# 9 Guyana

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## 9.1 Introduction

Guyana has vast forest resources that cover more than three-quarters of its land area and contain over 1,000 different tree species. Currently, between 12 and 15 of these species are being logged on a commercial scale through a system of concessions. The most sought after species include Greenheart (*Chlorocardium rodiei*), Mora (*Mora excelsa* and *Mora gonggrijpii*), Baromalli (*Catostemma commune*), Purpleheart (*Peltogyne* spp.), Crabwood (*Carapa guianensis*), and Kabukalli (*Goupia glabra*). In 2005, Guyana exported over US$ 52 million in forest products, ranging from roundwood logs and sawn timber, to plywood, moulding and furniture products.

Approximately 52 percent of State Forests have been allocated to timber harvesting concessions. Three types of concessions are being awarded, based on area size and duration:

- Timber Sales Agreement – granted up to twenty-five years for areas in excess of 24,000 hectares
- Wood-cutting Lease – granted for up to ten years for 8,000 - 24,000 hectares
- State Forest Permission – granted for a two-year period on no more than 8,000 hectares

Although Guyana neighbours Suriname directly to the West and although the two countries share a substantial number of commercial timber species, their forests differ considerably. An important difference is the occurrence of stands that are dominated by one or few species, notably Greenheart (*Chlorocardium rodiei*), Morabukea (*Mora gonggrijpii*) and Wallaba (*Eperua* spp.). Despite the occurrence of these so-called reefs, the average volume harvested per hectare is remarkably low. This is due to the high incidence of decay in the aforementioned species – extremely high among Morabukea - and reefs being interspersed by less valuable stands.

## 9.2 History of forest management in Guyana

The oldest record of timber trade from Guyana dates from 1624. Just as in Suriname, one of the most important activities in the early days of Dutch settlement was the bartering of trade goods with the Amerindians, one of these goods being *Brosimum guianense* (syn. *Piratinera guianensis* – Letterwood or Captain's Letterwood). The trade in Letterwood (see Chapter 2) must have flourished because in 1669 a single ship is reported to have transported 10,000 kg of the timber (Swabey 1950). Letterwood dominated the timber trade until the later part of the 18th century, when *Chlorocardium rodiei* (Greenheart) was first produced in commercial quantities. Most timber came from the old 'Dutch' estates. As they were private property, this situation resulted in a lack of control of woodcutting and, moreover, no direct return to the colonial power, which was by then British (McTurk et al. 1882). This led to the first attempt to regulate woodcutting under the Crown Lands Ordinance of 1871. That provided that rent was payable on woodcutting tracts.

At that time, logging was restricted to the lower rivers. Strenuous manual overland extraction was undertaken within a narrow strip of land about 1 km deep inland along the banks of the rivers. Yet, in 1882 uneasiness concerning the destructive methods of the woodcutters was voiced by McTurk et al. Further observations by the Crown Surveyor in 1889 (ex Swabey 1950) that reefs of Greenheart close to navigable watercourses were becoming increasingly depleted and hence accessible timber stocks scarce, lead to the prospect that timber stocks would be exhausted in the foreseeable future and pressure built to establish some system of forest conservation. This culminated in the passing of the Crown Lands Ordinance of 1886 and new forest regulations in 1890 which featured the following measures: the institution of minimum cutting limits, the obligation to retain economic species spaced throughout the forest, the payment of royalty, the institution of grant registers and removal permits, and the marking out of working blocks.

During the 1880s, a rush from the coastal population to the interior began due to a boost in gold mining and a growing trade in Balata - the coagulated latex obtained from tapping *Manilkara bidentata* (Bulletwood). During the later part of the 19th century and the earlier part of the 20th century, firewood and charcoal production, mainly for domestic use and export to the Caribbean, and Balata bleeding outstripped timber production.

An important step in the recognition of forest management problems was the establishment of a forestry branch at the Department of Lands and Mines in 1908 and the appointment, in 1910, of five forest rangers and a forest officer. During the next 15 years the first forest surveys were undertaken by C.W. Anderson, the first forest officer, and his successor, L.S. Hohenkerk. Between 1908 and 1916 a total of 34 expeditions were made covering all of the easily accessible forest areas (Welch et al. 1975).

In 1925 a Forest Department, independent of the Lands and Mines Department, was established, with B.R. Wood as the first Conservator of Forests. During the next 25 years the Forest Department undertook forest inventories of the most important forest areas by strip enumeration surveys, identified and took samples of hundreds of tree species, prepared and distributed samples of timbers for testing, started investigations on the regeneration of Greenheart forests and established seasoning techniques for local timbers. By 1935, the distribution of the main commercial species, and in particular Greenheart, was well understood. In the 1920s, Greenheart had a prominent position with a log output of 20,000 $m^3$ per year, accounting for 77 % of the total roundwood output, and rising to 80 % in 1939.

The Second World War affected the supply of mechanical equipment on which the industry depended by that time. Timbers other than Greenheart - especially *Mora excelsa* (Mora) and *Carapa guianensis* (Crabwood) - were available adjacent to rivers and could be extracted with little or no mechanical equipment and an increase in the production of these species was seen. Sawmills to deal with this production sprang up everywhere, and by 1949 their number had increased to 79 (Swabey 1950).

Just after the war, a Developmental Committee was set up to consider the allocation of development aid provided by the British government. A forestry subcommittee was appointed with the task to 1) frame a forest policy, 2) estimate future forest production targets, and 3) draw up specific development projects. C. Swabey, who succeeded B.R. Wood as Conservator, strongly urged that the forest policy should have two basic aims, namely increasing production in order to fill local as well as export demands, and managing the forests on the basis of a sustained yield concept.

In 1948, draft amendments to the Forest Ordinance were published with the aim to work the forests in such a way that they would be permanently productive and not 'mined' as for a mineral (Welch et al. 1975, p.50):

- exploiters were required to submit logging programmes to work their leases in a sequence of contiguous blocks;
- all merchantable timber should be worked out from one block before exploitation extended into the next;
- seed bearers were to be retained for silvicultural purposes;
- worked-out blocks were to be surrendered to the department for regeneration or improvement work to be undertaken.

It took five years for these amendments to be passed and in 1954 the new Forest Ordinance came into effect. This committed the government to create another legal land category, the Crown Forests. Thus the year 1954 marked the legal beginning of control of the Forest Department over 7.5 million ha of Crown Lands, now declared to be Crown Forests. The year 1954 also marked the beginning of a new Ten Year Development Plan for forestry through grants from the Colonial Development and Welfare Scheme of the British government. Four schemes got off the ground, i.e. training of staff, the establishment of a Central Timber Manufacturing Plant, introduction of aerial photo interpretation for forest inventory, and a silvicultural programme.

Also in 1954, new lease agreements under the new Forest Ordinance were concluded for three major firms operating in the Bartica Triangle (West of the Essequibo River and South of the Mazaruni River): British Guiana Timbers Ltd., Willems Timber and Trading Co. Ltd. and Charlestown Sawmills Ltd. These lessees were subjected to the new Regulations compelling them to extract all merchantable timber to the satisfaction of the Forest Department, and to work a sequence of contiguous blocks which were to be handed back to the government (Fanshawe ex Clarke 1956). The intention was then to assist natural regeneration of Greenheart or, at least, to increase the stocking of Greenheart substantially by poison girdling undesired trees and climber cutting, using funds from the Development Programme (Clarke 1956). Meanwhile, the above mentioned three firms were laying the foundations of the Golden Age of Greenheart. This was largely related to the higher level of mechanisation and the creation of road access to previously inaccessible areas. By 1957, there were 104 woodcutting leases, covering nearly 860,000 ha, and 92 sawmills. The output of timber was 210,000 $m^3$ per year of which 63 % was Greenheart. About 50 % of all timber was exported, some 90 % of which was Greenheart. These levels of timber output and export were maintained up to 1974.

Early exploitation had taken the form of highly selective felling of choice stems of Greenheart, mainly geared towards the export of roundwood pilings and medium sized squared timber. Since the new Forest Regulations were introduced and the mechanisation of the timber industry had increased - especially regarding the production of dressed lumber - logging had become less selective. However, this happened in the sense that almost all the Greenheart was now removed from the felling area rather than the utilisation of other species being increased as intended with the new legislation (Gordon 1961). Clarke in 1956 and Gordon in 1961 stated that supplies of old growth Greenheart were limited and would not last for much more than 30 years at the rate of exploitation at that time, and that, as the more accessible areas would have been worked out, the cost of obtaining Greenheart was to start rising very soon.

Just as at the end of the 19th century, the 1920s and 1940s, it appeared, however, that Greenheart stocks were not exhausted because virgin forests were opened up. This was made possible by the development of new methods of extraction: from manual ('grail stick') haulage to cattle haulage by the end of the 19th century, to steam (and later gasoline) sleigh winches in the 1920s. In the 1930s, the introduction of trucks and semi-trailers had thrown open large areas of forests for logging. In the 1950s, access was further expanded through the introduction of heavy road construction machinery, crawler tractors for stumping and semi-trailer trucks (articulated lorries) for road transportation, and since 1967 through the introduction of the chainsaw and articulated, wheeled skidders. Every time the pressure to regulate timber harvests was thus released by opening up new areas.

In 1966, a Forest Industries Development Programme was launched with the assistance of FAO/UNDP with the aim to carry out a full scale appraisal of the forest resource potential of the country, including forest inventories using aerial photography, and utilisation and marketing surveys. Significant achievements were recorded in the field of sawmilling and saw doctoring, forest inventory, modernising logging equipment and wood preservation by the time the programme was concluded in 1970 (Welch et al. 1975).

In 1979, the Guyana Forestry Commission was established to replace the Forest Department with the intention to finance the Commission using the revenues derived from the harvest of timber, fuelwood and other forest products. However, circumstances, due in large part to the general decline in the national economy, resulted in revenues lower than the cost of its staff and its activities (GNRA 1989). Consequently, these activities were limited to the issue of woodcutting licenses, the occasional adjudication of boundary disputes, and the assessment and collection of revenues.

Despite these constraints, the Forest Regulations were amended with the aid of Canadian International Development Agency (CIDA), creating a new type of harvesting rights, the Timber Sales Agreement, aiming at improved forest management through security of land tenure for 25 years. These Timber Sales Agreements were made available in 1985 and were issued to larger operators. The terms of these agreements, besides the stipulations of the 1953 Forest Act, required the holder to conduct forest inventories and to submit an operating plan for three years' logging and road construction to the Commissioner for approval.

Photo 9.1. A Locust (*Hymenaea courbaril*) log of 20 $m^3$ proved to be too heavy to extract in one piece. (Photo P. van der Hout)

From 1990 on, in light of the projected decline of timber stocks in Asia and Africa, the global market started to look to South America to fill the gap (Colchester 1994, 1997; Sizer & Rice 1995; Sizer 1996). This led to a number of originally Asian timber companies establishing themselves in Guyana and elsewhere in South America. Probably the most radical change for the timber industry in Guyana was the establishment of a large plywood mill in 1992. From 1994, the documented annual timber production soared from 130,000 $m^3.y^{-1}$ to 420,000 $m^3.y^{-1}$ in 1996, accompanied by a shift from sawn timber to plywood species: the share of plywood species in the total production rose from 3 % in 1990 to 53 % in 1996. The arrival of foreign owned companies also led to a recovery of the production of Greenheart. Since its Golden Age during 1954 to 1975, when annual roundwood output reached highs of 130,000 $m^3.y^{-1}$, its production had receded to about 50,000 $m^3.y^{-1}$ by the end of the 1980s, but, since 1993, the annual production has been on the rise again with an average of 68,000 $m^3.y^{-1}$ over the years 1993 to 1996 (Guyana Forestry Commission records). The shift in attention towards plywood species raised the number of readily merchantable species from a handful to about 25. The most important plywood species is *Catostemma commune* (Baromalli).

In 1989, the Government of Guyana excised 360,000 hectares of rain forest and donated it to the Commonwealth for research into the conservation and the sustainable and equitable use of tropical rain forests, resulting in the official establishment of the Iwokrama International Centre for Rainforest Conservation and Development in 1996. In addition, in 1989, an intergovernmental agreement was signed with the Netherlands, marking the start of the Tropenbos-Guyana Programme.

The post-1996 period witnessed an Institutional Strengthening Programme on the part of the Guyana Forestry Commission. This was in an attempt to transform the GFC from a traditional public service bureaucracy to a more customer- and performance-focused organisation. This policy was given impetus through the Guyana Forestry Commission Support Project which ran from 1995 to 2002.

As part of the support programme, steps were taken at institutional strengthening in areas of planning capability and management procedures, transparency and accountability of operations, improved staff performance and training, improvement in working environment and facilities and an enhanced public image:

- A National Forest Policy calling for "improved sustainable forest resource yields while ensuring the conservation of ecosystems, biodiversity and the environment" was published in 1997;
- A new forest revenue system was introduced in 1997;
- Improved facilities and staffing at field levels and an independent monitoring unit increased GFC controls;
- A Code of Practice for Timber Harvesting was prepared in 1998 and revised in 2002 providing a set of guidelines and requirements covering all aspects of logging;
- Forest inventory procedures, both strategic and operational, were produced;
- Guidelines for forest management planning were produced;
- Growth and yield models were developed based on tree data collected by Tropenbos and Barama Co.Ltd;
- A management tool called "silvicultural (post-harvest) survey" to determine differential minimum diameter cutting limits was introduced;
- A log tracking system was introduced to control forest operations;
- Revised curricula and syllabuses for the University and School of Agriculture were introduced;
- In-service management training for GFC staff was delivered;
- An in-service training programme incorporating social development and participatory skills for GFC and others was delivered.

The log tracking system in Guyana, introduced in 2000, provides detectable evidence on the legitimacy, location and magnitude of forest operations. The log tracking system currently applies to all operations, including those in State Forests, Amerindian Reservations and Private Properties, and is linked to the State Forest Permit (SFP) Quota System - an initiative to control the volume of produce harvested. The log tracking system is regulated by the use of log tags which are assigned to legal operators at the commencement of an operator's annual renewal of his SFP licence and are available to the operator free of charge. An operator's quota (forest produce volume) is calculated by an estimate of the sustained yield which considers the size of the forest area and captures the minimum log harvesting variables of felling cycle, felling distance and minimum diameter. The quota is equated to the number of standing trees which will yield this volume; and it is the number of trees computed that indicates the number of tags to be issued.

Guyana started working on a national forest certification initiative in 2000 with technical support from the UNDP-Programme for Forests (PROFOR). An NGO, the Guyana National Initiative on Forest Certification (GNIFC), comprising a balanced representation of stakeholders, has developed national standards based on the FSC Principles and Criteria. Guyana's forest certification standards were finalised through a multi-stakeholder process and endorsed by FSC in 2005 after three years of countrywide consultations.

## 9.3 Research

Guyana has a long history of botanical and ecological study, vegetation analysis, and inventory and tree volume work. Fanshawe (1952) wrote a study of the vegetation types and forest structure some 60 years ago. FAO in the late 1960s undertook countrywide reconnaissance surveys, produced stand tables, vegetation types and volume tables, whilst CIDA in the early 1990s conducted additional inventory, mapping and volume sampling work.

### *History of silvicultural trials*

The first silvicultural trials were established at Aruka in the North West district, where exotic *Khaya ivorensis* and *Tectona grandi*s were planted in 1926, but these trials were soon abandoned. In 1931 planting experiments continued at the new headquarters of the Forestry Department at the Penal Settlement on the Mazaruni River. Seeds of exotic species, such as *Swietenia macrophylla*, *S. mahagoni*, *Cedrela mexicana* and *Tectona grandis*, as well as indigenous species, such as *Hymenaea courbaril* (Locust), *Virola michelli* (Hill Dalli), *Peltogyne venosa* (Purpleheart), *Diplotropis purpurea* (Tatabu) and *Dipteryx odorata* (Tonka Bean), were sown.

Simultaneously, experiments concentrating on the natural regeneration of *Chlorocardium rodiei* (Greenheart) were started. The first operations consisted of underbrushing - removing all undergrowth competing with Greenheart seedlings and saplings - in lightly creamed forest near the Mazaruni Station, and were inspired by the Malayan Regeneration Improvement Felling System (e.g. Wyatt Smith et al. 1963).

In 1935, T.A.W. Davis embarked on a series of experiments in order to gain insight into the conditions favourable to the regeneration and growth of Greenheart. Several treatments were compared, including different combinations and levels of thinning of undergrowth, 'understorey' and canopy in unexploited Greenheart forest (Clarke 1956). In 1936, casual examination of the first improvement operations indicated that the technique used was successful to a remarkable degree in stimulating regeneration of Greenheart (Welch et al. 1975). It was therefore decided to concentrate silvicultural work on natural regeneration techniques and the plantation trials were stopped around 1939.

Routine forest improvement operations were launched. About 240 ha of logged forest near the Mazaruni Station were treated in 1937. Further improvement operations were carried out over selected areas of partially exploited forest on both banks of the Essequibo River. Between 1937 and 1943, a total of 8,750 ha of forest were treated in the Labakabra-Tiger Creek and the Moraballi-Seba Creek areas (Fanshawe 1944a, 1944b). The treatment consisted of climber cutting and manipulating the canopy over groups of seedlings, saplings or poles by poison girdling large, undesirable trees. During 1945-46, some 1,290 ha were treated a second time. The improvement work was suspended after 1946 in anticipation of the introduction of the new forest act in which a systematic block method of logging was envisaged.

After the new Forest Regulations were passed in 1954, silvicultural work aiming at the natural regeneration of exploited Greenheart stands was resumed at Barabara at the right bank of the Mazaruni river (Clarke 1956). The silvicultural prescriptions differed from the earlier work. Treatments of increasing intensity were staged over several years (Prince 1971a, 1973) with removal of undergrowth surrounding Greenheart regeneration over a period of six years and finally poison girdling of all canopy trees other than Greenheart in the tenth year. These prescriptions aimed at a gradual conversion to pure stands of Greenheart and were inspired by the Tropical Shelterwood System (e.g. Lowe 1978; Kio et al. 1986).

In 1957, improvement operations continued in the Moraballi-Seba Creek area, although with a modification of the original aims of 1937. Preference of treatment was still given to Greenheart where it occurred, but instead of promoting regeneration of Greenheart solely, regeneration of all valuable species over as much of the forest as possible was promoted. Between 1957 and 1959, 888 ha were given a first treatment, of which 583 ha were given a second treatment to remove all remaining undesirable species from the upper canopy. Two permanent sample plots measuring 80 x 80 m were laid down. One half of each plot - 40 x 80 m - was treated in the way described above and the other half was left untreated. In 1963, K.F.S. King laid down two increment plots, the first in exploited forest near the Mazaruni Station, the second in exploited forest at Barabara which was treated as described above. All Greenheart trees of 5 cm dbh and over were measured annually until 1969.

Based on these two sets of records, Prince (1971a, 1971b, 1973) estimated a rotation for Greenheart up to 50 cm of 150 to 218 years in untreated forest and of 74 to 136 years in treated forest. Given a felling limit of 34 cm (legal limit), he suggested a felling cycle of 100 years in untreated forest and of 60 years in treated forest. The treatments were considered successful in stimulating growth and survival rates of Greenheart. However, these treatments demanded huge investments in time and funds and Prince (1973) concluded that the marginal return on investment was stretched over such a long period and therefore so low that it was not worthwhile to continue improvement operations along these lines.

Other silvicultural investigations during this period focused on *Pinus caribaea* trials on white sands (Vieira 1967; Paul 1977) and on increasing growth of *Virola surinamensis* (Dalli) in the coastal swamp forest (John 1961). Interest in the latter species was instilled by a great demand for plywood production in Suriname at the time.

### *9.3.1 The Tropenbos-Guyana programme*

The Tropenbos programme in Guyana started in 1989 and focused on various biological and physical characteristics and processes, both in unlogged and logged forests. The aim of the programme was to design sustainable forest management systems based on a better understanding of various biological and physical processes. The first phase (1989-1993) of the programme comprised four groups of projects (Ter Steege et al. 1996):

- Inventory and projects of general value;
- Hydrological balance and nutrient cycling;

- Population structure, dynamics and reproduction of important tree species; and
- Growth and productivity in relation to environmental constraints.

Most of the initial Tropenbos research took place close to Mabura Hill at the timber concession of Demerara Timbers Ltd in Central Guyana. Several experiments were conducted in logged and unlogged Greenheart-bearing forests on soils belonging to the Berbice (dekzand) formation, characterised by white sand plateaus with dry evergreen forest (savannah forest) and brown sands and sandy clay loams on slopes and footslopes with mixed evergreen rain forest (mesophytic forest). The first projects focused rather on a better understanding of the processes involved than in measuring impacts of different forest management strategies, such as logging intensity, cutting cycles, harvesting methods, or silvicultural treatments.

Main results from this first phase were (Ter Steege et al. 1995, 1996):

- Nutrient levels, cation exchange capacity, and fertilizer efficiency are very low in sandy soils. Low intensity logging seems to be the best land use option;
- Low intensity logging (< 25 $m^3.ha^{-1}$) appears to have fairly little impact on the hydrological and nutrient cycle at catchment level;
- To avoid erosion and siltation, logging should not occur in a buffer strip along creeks and on steep slopes;
- Shortage of individuals in the lower size classes of Greenheart does not allow a second harvest within 20-25 years;
- Uncontrolled skidding is a main cause for damage to the ecosystem because of destruction of seedlings and saplings, soil compaction on skid trails, leaching losses on skid trails and landings, and unfavourable growth conditions due to high aluminium concentrations and high acidity on trails and landings;
- Gap size should be kept small to minimize changes in microclimate, to favour the establishment of commercial climax species, and to buffer losses in nutrients and water through root absorption and litter input;
- Gaps should be spaced as evenly as possible over the exploited area;
- Single tree fall gaps are preferred above multiple tree fall gaps;
- Exploitation of Greenheart in a polycyclic natural regeneration system seems possible (Zagt 1997); but
- Substantial silvicultural intervention is indicated for sustained yield of Greenheart which should also target seedlings and small saplings (Zagt 1997).

During the second phase the Tropenbos-Guyana programme carried out research with the objective of developing guidelines for sustainable forest management and conservation. Its activities focused on:

- Knowledge of natural resources: physical environment, biodiversity, timber characteristics;
- Parameters for sustainable forest management;
- The significance of non-timber forest products for indigenous communities;
- Training and capacity building.

The research projects were carried out at two sites (Mabura Hill and the North-West district), in or around logging concessions.

Building on results of the CELOS experiments in Suriname an experiment was set up to evaluate the effect of logging intensity on growth and yield in Pibiri (50 km south of Mabura Hill) in 1992. Fifteen plots measuring 2 ha were established in Greenheart-bearing forest. This logging experiment is further described in detail in the following section. The experimental plots were also used for a study on plant diversity (including lianas and herbaceous plants) which was also assessed in plots where logging had taken place earlier in nearby areas. The experimental plots were also used to assess seedling performance, whereby growth and mortality of all seedlings was monitored in 250 quadrats (Rose 2000). At a later stage, 1999-2002, the Pibiri experimental plots were used in two studies; one focusing on the modeling of seed dispersal and regeneration of tropical trees (Van Ulft 2004) and one on long-term responses of tree populations and forest composition (Arets 2005).

Since the first phase of the programme had indicated that gap size was of overriding importance on long-term forest composition and productivity, a large gap experiment was set up at the Pibiri site. The gap experiment was an integrated study of soil, climate, nutrients, plant demography and ecophysiology in artificial gaps varying in size from 50 to 3,200 $m^2$.

Over the period that Tropenbos was active in Guyana (1989-2001), 48 projects were carried out, 19 during phase I, of which 6 were carried over to phase II, and 29 new projects during phase II.
Some conclusions from these projects in relation to forest management are (conclusions from the logging experiment are discussed separately):

- The 'allowable' gap size – in which the species composition is not significantly different from unexploited forest – is 300 $m^2$ (Ek 1997);
- Total skid trail area has a significant influence on the number of species after logging: skid trail area should be kept to a minimum (Ek 1997);
- Combined gap and skid trail area has the strongest influence on the number of newly established species after logging: skidding within gaps should be kept to a minimum (Ek 1997);
- Only some liana species are able to connect more host-trees and develop such a diameter that they can have a high impact on logging damage: pre-harvest liana cutting only needs to be applied to those liana species able to connect more host-trees (Ek 1997);
- Most species show their maximum growth rates in gaps of 200 to 800 $m^2$. A slow growing species adapted to shaded environments can only maintain itself after gap creation by having a size advantage over fast growing pioneers. Consequently damage to seedlings and saplings of desirable species should be kept at a minimum during logging activities (Rose 2000);
- If the gaps created are larger than 800 $m^2$, this initial size advantage may quickly disappear in the presence of high pioneer species abundances (Rose 2000);
- Indiscriminate skidder activity in conventional logging (as opposed to controlled activity in reduced impact logging) may destroy de seedling bank which consists mainly of shade tolerant (commercial) species while dormant seeds of pioneer species may benefit strongly from soil disturbance (Rose 2000);

- 95 % of natural tree fall gaps were smaller than 300 $m^2$ and 55 % of the gaps were less than 100 $m^2$ in size. If it is the objective to preserve current species composition and biodiversity, the impact of logging should stay within these limits;
- Leaching, acidification and mobilisation of aluminium strongly increased in gaps larger than 400 $m^2$. Considering these hydrochemical aspects, logging gaps should not exceed 400 $m^2$ (Van Dam 2001);
- Seedlings of pioneer species were found more in logging gaps and especially on skid trails in logging gaps (Van Ulft 2004);
- Since seeds are dispersed over short distances only, it is important that a number of healthy, large trees are left in the forest and that these remaining seed trees are distributed evenly over the forest to ensure that seeds will be available and evenly distributed throughout the logged area (Van Ulft 2004);
- It is possible to manage the forest in a way that results in relatively small changes in functional group composition and still achieves more or less sustained yields (Arets 2005);
- The time after logging to return to commercial volumes and abundances of functional groups that would be similar to unlogged forest may take as much as 100 to 120 years (Arets 2005);
- During logging large, reproductive trees are harvested, which may have implications for the regeneration of the forest after logging; omission of the relation between numbers of adults and numbers of recruits over time will lead to underestimation of the effect of logging on abundances and commercial volumes (Arets 2005).

### *9.3.2 The Tropenbos logging experiment*

The main objective of the logging experiment was to formulate a silvicultural system for sustained timber yield from Greenheart forest in Guyana and similar forests elsewhere (Van der Hout 1999). An experiment was set up whereby conventional and reduced impact logging (RIL) were compared at three different logging intensities; *i.e*. 4, 8 and 16 trees per hectare. To this effect, 18 experimental plots of 2 hectares each were established in Greenheart forest in 1993. Trees of all species with a diameter above 20 cm dbh were identified and measured over the entire plot area, while smaller tree sizes were sampled in subplots of varying size. Logging took place in 1994 and its impacts on the residual tree population, gap sizes and ground disturbance were assessed in 1995. The plots were subsequently measured in 1996, 1997 and again in 2000 (Arets 2005). Silvicultural treatment took place in 1996. Besides the effect of the logging method, the effect of logging intensity was studied to determine at which level of extraction the gains of using RIL would be outdone by increasing logging intensity. The study also examined the costs and benefits associated with a transition from conventional timber harvesting practice to RIL and whether or not post-harvest silviculture would be an option to increase productivity of logged forest (Van der Hout 1999).

The study revealed that total canopy loss due to felling did not differ between conventional and RIL operations at a logging intensity of 8 trees per hectare, but raising the logging intensity to 16 trees per hectare resulted in a greater canopy loss in case of RIL. This interaction was explained by the difference in felling pattern. In case of conventional logging, trees were felled in clusters, which led to overlapping felling gaps. In case of RIL, felled trees were more uniformly spaced and a herring-bone felling pattern was strictly applied. Multiple treefall gaps occurred much more often in the conventionally logged plots. An increase of logging intensity meant an increase of the number of trees in a cluster in case of conventional logging; *i.e.* an increased overlap in felling gaps. In case of RIL, this meant only a marginal increase in overlap of felling gaps. The average size of felling gaps according to a modified Brokaw definition (*sensu* Van der Meer & Bongers 1996) amounted to 209 $m^2$ in case of RIL with an intensity of 8 trees per hectare. In case of conventional logging, it amounted to 264 $m^2$ at this intensity. At 16 trees per hectare, the average gap size amounted to 439 $m^2$ for RIL and 333 $m^2$ for conventional logging (Van der Hout 1999).

Photo 9.2. Measuring the diameter of a Wadara (*Couratari guianensis)* above the buttress in one of the experimental plots at Pibiri. (Photo P. van der Hout)

Proper planning and marking of skid trails, a herring-bone felling pattern and the application of winching reduced the ground area affected by skidding considerably: at a logging intensity of 8 trees per hectare the ground area affected by skidding was reduced from 13 % to 8 % of the total area and at a logging intensity of 16 trees per hectare from 21 % to 9 %. In case of RIL, ground disturbance as a result of skidding occurred in 5 % to 8 % of the total felling gap area at logging intensities of 8 to 16 trees per hectare respectively, since ground disturbance was restricted to gaps along skid trails. In the conventionally logged plots this amounted to as much as 30 % to 36 % of the total felling gap area. This difference is of great importance for the future tree species composition in these gaps, since in gaps successful regeneration of shade-tolerant species, a group to which most commercial species belong, is depending on pre-existing seedlings (Brown & Whitmore 1992; Zagt & Werger 1998). Greenheart is locally very common as a seedling but its growth rate is lower than that of accompanying seedlings belonging to other species. Zagt (1997) suggested, therefore, that Greenheart would only be successful in filling a canopy opening if it has an advantage in size compared to close neighbours. Skidding in felling gaps crushes the few commercial seedlings that have this advantage and should therefore be avoided.

In all, RIL damaged fewer trees of dbh ≥ 10 cm per extracted tree than conventional logging (CL) at both logging intensities; 13.1 versus 16.4 trees were damaged at a logging intensity of 8 trees/ha (a reduction by 20 %) and 9.1 versus 10.2 trees at 16 trees/ha (a reduction by 11 %). Felling damaged less trees in RIL at a logging intensity of 8 trees/ha (7.8 versus 8.9 trees damaged per tree extracted), whereas more trees were damaged in RIL at a logging intensity of 16 trees/ha (6.5 versus 5.8 trees). Less trees were injured or killed during skidding in RIL than in CL at both logging intensities. The reasons for these differences lie partly with the difference in felling method and partly with the fact that group-wise felling was practiced with conventional logging. In case of such clustered felling, the number of neighbouring large trees that can potentially be damaged is smaller.

Several studies have shown that additional cost associated with planning and directional felling can be offset by an increased efficiency of the skidding operation (Hendrison 1990; Barreto et al. 1998; Holmes et al. 2002). In the logging experiment, the implementation of the RIL system led to a threefold increase in pre-harvest planning cost and a twofold increase in felling cost. Those increases were only partly offset by a reduction of skidding cost, which amounted to 5 % only. The aggregate direct cost at the landing was increased by 15 %. On the other hand, the output per day and per hectare was higher under the RIL regime. Without the higher timber recovery the cost-benefit balance of RIL turned out more costly than conventional logging practice.

Logging costs and performance are affected by many different factors. The quantity and quality of available labour, the type and size of the trees to be harvested, topography, carrying capacity of soils, accessibility of the area to be logged and the skidding distances all influence the cost and performance of a particular logging system (Sundberg & Silversides 1988). The impact of these factors was assumed to be substantial due to the size and lay out of the experimental plots. The operational data were therefore standardised by setting a fixed logging intensity of 10 trees per hectare and a skidding distance of 383 m. By costing each activity on a per $m^3$ - basis, the influence of differences in site quality on the cost benefit analysis was reduced. Modelling skidding costs for a certain fixed distance and load size eliminated the effect of differences in extraction distance and load size. Standardisation let to similar costs of conventional and RIL; i.e., US$ 28.29 in case of conventional logging and US$ 28.23 for RIL (price level 1998). Cost and performance of pre-harvest planning, tree marking and skid trail demarcation, and loading and trucking were estimated using general guidelines, these figures were less accurate than the cost and performance of felling and skidding. Focusing on the felling and skidding work cycles only showed that the cost of a cubic metre of timber landed at the roadside landing was estimated at US$ 5.60 in conventional logging and US$ 6.32 in RIL.

Photo 9.3. Directional felling techniques applied while felling a Greenheart (*Chlorocardium rodiei*) in RIL. (Photo P. van der Hout)

### *9.3.3 Effect of logging intensity and silvicultural intervention on growth and yield*

Logging in 1994 removed mean basal areas of 1.2, 2.0 and 3.7 $m^2.ha^{-1}$ at logging intensities of 4, 8 and 16 trees per ha, respectively, which translated into removals of 10 %, 13 % and 30 % of the basal area of commercial and potentially commercial trees[1]. Mortality associated with logging considering all trees ≥ 20 cm DBH amounted to 0.4 $m^2.ha^{-1}$ (1.7 %), 0.6 $m^2.ha^{-1}$ (2.8 %) and 1.0 $m^2.ha^{-1}$ (5.0 %) of the initial basal area. Considering commercial and potentially commercial trees only, this amounted to respectively: 0.1 $m^2.ha^{-1}$ (1.8 %), 0.2 $m^2.ha^{-1}$ (2.4 %) and 0.3 $m^2.ha^{-1}$ (2.7 %). Greenheart made up about half of the harvest with an average basal area of 0.5 $m^2.ha^{-1}$, 1.1 $m^2.ha^{-1}$ and 1.6 $m^2.ha^{-1}$ having been removed (23 %, 28 % and 48 % of the initial basal area of Greenheart trees with good and acceptable stem quality, respectively) with associated mortality of 0.6 %, 0.9 % and 1.8%, respectively.

During the two years after logging (1995-1997), net basal area increment rates were positive for the group of commercial and potentially commercial trees but negative for trees of these species with poor stem quality (hollow or crooked) and trees of non-commercial species. This led to an overall decrease in basal area over this period for all treatments (Figure 1). For the period 1997-2000, net basal area of all trees slightly increased in most treatments.

Converting the annual basal area increment to annual volume increment by multiplying the basal area with a conservative form-height factor 10 presented a strong annual volume growth of 1.1 $m^3.ha^{-1}.y^{-1}$ for commercial and potentially commercial trees over the period 1995-1997 in the control plots, reasonable annual volume growth of 0.7 $m^3.ha^{-1}.y^{-1}$ at logging intensities of 4 trees/ha and 8 trees/ha, and 0.4 $m^3.ha^{-1}.y^{-1}$ at a logging intensity of 16 trees/ha. In the following period, 1997-2000, net volume increase became less in the control plots and at a logging intensity of 4 trees/ha but increased strongly at the two higher logging intensities (Table 9.1).

Table 9.1. Net annual volume increment per hectare for the periods 1993-1995, 1995-1997 and 1997-2000 with five treatments: control (no logging), logging intensity 4, 8 and 16 trees/ha and logging intensity 8 trees/ha followed by silvicultural treatment; and three species/quality groups

| Treatment | Commercial trees - good or acceptable stem quality | | | Greenheart - good or acceptable stem quality | | | Non-commercial species and commercial trees – poor stem quality | | |
|---|---|---|---|---|---|---|---|---|---|
| | **'93-'95** | **'95-'97** | **'97-'00** | **'93-'95** | **'95-'97** | **'97-'00** | **'93-'95** | **'95-'97** | **'97-'00** |
| 0 | 0,2 | 1,1 | 0,6 | 0,4 | 0,4 | 0,0 | 0,4 | -2,5 | -0,6 |
| 4 | -8,5 | 0,7 | 0,4 | -3,7 | 0,2 | 0,1 | -0,5 | -1,7 | -0,9 |
| 8 | -13,1 | 0,7 | 1,0 | -7,9 | 0,4 | 0,4 | -2,2 | -2,8 | 0,1 |
| 16 | -25,3 | 0,4 | 1,2 | -11,5 | 0,4 | 0,4 | -4,8 | -3,5 | 0,2 |
| 8 + | -15,7 | -0,1 | 2,0 | -6,9 | 0,0 | 0,5 | -1,2 | -35,0 | 1,5 |

1 Commercial and potentially commercial trees are trees of commercial and potentially commercial species with good and acceptable stem quality – thus excluding hollow and crooked trees of these species.

If the latter net annual volume growth would be sustained the initial basal area would be restored within 31 years with a logging intensity of 4 trees/ha, 19 years with a logging intensity of 8 trees/ha and 32 years with a logging intensity of 16 trees/ha. To estimate the required cutting cycle the net annual volume growth of only the trees with a diameter ≥ 40 cm DBH was considered. This indicated a cutting cycle of 18 years with a logging intensity of 4 trees.$ha^{-1}$ (12 $m^3.ha^{-1}$), of 31 years with a logging intensity of 8 trees/ha (20 $m^3.ha^{-1}$) and 62 years with a logging intensity of 16 trees/ha (37 $m^3.ha^{-1}$). The sustainable annual allowable cut would thus be around 0.65 $m^3.ha^{-1}.y^{-1}$. This figure is twice the allowable cut that is currently prescribed by the Guyana Forestry Commission. It is, however, uncertain whether the growth rates for 1997-2000 were indeed sustained (the net annual volume increment for this period for this species group in the control plots amounted to 0.40 $m^3.ha^{-1}.y^{-1}$). It would be of great value if the plots of the logging experiment were measured again within the foreseeable future to allow verification of these results.

As far as Greenheart is concerned an annual allowable cut of 0.07 $m^3.ha^{-1}.y^{-1}$ is indicated with a logging intensity of 4 trees/ha, 0.14 $m^3.ha^{-1}.y^{-1}$ with 16 trees/ha and 0.28 $m^3.ha^{-1}.y^{-1}$ with a logging intensity of 8 trees/ha (around 10 $m^3.ha^{-1}$ with a cutting cycle of around 40 years). This implies that the sustainable allowable cut should only include around 40% Greenheart. If a cutting cycle of 25 years is applied, as with the CELOS Management System, this would suggest a logging intensity of 16 $m^3.ha^{-1}$ (around 7 trees/ha) whereby the Greenheart harvest would be restricted to 7 $m^3.ha^{-1}$ (around 3 trees/ha).

The silvicultural treatment consisted of a selective release of potential crop trees by localised elimination of undesirable trees within a radius of 10 m around favoured trees. This treatment reduced the basal area by on average 7.0 $m^2.ha^{-1}$ leaving a mean basal area of 12 $m^2ha^{-1}$. This implies that the basal area was reduced to approximately 55 % of the pre-harvest value and that the treatment was milder than the treatments that were applied in the CELOS experiments in Suriname and also milder than the treatment advocated by Jonkers (1987, see Chapter 3).

Net annual basal area increment rates were increased strongly by the silvicultural treatment (Table 9.1, Figure 9.1). If this increment rate would be sustained the initial basal area would be restored in only 10 years and a cutting cycle of only 14 years would be suggested with a logging intensity of 8 trees/ha (20 $m^3.ha^{-1}$) followed by silvicultural treatment. The sustainable annual allowable cut would then be around 1.45 $m^3.ha^{-1}.y^{-1}$, which is more than double than without silvicultural treatment. It is not likely that this increased volume increment rate will be sustained, but it is clear that the cutting cycle can be reduced substantially.

Greenheart did not show the kind of reaction that the other commercial species did and the net annual volume increment for Greenheart hardly differed from the same logging treatment without silvicultural intervention. It is perceivable that Greenheart reacts slower to the treatment in the light of its general lower growth rate.

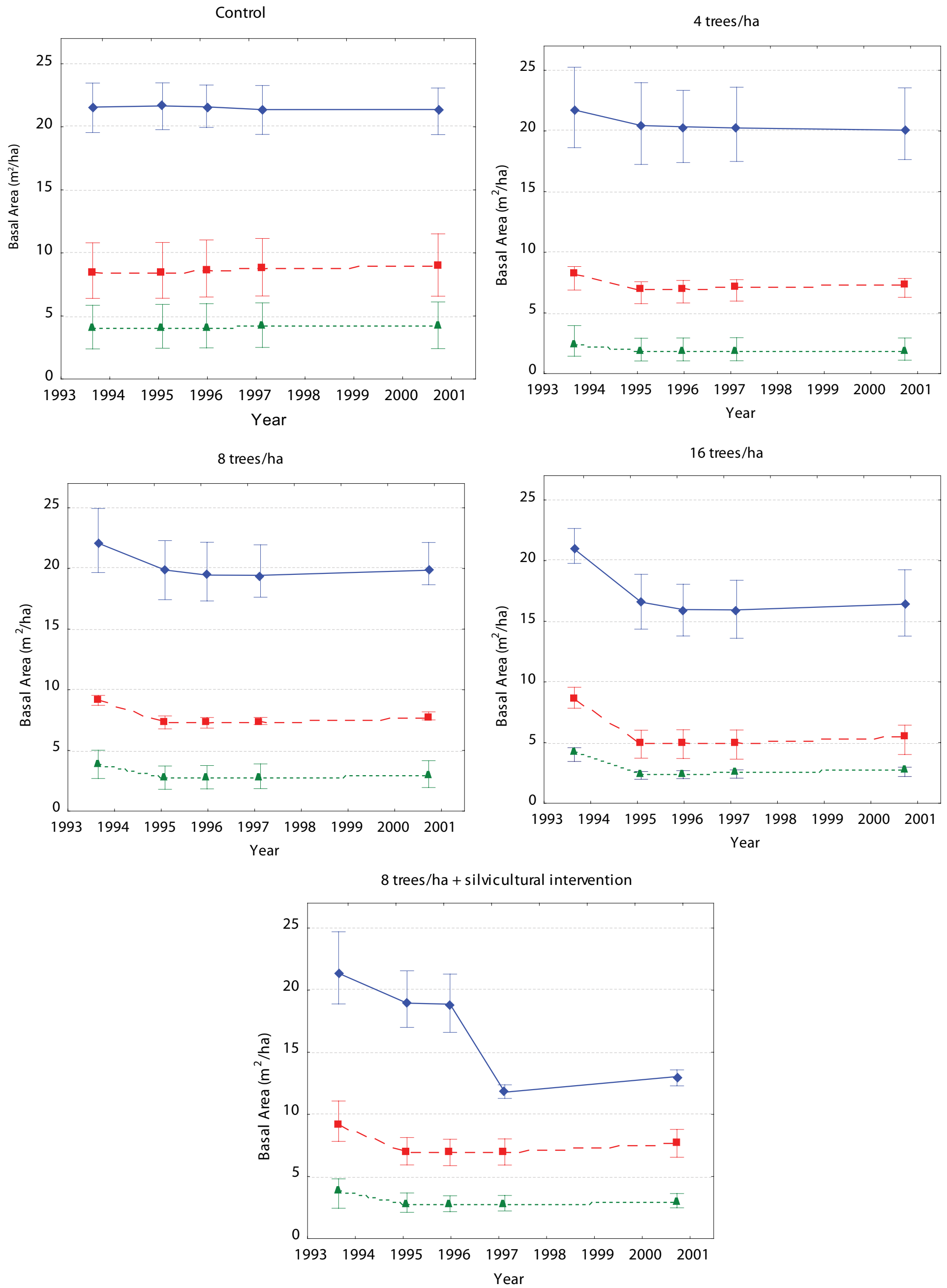


Figure 9.1. Development of net basal area of trees with a diameter ≥ 20 cm DBH for five different treatments: all trees of all species blue diamonds and blue solid line, commercial and potentially commercial trees with good or acceptable stem quality red squares and red broken line and Greenheart (*Chlorocardium rodiei*) with good or acceptable stem quality green triangles and green dotted line. Basal areas are means of three plots; whiskers denote the spread in the plot values.

Based on this study a number of conclusions were drawn:

- Felling damage, in terms of the number and size of logging gaps or the number of injured or killed residual trees, is foremost determined by the logging intensity, and subsequently by the felling pattern, the spacing between felled trees and the felling method;
- Logging intensity should be limited to 8 trees/ha to avoid excessive logging gap sizes;
- Implementation of RIL reduced the disturbed ground area by two-thirds compared to conventional logging;
- Implementation of RIL was cost-neutral compared to conventional logging;
- Systematic elimination of undesirable trees down to 20 cm dbh is not more effective in improving the illumination of future crop trees than a treatment within a fixed radius of 10 m around future crop trees;
- Silvicultural treatments that are based on a systematic elimination of undesirable trees above a certain diameter limit are wasteful because more trees are eliminated than necessary;
- Preliminary results from the monitoring of the experimental plots suggests an optimum logging intensity of 7 trees per hectare with a logging cycle of 25 years and a maximum logging intensity of 3 Greenheart trees per hectare;
- Preliminary results suggest that the currently prescribed annual allowable cut of 0.33 $m^3.ha^{-1}.y^{-1}$ could be increased;
- Silvicultural treatment showed a strong positive reaction in the first four years after treatment, increasing the net annual volume increment of commercial species (sound trees only) from 0.65 to 1.45 $m^3.ha^{-1}.y^{-1}$;
- In the light of these preliminary results it is strongly recommended to remeasure the experimental plots to verify these preliminary results.

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