume composition (species abundance) of the forest stands had to be achieved, promoting the valuable species from a mere 10 % towards a multiple value of that original percentage. This seemed to be possible, from early interpretations of the first experiments, and was considered as ecologically acceptable. A lower final stand volume than originally present was seen as acceptable in this system. New methods to remove trees of non-commercial species had become available during World War II by means of synthetically produced arboricides which fatally disturbed (especially) root growth already at very low concentrations. Removing in this way nearly all of the dominant canopy trees proved to be very effective and relatively cheap. Also the ravage from falling branches and stems of treated trees was considerably less than from felled trees (Boerboom 1964).

Dawkins visited the Suriname Forest Service in 1955 (LBB 1956) and recommended as best practice a shelterwood system with clear felling after establishment of sufficient regeneration, because a polycyclic systems was considered to be very damaging to the residual forest. The shelter wood approach was followed in Trinidad with apparently good results in similar forests as in Suriname (Boerboom 1965). There was, however, a good market for firewood in Trinidad at that time, allowing revenues to compensate for the labour-intensive clearing, but that was not the case in Suriname. Here, the researchers thus had to use arboricides to remove the canopy.

Results obtained in these first regenerating experiments were encouraging enough to continue with research, but the high costs of tending the young stands were a drawback. Early assumptions (Schulz 1960) that once established stands (cohorts) of saplings of a few meters tall could keep sufficient dominance over the abundantly regenerating pioneer and secondary species proved to be over-optimistic (Photo 2.7). The stands were swamped with pioneer trees and other undesirable vegetation, which made increment of desirable species often very slow (Boerboom 1964; Schulz 1967). Nevertheless, Boerboom intensively tested the monocyclic regeneration system and tried to formulate the goals. Furthermore, he proposed new experiments to clear up the then vague perceptions on forest regeneration.

2.6.3 Silvicultural research of De Graaf

A few decades later De Graaf (1982, 1986), concluding from Boerboom's studies on forest succession after clearing, opposed a monocyclic system with the argument that a final clear felling, even under a reasonably successful shelterwood regeneration system, would lead to an interim dominance of invading pioneer and early secondary tree species as well as climbers. This dominant layer would suppress the valuable species for several decades or would have to be removed by costly and repeated interferences. It seemed that the early researchers repeatedly underestimated the overpowering vitality of the pioneer and early secondary vegetation after intensive refining in this forest ecosystem. As most of these fast-growing species are not marketable, much unlike the situation in Southeast Asia, in Suriname this interim dominance had to be avoided by allowing only a reduced opening of the canopy.

New field experiments to test the monocyclic system were started by Boerboom at the field stations of the Centre of Agricultural Research

Photo 2.7. Early treatment schedules were very intensive, with stand basal area reductions from an original 28 $m^2.ha^{-1}$ of the logged forest to a mere 4 $m^2.ha^{-1}$. Regrowth after such treatment was very dense, and several secondary species strongly dominated. The person in the bush is Dr Jan Boerboom. (Photo J.P. Schulz)

in Suriname (CELOS) and were continued by De Graaf as from 1970, with logistic support of LBB. This research is discussed in detail by De Graaf (1986), who compared the results of these quite diverging experiments by using the same parameters and methods to analyse the records. Previous conclusions were confirmed after renewed inventories of the experimental plots (De Graaf et al. 1999; Poels et al. 1998). These field experiments, some of them dating from about 40 years ago, still exist in the Mapane research area.

The oldest experiment was set up in an area of 20 ha in 1965 to study the effects of delayed liberation treatments on populations of young trees of valuable species in heavily refined stands. Another field experiment in two blocks of 5 ha, started in 1967, aimed at studying developments in a forest that was lightly logged without post-harvesting silvicultural treatment. A third experiment on 25 ha, also started in 1967, was to test a series of silvicultural liberation techniques after refinement, each technique with various liberation schedules. Finally, a 25-ha extension of this third experiment was established in 1975, to test the best technique and schedule so far found, but now on a practical scale. Even an assessment of the treatment costs was possible, as the plot size was large enough to allow regular manual operations. The data would be compared with those from the Forest Service's experiments. In all these trials the refinement and liberation was done using the arboricide 2, 4, 5-T solved in diesel oil.

The experiments have been intensively recorded the first years, some even annually (De Graaf 1986), but after 1982 the recording and monitoring stopped, because of the instable political situation in Suriname. Only one occasional observation by Van Rompaey took place in a selection of experimental sites in 1987 (De Graaf et al. 1999). The next opportunity for measurements in the experimental plots came eight years later, in 1995. The absence of data in the time gap of 13 years could partly be compensated by the long period of annual recordings from 1965/1967 up to 1982, so that De Graaf was able to process and analyse the data (De Graaf et al. 1999).

Already in 1978 De Graaf proposed to test his findings on a practical scale. He designed a large-scale experiment in the Kabo area named "Experiment 78/5 - Mortality, Natural Regeneration and Increment" to study the effects of logging and refinement on the residual forest, and conducted the logging operations as a first treatment of a pristine forest (De Graaf 1986). In the follow-up research carried out by Jonkers (1987) the experiment was revised and coded as "MAIN experiment". A few years later De Graaf proposed that a more in-depth study should be undertaken on the various impacts of timber harvesting and terrain transport of timber, because the way in which this first human interference is carried out is decisive for the regeneration ability of the forest. Both extensions of the original research programme took place within a new university cooperation structure (Section 2.6.4).

2.6.4 Research at the Centre for Agricultural Research in Suriname

After the independence of Suriname in 1975 the previously discussed silvicultural research was continued within the framework of a project named "Human interference in the tropical rain forest ecosystem" (LH-UvS01 Project, registered as MAB Project 94). This project, a cooperative effort of Wageningen University and the University of Suriname,

started in 1978 and was suspended in 1983. Its overall objective was: "An evaluation of the consequences of interference on the potential productivity of the ecosystem, on its environment and on its capacity for sustained timber production."

The specific research objectives were formulated as:

- Analysing the effects of management and operational practices on the forest ecosystem;
- Investigating ecological processes, particularly those related to production, and the effects of stand treatments on neighbouring systems (e.g. aquatic systems);
- Developing principles on which to base the planned management of tropical rain forest.

The field research of the project was facilitated by the Centre of Agricultural Research in Suriname (CELOS). Two field stations were established, one near the bridge over the Mapane River and another in yet unexploited forest at Kabo, near the Tibiti River. A total of 60 field plots, including plots from older experiments, were laid out. Most of the experimental plots are today still detectable at the research sites. They were all marked and coded, mapped, and described in a manual that is still in use. Around 1982, six scientists and 30 field assistants were employed in the project.

The Silvicultural experiments. The largest silvicultural experiment, the MAIN experiment at Kabo, aimed at determining which combination of logging intensity and silvicultural treatment would result in optimal development of the commercial stand. The scheduled silvicultural treatments were two varieties of CSS (CELOS Silvicultural System, see Chapter 3) and a control treatment, and the logging treatments were tree levels of semi-controlled selective felling. This completely factorial block experiment originally consisted of three randomized blocks (replications), each of nine treatment plots, and tree virgin plots which were added in 1981.

Photo 2.8. The encampment at Tonka site, near the MAIN Experiment. Such traditional huts are comparatively cool and comfortable for those accustomed to sleep in a hammock. (Photo N.R. De Graaf)

The MAIN experiment was revised by Jonkers who applied the silvicultural treatments and observed both the refining and logging impacts for three years (Jonkers 1987). The impacts on three growth, recruitment and mortality, as well as the findings which contributed to the design for CMS, are discussed in Chapter 4.

The ecological studies. Under all circumstances the envisaged forest management system should be developed within the ecological constraints of the ecosystem, including the question to what extent one can interfere in the tropical rain forest ecosystem without jeopardizing its capacity to recover and to maintain its biological productivity. The ecological research was carried out at both research sites simultaneously with the silvicultural studies (Schmidt 1981, 1982). The observed impacts on forest structure and

plant species composition are discussed in Chapter 5, the impacts on animal species in Chapter 7, while a number of related ecological aspects are highlighted in Chapter 6.

The hydrological and nutrient studies. Silvicultural and logging treatments can also impact the hydrological system and the nutrient balance of the forest. Hydrological aspects included observations and measurements of rainfall, discharge (runoff), evaporation and groundwater levels. A computer model (WOFOST4) was used for simulating water flow and forest growth in the research area. The nutrient balances of undisturbed and treated forest were compared to determine the effects of refining and logging. The findings from this research are discussed in Chapter 6.

The timber harvesting experiments. The first efforts to reduce logging damage in tropical rain forest date from the 1950s, when directional felling was introduced in the Philippines as a means to avoid damage to potential crop trees (Reyes 1968). In the same period, the first publications on logging damage in Malaysia appeared (Nicholson 1958; Wyatt-Smith & Foenander 1962) and this led to the introduction of pre-felling climber cutting in the late 1960s (Fox 1968). However, serious efforts to modify the complete logging operation with the dual aim to reduce damage and to improve efficiency were not undertaken in South East Asia until the late 1970s, and even later in Latin America and Africa.

In addition to the study of logging damage in the MAIN experiment, a more specific research on various aspects of logging impacts was carried out by Hendrison (1990) in the Mapane area in 1981. The best management practices to reduce damage (then defined as damage-controlled logging) were investigated in the context of sustainable forest management. Further observations of logging impacts were made in the concession area of BSH at Patamaka. The background of this study, including the formulation of a controlled harvesting system, called the CELOS Harvesting System (CHS), are discussed in Chapter 3.

Suspension of fieldwork. In fact the CMS fieldwork was already suspended by Wageningen University in December 1983 after the serious political problems involving developmental cooperation between Suriname and The Netherlands emerged. This was very unfortunate, especially with respect to the planned observations in the experiments at Kabo and Mapane. The first phase of development of the CMS was ended after processing and analyses of field data and the publications of the results (De Graaf 1986; Poels 1987; Jonkers 1987; Hendrison 1990).

2.6.5 The design of the CELOS Management System

Development of a sustainable forest management system such as the CMS was somewhat complex and it took quite a number of years before a polycyclic management system was finally considered most suitable for the tropical rain forest of Suriname. Such a system can restrict the invasion of woody weed species, in contrast to the heavy disturbance caused by application of a monocyclic system, as was concluded from the Mapane and Kabo field experiments.

The relatively small volume of projected harvests of 20 to 30 $m^3.ha^{-1}$ in polycyclic systems is economically a disadvantage, but restricts disturbance of the ecosystem, which is

very important for tree regeneration and continuity of other ecosystem processes. Furthermore, no intensive (and thus expensive) silviculture, such as clearing, planting and weed-control, appears to be needed to create large standing volumes over long periods. These and a number of other aspects were essential for the development of the CELOS Silvicultural System (CSS) and the CELOS Harvesting System (CHS), and finally for their integration in the CELOS Management System (CMS) as is explained in Chapter 3.

Societal acceptance of the CMS was thought to be gained when jobs would be created, sustainable production achieved, and the forest ecosystem would not unduly change so that other functions would be maintained, such as water and erosion control and provision of non-timber forest products. These aspects later became more complex and sensitive to trends in the perception of issues, such as needs for nature conservation and respect for indigenous people's rights, while the use of arboricide in forest management turned out to be questionable. However, these issues were not included in the original research programme.

The findings of the various specialists in the LH-UvS01 Project were finally integrated into the CELOS Management System. De Graaf & Hendrison (1987) presented a preliminary version of the CMS at a seminar in Honduras followed by another description by De Graaf (1987). A comprehensive description of the system, including previously formulated elements, is found in Hendrison (1990). Since then a few more aspects were elaborated, which could be considered as CMS-related research, such as the further development of methods to reduce impacts of logging (RIL).

RIL research really gained momentum in the 1990s. Many studies were initiated, e.g. in the Malaysian state of Sabah (Pinard et al. 1995), Indonesia (Bertault & Sist 1995), Brazil (Johns et al. 1996), Guyana (Van der Hout 1999, 2000) and Cameroon (Jonkers & Van Leersum 2000). Furthermore, a code of practice for forest operations (COP) was formulated by FAO, which applies worldwide (Dykstra & Heinrich 1996). Meanwhile, a number of countries, including Brazil and Guyana, have adapted the COP to their specific requirements, in close cooperation with stakeholders from the forest sector. Recently, Suriname has requested FAO assistance to design a COP of its own.

Probably the first true Reduced Impact Logging System was already developed in the late 1970s in Sarawak, Malaysia (Mattson Marn & Jonkers 1981). In the 1980s, another RIL system was developed in Australia (Ward & Kanowski 1985), followed by the CELOS Harvesting System (CHS) as proposed for Suriname (Hendrison 1990; Jonkers & Hendrison 1987). Hence, CHS is the oldest RIL method developed in South America.

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