Resource Assessment and Forest Management Plan for the CITES-Listed Species *Cedrela Odorata* (red cedar) In Guyana

Final Draft

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Executive Summary

Background to the report

This report provides an overview of the population size, distribution, stand density, size structure, regeneration dynamics and possible strategy for the sustainable management of the timber species *Cedrela odorata* L. in Guyana. In Guyana the species is known under the common name red cedar.

Cedrela odorata is deciduous, strongly light-demanding, behaves as a long-lived pioneer (Cintron, 1990; Lemmens, 2008) and is naturally distributed from northern Mexico throughout lowland Central America and South America to northern Argentina and most Caribbean Islands (Lamb, 1968; Pennington, 1981; Cintron, 1990). In its natural area of distribution *Cedrela odorata* occurs in both primary and secondary, evergreen to semi-deciduous lowland or lower montane rain forest (Pennington, 1981; Patiño, 1997). In Central America and Mexico it only occurs on non-flooded sites, often on well-drained limestone (Cintron, 1990; Lamb, 1968). In Amazonian Peru Bolivia and Brazil, it is mainly found on seasonally flooded lowland along watercourses (Gentry, no date; Pennington, 2006, cited in CITES, 2007) and in the transitional zone between evergreen forest and savannah forest (*cf* Brown et al, 2003). In Guyana, the species is rare to locally occasional in *Mora* forest along creeks, seasonal forest and poor types of rain forest (Fanshawe 1961).

Although *C. odorata* is widespread, it is seldom common - individuals of this species are few in number and are widely dispersed. The high value of the species, the decrease in the supply of other timber species (e.g. *Swietenia macrophylla* King), and the vulnerability of *C. odorata* to overharvesting due to its natural history, population dynamics, and habitat preferences have contributed to growing signs of depletion in many parts of its range (Navarro-Cerrillo, 2013).

In 1998 *Cedrela odorata* was assessed as globally Vulnerable in the IUCN Red List and it has been listed in Appendix III of CITES since 2001. The species was subsequently proposed for listing in Appendix II of CITES in 2007. Appendix II listing requires non-detriment findings (NDF) that ensure that export will not be detrimental to the survival of the species being traded. NDFs should be based on a comprehensive review of available information on the population status, distribution, population trend, harvest, and other biological and ecological factors, as appropriate, and trade information relating to the species concerned. Because such information was lacking for nearly all range states, an Action Plan was adopted to complete knowledge on the status of conservation of, trade in and sustainable use of *Cedrela odorata.*

This report aims to complete and update the available information on *Cedrela odorata* in Guyana, using a variety of existing, available information sources on the distribution, population structure and production. The main sources of information are formed by national forest inventories and forest inventories and stock surveys carried out by forest concessionaires. Another source of information is formed by production records.

Geographic distribution within Guyana

The FAO-supported Forest Industry Development Survey (FIDS) was undertaken as a national inventory during 1969-73. As part the FAO-FIDS reconnaissance surveys, detailed forest type maps were prepared using aerial photography interpretation (De Milde & De Groot, 1970a-e and g). In 2001, a vegetation map of Guyana was produced by Hans ter Steege (Ter Steege, 2001a), developed from a variety of sources including satellite imagery, a digital elevation model, soil maps, research plots and the FAO-FIDS forest inventory plots. The CIDA-financed Interim Forestry Project (IFP) was undertaken during 1990-95. During 2000-2002 the Guyana Forestry Commission developed its own inventory methodology, which was subsequently recommended for State Forest Exploratory Permits (SFEPs) and companies conducting management level inventories (MLI) for their long-term forest management plans. From 2006 onwards, GFC has conducted such MLIs itself to obtain information on the stocking of State Forest Permission areas targeted to guide decisions on their (re)allocation.

Red cedar was only very occasionally encountered during the abovementioned forest inventory programmes. Only 15 trees showed up in 13 out of 4,609 MLI sample plots; 5 trees in 5 out of 1,016 FAO-FIDs plots; and 6 trees in 6 out of 7,992 IFP sample points.

Large forest concession [Timber Sales Agreements (TSAs)] holders are required to conduct a systematic 100% pre-harvest inventory (stock survey) covering their annual operating area. Such stock surveys over the period 2010-2014 were assessed for occurrence of red cedar. The species was encountered in 11 out of the 23 active TSAs. In total, 393 red cedar trees were found in 224 out of 2728 blocks that were surveyed.

In Guyana, red cedar occurs widely from the North West to the South East of the country. Occurrence was confirmed for about three quarters of Guyana's territory according to the national forest inventories, stock surveys and production records. Its potential geographic distribution covers nearly the entire country with the exception of the coastal lowlands, the Rupununi and other savannahs and the Pakaraima mountain region based on the geographic distribution of the forest types in which it appears to occur.

Site preference and local distribution

The species does not appear to have a specific preference for a certain forest or soil type; it is reported to occur on many soil types from pegasse, to clay, to brown sand and white sand and in many forest types such as swamp forest, mixed forest on flat to undulating, undulating to hilly, deeply dissected terrain and steep high hills, and in wallaba forest on white sand soils.

Forest and soil typing of the inventory plots may have been based on the general area and small-scale ecotope differences, e.g. along small creeks and seasonal streams, may have been overlooked when assessing the plot characteristics. The same applies to forest typing based on the FAO-FIDS regional forest type map and the national vegetation map, which typing is rather course and ignores small-scale ecotope differences.

Local distribution of red cedar was examined by plotting 249 red cedar trees, enumerated in 142 pre-harvest inventory blocks in the Barama Co. Ltd. concession, on 1:50,000 scale topographic map sheets. It appeared that the local distribution of the species commonly traces creeks and that 52% of the 249 enumerated red cedar trees were located in flood plains, 42% of the trees located within 100 m distance of a creek and 22% within 50 m distance. It was further revealed that 52% of the 249 enumerated red cedar trees were located in floodplains and that 47% of the trees were encountered in mixed Forest, 42% in *mora* Forest, 9% in *wallaba* Forest and 2% in *greenheart* Forest.

The depiction of watercourses on the 1:50,000 map sheets are based on aerial photo interpretation and forms an approximation of their true course, while small creeks are usually not depicted. Creeks, small streams and gullies are normally mapped during the stock survey exercise and 23 such detailed stock maps were available. In these 23 blocks, 35 red cedar trees had been enumerated, out of which trees 20% were located within 10 m distance of a creek and 51% within 10 m distance of a gully or seasonal stream. Another 12% was located within 20 m distance of a creek.

At a local scale, the species thus appears to occur mainly in mixed and *mora* forest along watercourses; particularly gullies and seasonal streams, but also larger creeks. It is estimated that 20% of the trees are within a 10 m distance of a creek and another 10% within a 20 m distance, while 63% grow within 20 m of a gully or seasonal stream. This has crucial implications for the management of the species because trees may not be harvested within riparian buffer zones along creeks according to Guyana's Code of practice (2014) and hence an estimated 20% of the red cedar population is apparently excluded from harvesting.

Rarity of red cedar in Guyana

Red cedar appears to be rare in Guyana (< 1 tree/ha), and according to the studied stock surveys the species is even very rare (< 1 tree per 100 ha). According to the three national forest inventories, the estimated average density of red cedar ≥ 10 cm dbh ranges from 1.7 trees per 100 ha (FAO-FIDS) to 8.5 trees per 100 ha (MLI). The estimated density of trees ≥ 35 cm dbh is estimated to range from 0.9 trees per 100 ha (IFP) to 2.0 trees per 100 ha (MLI). Stock surveys conducted between 2010 and 2014 suggest an average of 1.7 trees per 100 ha (maximum 7 trees per 100 ha) in the blocks where the species was encountered.

The estimated volume of red cedar ≥ 35 cm dbh ranges from 2.4 m^3 per 100 ha (FAO-FIDS) to 6.0 m^3 per 100 ha (MLI) according to the national forest inventories. An average volume of 8.7 m^3 per 100-ha block (maximum of 37.8 m^3 per 100-ha block) was reported for the 246 blocks where red Cedar was encountered during 2010-14.

Occurrence of red cedar was only reported in 8% of the blocks that were surveyed during 2010-2014, but the fact that a species is not recorded in a certain concession does not necessarily mean that the species does not occur in that concession. Neither concessionaires nor their inventory teams appear to be familiar with the species. Not all concessionaires include the species on their species list for 100% pre-harvest inventory, while many inventory crews do not recognize the species. The latter was clearly indicated by a small verification exercise of seven blocks in five large concessions. In three concessions other species had been mistakenly identified as red cedar, while in four blocks in two other concessions, where three and twelve harvestable red cedar trees respectively were recorded during stock surveys, the species was correctly identified but the verification exercise also showed that two harvestable red cedar trees were overlooked during stock surveys in each concession.

The most reliable stock survey seems to be the one carried out by Barama Co. Ltd., where 249 red cedar trees were found in 142 out of the 1033 blocks (14%) that were surveyed over the period 2010-14; indicating a density of 0.24 tree per 100 ha. As the verification exercise showed that two trees had been overlooked in two blocks, the estimated density was adjusted upward to 0.30 trees ≥ 40 cm dbh per 100 ha. Application of a net form height factor of 12.61 yields an initial volume at first harvest (MCDL =40 cm dbh; Year 0) of 1.49 m^3 per 100 ha.

Size class structure

The diameter class frequency distributions vary between the inventories, but the size-class structures recorded in the three national forest inventories are all reverse-J-shaped, with more juveniles than adults indicating a favourable population structure for sustainable forest management. Clear depressions in the middle size classes and increasing densities again towards larger size classes are shown for all inventories. Such depressions could coincide with the size at which the trees reach their maximum growth rates, and may thus be caused by faster growth through these size classes followed by accumulation at larger size classes with lower growth rates. The size-class structure shown for the combined stock survey shows the opposite with fewer juveniles than adults and no depressions in the mid-size classes. This could be due to the minimum diameters that were stipulated for the stock surveys, which could be higher than 35 cm dbh in certain stock surveys.

Stand table projection

Current growth and yield data for red cedar in Guyana is limited to measurements of three trees in PSPs over the period 1993-1996. Therefore, it was decided to use time of passage and mortality data from Brienen & Zuidema (2006a, 2006b) from Bolivia. A simple stand table projection model was constructed based on Uniform Distribution, Mean Increment assumptions (Husch *et al*. 1982, Alder 1995), published increment and mortality data from Brienen & Zuidema (2006a) and applied to the pooled stock survey data.

Stand table projection of harvested stands with a minimum cutting diameter limit of 40 cm and progressive reduction in recruitment into the 10-19 cm class in proportion to the reduction in trees ≥ 20 cm diameter in each subsequent 5-year modelling interval shows that the volume taken at the first harvest cannot be sustained if all trees are allowed to be harvested. According to the pooled stock surveys the volume at first harvest would be 1.49 m^3 per 100 ha, which would decline to 0.38 m^3 per 100 ha at the second harvest (year 25) and eventually, to 0.17 m^3 per 100 ha at the fifth harvest (year 100). The strong reduction in volume after the first harvest is associated with the presence of large (dbh ≥ 70 cm) old-growth trees at the first harvest ('primary forest premium').

Effect of retention of buffer zone trees

Guyana's Code of Practice (2014) prescribes that trees may not be felled in streamside buffer zones. As shown above, an estimated 20% of the red cedar trees occur in such buffer zones and should therefore be excluded from harvesting. Retention of buffer zones trees results in a reduction of the allowable yield by 20%, but substantially improves the sustainability of the harvestable volume in future cutting cycles. At the first harvest the volume is estimated at 1.20 m^3/100-ha, reducing to 0.31 m^3/100-ha at the second harvest (year 25) and eventually to 0.16 m^3/ha at the fifth harvest (year 100). This harvesting regime does not result in truly sustained yields, but it forms a substantial improvement compared to the situation whereby all available stems may be harvested. Moreover, the retention of 20% of the red cedar trees in buffer zones guarantees that the current harvesting practice is not detrimental to the species' survival provided that felling restrictions are strictly enforced.

Effect of raising the minimum cutting diameter limit

The legal minimum cutting diameter limit (MCDL) for red cedar in Guyana is 34 cm dbh. From a silvicultural point of view, the optimum minimum cutting diameter would rather be close to 60 cm dbh, because the mean annual increment (MAI) rate of the species is reported peak after the tree has reached this size. If the MCDL is raised to 60 cm dbh sustained yield levels are being approached. At the first harvest the volume will be reduced to 0.94 m^3/100-ha (78% compared to a MCDL of 40 cm), but harvests will be higher at the second harvest (year 25); i.e. 0.52 m^3/100-ha (169%), and eventually 0.28 m^3/ha (176%) at the fifth harvest (year 100).

Effect of recruitment rate assumptions

Red cedar is strongly light-demanding, regenerates well in forest clearings, on abandoned agricultural plots and following disturbances such as forest fires and hurricanes and is therefore regarded as a 'long-lived' pioneer. It is thus plausible that recruitment does not decrease after removing parent trees at each harvest. Stand table projection assuming that recruitment rates remain constant suggests that sustained yields can be achieved within two 25-year cutting cycles. In point of fact recruitment rates will lie somewhere between a constant rate and a proportionately decreasing rate. Sustained yield levels in a 25-year cutting cycle, as determined by the yield after the third cutting cycle when the modelled stand structure stabilizes, would therefore lie somewhere between 0.24 and 0.31 m^3 per 100 hectare in case of a MCDL of 40 cm dbh and between 0.36 and 0.43 m^3 per 100 hectare in case of a MCDL of 60 cm dbh.

Allowable red cedar yield

Based on the observation that the species occurs in all forest types along watercourses; particularly along gullies and seasonal streams it can safely be assumed that the species occurs in all forest concessions. The annual coupe of all large concessions (TSAs and WCLs) amounts to roughly 140,000 ha and the long-term annual sustained yield for these concessions would lie between 350 and 450 m^3 per year. Raising the MCDL to the silviculturally desirable 60 cm dbh would result in a long-term sustained yield between 500 and 600 m^3 per year.

Small concessions (SFPs) are managed per log quota and not per an annual coupe. For the purpose of assessing sustained yield levels, the annual coupe for small concessions is estimated at roughly 64,000 ha in lieu of log quota. Under the current forest management regulations with a practical MCDL of 40 cm and prohibiting harvesting in riparian buffer zones, long-term annual sustained yield for small concessions would lie somewhere between 150 and 200 m^3 per year. Raising the MCDL to the silviculturally desirable 60 cm dbh would result in a long-term annual sustained yield of between 250 and 300 m^3 per year.

Produce stemming from Amerindian Reservations and Private Properties is not subject to maximum cut restrictions because these lands do not form part of the State Forest Estate and are not managed by the GFC, but sustained yield for the Amerindian reservations is estimated at 200-250 m^3 per year.

The total area of available productive forest - both allocated State Forest and Amerindian reservations - is roughly 9.0 million hectares. Applying a 25 year cutting cycle would produce a theoretic national annual coupe of 288,000 hectares. Under the current forest management regulations with a practical MCDL of 40 cm and prohibiting harvesting in riparian buffer zones for

State Forest and assuming similar practices in Amerindian reservations, long-term annual sustained yield would lie between 700 and 900 m^3 per year. Raising the MCDL to the silviculturally desirable 60 cm dbh would result in a long-term annual sustained yield between 1,050 and 1,250 m^3 per year.

Production levels in comparison with allowable yield

Over the period 2007-14, red cedar production amounted to 641 m^3 per year on average and is thus 92% of the lower estimate of the sustained yield of 700 m^3 per year and 71% of the higher estimate of the sustained yield of 900 m^3 per year. Red cedar is principally sourced from small concessions where harvests are three times the lower sustained yield estimate and 2.5 times the higher estimate. Large concessions harvest only 12-16% of their sustained yield, while production from Amerindian Village Lands does not exceed 34-43% of the sustained yield. Sustainable management of red cedar hence does not appear to be threatened under current forest regulations and harvesting practice in large concessions and Amerindian reservations, but is possibly being overharvested in small concessions. There appears to be scope for intensification of production from large concessions.

Conclusions

- Although red cedar is very rare in Guyana, current harvesting regimes (and export levels) do not appear to be detrimental to the survival of the species, because a considerable proportion of the population (20%) occurs along streamside buffer zones, where logging is prohibited in Guyana, and trees are protected. Secondly, harvest levels, about 640 m^3 per year on average, are below the estimated national sustained yield level, which lies close to 800 m^3 per year.
- Under the current forest management regulations and harvesting practice there appear to be no clear grounds for including Guyana's red cedar population in CITES Appendix III.
- Production of red cedar from large concessions is low and there appears to be an opportunity to expand production from these concessions. This is likely related to poor knowledge of the species among concessionaires and inventory teams. Large concessionaires do not seek specialty markets for red cedar but are reported to sell the species as mixed hardwood; i.e. below its intrinsic value. Better promotion of possibly attractive markets for the species and training of inventory teams in identification of the species are recommended.
- Finally, red cedar is reported to attain maximum diameter increment rates through the diameter class 40-60 cm dbh. Sustainable yield levels can therefore be increased by raising the minimum cutting diameter limit (MCDL) to 60 cm dbh; long-term annual sustained yield is currently estimated to lie close to 800 m3 per year with a MCDL of 40 cm, while with a MCDL of 60 cm dbh a long-term sustained yield of around 1,150 m3 per year seems achievable.

Contents

List of Abbreviations

AVL	- Amerindian Village (& Community) Land
BAF	- Basal Area Factor (in point sampling)
CIDA	- Canadian International Development Agency
CITES	- Convention on International Trade in Endangered Species of Wild Fauna and Flora
DBH	- Diameter at breast height (1.3 m)
DFID	- Department for International Development (UK)
FAO	- Food and Agriculture Organisation of the United Nations
FIDS	- Forest Industry Development Survey (1969-1973)
GEMFORM	- Guyana Empirical Model for Forest Management
GFC	- Guyana Forestry Commission
GIS	- Geographic Information System
IFP	- Interim Forestry Project (1990-94)
ITTO	- International Tropical Timber Organization
IUCN	- International Union for Conservation of Nature
MCDL	- Minimum Cutting Diameter Limit
MIS	- Management Information System
MLI	- Management Level Inventory
MYRLIN	- Methods of Yield Regulation with Limited Information.
NDF	- Non Detriment Finding
NWD	- North West District
PSP	- Permanent Sample Plot
SFEP	- State Forest Exploratory Permit
SFP	- State Forest Permission
SLA	- Small Loggers' Association
SUA	- Sustainable Use Area
TSA	- Timber Sales Agreement
UNEP-WCMC	- United Nations Environment Programme's World Conservation Monitoring Centre
WCL	- Wood cutting lease

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1 Introduction

1.1 Terms of Reference

The consultant was contracted to work with GFC to enhance the sustainable management and commercial utilisation of the CITES-listed species *Cedrela odorata* (red cedar) in Guyana, a small project within the ITTO thematic programme on trade and market transparency (TMT). The ITTO thematic programme on trade and market transparency supports among others the ITTO-CITES programme. The project number of this small project is TMT-SPD 014/13 Rev.1 (M).

The Terms of Reference for this work can be summarized as involving the following objectives:

1. Produce a resource assessment and forest management plan for red cedar
2. A reporting framework for CITES timber exports
3. Support capacity building on CITES and its implication for the forest sector in Guyana

The first objective concerns:

a) the design and execution of a resource assessment for red cedar in Guyana; and
b) developing a forest management plan for red cedar

The second objective concerns:

a) developing a protocol framework for international trade of red cedar;
b) developing markets for red cedar locally and internationally; and
c) compiling market information and trade statistics on red cedar.

The third objective concerns:

a) supporting the Training Consultant in developing and executing a stakeholder awareness programme and a training programme on CITES and its implication for the forest sector in Guyana;
b) assist the GFC in consolidating information on timber utilization; and
c) supporting interactions between local partners and international contacts at level of US, EU and CITES.

This report is the consultant's first delivery within the framework of a project by the Guyana Forestry Commission to enhance the sustainable management and commercial utilisation of the CITES-listed species *Cedrela odorata* (red cedar) in Guyana.

1.2 Background

The ITTO-CITES programme provides specific assistance to countries throughout the tropics to design forest management plans, forest inventories, provide guidelines and case studies for making "Non Detriment Findings" (NDFs) for CITES listed tree species, and to develop and disseminate tools for timber identification with the overall objective to ensure that international trade in CITES-listed timber species is consistent with their sustainable management and conservation[1].

This report provides an overview of the population size, distribution, stand density, size structure, regeneration dynamics and possible strategies for the sustainable management of the timber species *Cedrela odorata* in Guyana. The species is listed in CITES Appendix III. In Guyana the species is known under the common name red cedar. Red cedar produces a commodity timber traditionally traded in high volumes, but only small volumes are traded internationally from Guyana.

1.3 Red cedar

Cedrela odorata L. is a tropical timber species, which has been harvested for its timber for over 500 years in Central and South America (Navarro-Cerrillo, 2013). As the second most valuable tropical timber in the neotropics, *C. odorata* (international trade name: cedro or Spanish cedar) is threatened by over-exploitation and deforestation throughout much of its range. The species is widely distributed from Mexico and the Caribbean to northern Argentina. It is common in seasonally dry, semi-deciduous forests but less common in evergreen forest types (Cintron 1990; Lamb 1968), where it is mainly found on seasonally flooded lowland along watercourses (Gentry, no date; Pennington, 2006) and in the transitional zone between evergreen forest and savannah forest (*cf* Brown et al, 2003). In Guyana, the species is rare to locally occasional in *mora* forest along creeks, seasonal forest and poor types of rain forest (Fanshawe 1961). According to Hohenkerk (1923), the species was very scattered in the easily accessible forests already in the early 20th century, except in the North West District and locally in the Rupununi District where it was more abundant.

Cedrela odorata is deciduous; strongly light-demanding, behaves as a long-lived pioneer (Cintron, 1990; Lemmens, 2008), and is often associated with other Meliaceae (*Swietenia* and *Guarea* sp.) and leguminous trees (Pennington, 1981).

Since the 1990s the volume of trade in *Cedrela odorata* has increased, particularly in Mexico, Peru, Bolivia, and Brazil. World-wide, the direct trade in *C. odorata* timber peaked at a global annual volume of 55,719 m^3 in 2002 and 61,378 m^3 in 2007 (UNEP-WCMC, CITES Trade Database[2]), although a decline has set in since 2009 resulting in an average annual volume of 10,344 m^3 being traded during 2010-13. The high value of these species, the decrease in the supply of other timber species (e.g. *Swietenia macrophylla* King), and the vulnerability of *C. odorata* to overharvesting due to its natural history, population dynamics, and habitat preferences have contributed to growing signs of depletion in many parts of its range (Navarro-Cerrillo, 2013).

Logging of red cedar in Guyana has taken place since the 19th century (Institute of Mines and Forests of British Guiana, 1903), but has always accounted for a small fraction of the timber production; e.g., during 1955-61 the annual production amounted to less 250 m^3 per year on average (Flemmich, 1963). Exploitation of red cedar in Guyana has not changed much since, because during 2006-2014 the production was still only 280 m^3 per year on average (Guyana Forestry Commission production data). Most of this production was intended for export; sawn wood and log exports averaged 245 m^3 per year over the same period. Guyana's role in the *Cedrela odorata* trade thus appears to be quite

[1] http://www.itto.int/cites_programme/
[2] http://trade.cites.org/#

limited compared to a reported global average of approximately 24,000 m^3/yr. over the same period.

1.4 International conservation community concerns

In 1998 *Cedrela odorata* was assessed as globally Vulnerable in the IUCN Red List although this assessment needs updating[3]. The species has been listed in Appendix III of CITES since 2001. CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments that was conceived in 1973 to safeguard certain species from over-exploitation by regulating international trade in specimens of wild animals and plants whose survival is possibly threatened. Initially, commercial timber species were poorly represented in the CITES Appendices; restricted to e.g. *Caryocar costaricense* (ajo or costus) and *Swietenia humilis* (Pacific Coast mahogany) in 1975; *Swietenia mahagoni* (West-Indian mahogany) and *Pericopsis elata* (afrormosia) in 1992; and *Pterocarpus santalinus* (red sandalwood), *Swietenia macrophylla* (big-leaf mahogany) and *Prunus africana* (African cherry) in 1995. However, since the late 1990s there has been an increased focus on timber.

In 1998, the CITES Management Authority of the Netherlands published a document titled *Contribution to an evaluation of tree species using the new CITES listing criteria*. This comprehensive study, compiled by UNEP-WCMC, reviewed the conservation and trade status of 255 tree species that were viewed as globally threatened as a result of population decline through exploitation. Subsequently, a number of regional workshops on tree conservation were undertaken between 2004 and 2006. On the basis of recommendations from the Mesoamerican workshop (Gillett and Ferriss 2005), the CITES Plants Committee agreed to consider reviewing the listing of three species; i.e., *Cedrela odorata, Dalbergia retusa* and *Dalbergia stevensonii.* The species were subsequently proposed for listing in Appendix II of CITES by Germany at the 14th CoP meeting in 2007, based on a report by the CITES Management Authority of the Netherlands, in collaboration with UNEP-WCMC (CITES, 2007)[4].

Appendix II requires that an export permit shall only be granted when a scientific authority of the range State has issued a non-detriment finding (NDF) that ensures that such export will not be detrimental to the survival of the species being traded. An NDF should be based on the comprehensive review of available information on the population status, distribution, population trend, harvest, and other biological and ecological factors, as appropriate, and trade information relating to the species concerned. Because such information was lacking for nearly all range states, an Action Plan was adopted to complete knowledge on the conservation status of, trade in and sustainable use of *Cedrela odorata, Dalbergia retusa, Dalbergia granadillo* and *Dalbergia stevensonii.*

The 2007 proposal to list *Cedrela odorata* in CITES Appendix II was unanimously opposed by all 30 CITES Range States and subsequently withdrawn in 2013. However, the action plan to collect trade and conservation status data on the species was maintained and updated; range states are now urged to consider the inclusion, if necessary, of their populations of *Cedrela odorata* in Appendix III

[3] IUCN (2014), '*Cedrela odorata*', in the IUCN Red List of Threatened Species, Version 2014.3; assessor: Americas Regional Workshop (Conservation & Sustainable Management of Trees, Costa Rica, November 1996); date assessed: 1998; iucnredlist.org
[4] http://cites.org/sites/default/files/eng/cop/14/prop/E14-P33.pdf

and ensure the implementation and enforcement of CITES with regard to those species in that Appendix.

The implementation of the Action plan for the four species appeared to be quite onerous for range States and CITES approached ITTO to support future work on *Cedrela odorata* and other threatened timber species. A substantial number of projects related to the ecology, distribution, supply and strategies for the sustainable management of CITES listed species have been initiated since 2008 with support by the *ITTO-CITES programme for implementing CITES listings of tropical timber species*. The main species covered to date are *Pericopsis elata* (afrormosia or assamela), *Prunus africana* (African cherry) and *Diospyros* spp. (ebony) of Central Africa and Madagascar; *Swietenia macrophylla* (big-leaf mahogany), *Cedrela odorata* and other *Cedrela* spp. (cedro or Spanish cedar) in Latin America; as well as *Dalbergia* spp. (rosewood) in both Africa and Latin America; *Gonystylus* spp. (ramin) and *Aquilaria* spp./*Gyrinops* spp. (agarwood) in Southeast Asia.

During Phase I of the project activities were undertaken in the neotropics in Bolivia, Brazil, and Peru; in Central Africa in Cameroon, the Democratic Republic of Congo, and the Republic of Congo; and in Southeast Asia in Indonesia and Malaysia. Following up on the successful first phase of the program (2007-2011), a second phase continued work for four more years (2012-2015) entitled *ITTO-CITES Implementation for Tree Species and Trade/Market Transparency (TMT)*. Phase II continued the work of ITTO and CITES in helping target countries to ensure that trade in selected CITES-listed tree species is legal, sustainable and traceable. Activities continued in the countries that had received assistance during Phase I, and additional activities were initiated in those countries and also in Ghana, Madagascar and Guyana in Phase II.

1.5 Outline of the report

The first section describes the information sources and methodology that are used to assess the population size, distribution, stand density, size structure, and regeneration dynamics of red cedar in Guyana.

The second section of the report provides a description of the species *Cedrela odorata*, including taxonomy, botanical description, natural history and population dynamics, wood properties, technological characteristics, uses, habitat and population trends, threats and international trade.

The third section provides an overview of CITES, including the CITES Appendices, CITES export permit requirements, Non Detriment findings, Trade records, Inconsistent implementation of Appendix-III timber listings and the current listing of *Cedrela odorata*.

The fourth section describes the current and potential geographic distribution of red cedar, based on a variety of georeferenced inventory information, forest concession allocation maps and regional and national vegetation maps.

The fifth section will analyse the density, size class frequency distribution and volumes

The sixth and final section will assess regeneration dynamics and sustainable harvest levels and evaluate if current harvest levels exceed sustainable harvest levels or not and whether species-specific management of red cedar will be required and whether Appendix III listing of Guyana's red cedar population is warranted or not.

2 Methodology

2.1 Information sources

This report aims to complete and update the available information on *Cedrela odorata* using a variety of existing, available information sources on the distribution, population structure and production. Preliminary exploration of the available information and discussions with stakeholders in Guyana revealed that red cedar is considered to be extremely rare; being estimated at less than 1 tree per 50 ha. Because of the low density of its occurrence and uncertainty about site preferences, it was decided to explore existing resource assessment data and verify habitat preferences based on an analysis of existing information. It was not deemed opportune at this time to conduct any actual forest inventories because of the rarity of the species in Guyana.

The main sources of information are formed by national forest inventories and forest inventories and stock surveys carried out by forest concessionaires. Another source of information is formed by production records. Guyana's log tracking system requires that each harvested tree is measured and tagged. These tag numbers with measurements of each tree are reported on removal permits and associated production registers. This reporting system makes it possible to trace back the origin of the logs; in case of large concessions, so-called Timber Sales Agreements (TSAs), to the respective 100-ha harvest block, and in case of small concessions, so-called State Forest Permissions (SFPs), to the concession as a whole.

Two major inventories have been converted into Access databases; the FAO-supported Forest Industry Development Survey (FIDS) and the Canadian CIDA-financed Interim Forestry Project (IFP). The FAO-FIDS was undertaken as a national inventory, with most field work from 1969-73 and the CIDA-IFP, more or less restricted to Central Guyana, during 1990-94.

Large forest concessions are required to conduct a systematic 100% pre-harvest inventory (stock survey) covering their annual operating area and are obliged to provide this information to the Guyana Forestry Commission (GFC). Small forest concessions are not required to conduct forest inventories, but the GFC conducted systematic reconnaissance inventories in a substantial number of these small concessions. These so-called management level inventories (MLI) use systematically placed circular line plots with lines generally set 1 km apart and sample plots 200 m apart. Sample plots consist of a 0.1 ha circular main plot, where trees of all species ≥ 30 cm dbh are enumerated, and a 0.02 ha nested subplot, where trees of all species between 10 cm and 30 cm dbh are enumerated. Similar sampling-based inventories have been conducted by a number of large concessions for the preparation of long-term forest management plans and by the Iwokrama International Centre for Rainforest Conservation and Development of the Iwokrama Forest.

A sample of pre-harvest inventory blocks where red cedar was recorded were verified; 5 blocks in April 2015 and two blocks in August 2015. In total seven blocks were thus verified, two in the Barama Co. Ltd. concession and two in the Vaitarna Holding Private Inc. concession both in the Essequibo district and one block each in the W.A.I.C.O., Variety Woods & Greenheart Ltd. and Haiomarakabra concessions in the Demerara and Berbice districts. During this exercise a 10% strip sample was conducted to assess the density of sub-adult red cedar trees with a diameter less than 40 cm (dbh) and a 5% strip sample of trees between 10 and 20 cm dbh.

2.2 Geographic distribution

Plots of the national inventories and management level inventories have been georeferenced, while spatial locations of the 100-ha logging blocks are known as well. This allows mapping of the geographic distribution of red cedar in Guyana. Production records can be traced back to the origin of the harvested trees and locations can be mapped either at the level of 100-ha logging blocks in case of TSAs or at the level of the entire concession in case of SFPs.

A vegetation map of Guyana was produced in 2001 by Hans ter Steege (ter Steege, 2001a) developed from a variety of sources including satellite imagery, soil maps, research plots and the FAO-FIDS forest inventory plots. GIS shape-files of the national and regional vegetation map were made available to the consultant. By overlaying vegetation and plot location maps it can be determined in which vegetation type red cedar is likely to occur and the potential distribution can be estimated by extrapolation. Once the current and potential distribution is defined, densities and population structures can be assigned to the different vegetation types based on their precise spatial locations within regional and national vegetation maps.

For cases where there is no specific spatial information, but where origin of produce can be traced back to the concession level, the base layer for the forest concession allocations is used. red cedar is also harvested in Amerindian Lands, which are managed by the Amerindian Village Councils and not by the GFC. Produce from these so-called private properties can however be traced back just as in case of concessions. A layer with the spatial locations of Amerindian Lands will be overlaid on the vegetation map as well.

2.3 Density and size class frequency distribution

Size class frequency distributions can be derived from the national and MLI inventories down to a diameter at breast height of 10 cm. Commercial stock surveys usually consider trees from the legal minimum cutting diameter of 35 cm DBH or higher and are not really suited to assess regeneration dynamics. A 10% strip sample was conducted in two blocks within the Barama Co. Ltd. concession where adult red cedar trees had been recorded to assess the density of sub-adult red cedar trees between 20 cm and 40 cm dbh and a 5% strip sample of trees between 10 and 20 cm dbh.

2.4 Sustainability of current management practices

The current allowable cut and minimum diameter cut regulations in Guyana are not species-specific with a minimum cutting diameter limit of 35 cm DBH, an allowable cut of 20 m^3/ha and a cutting cycle of 60 years or pro-rated for shorter cutting cycles; e.g. 8.33 m^3/ha when a 25-year cutting cycle is applied instead. A growth and yield model, GEMFORM, is available for Guyana which allows sustainable harvest projections by varying parameters such as minimum cutting diameter, cutting cycle length, etc. (Alder, 2000, 2001, 2008)

3 Overview of CITES

3.1 The CITES convention

CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments and is currently signed by 180 countries. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Because the trade in wild animals and plants crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation. CITES was conceived in the spirit of such cooperation. States that have voluntarily joined CITES and agreed to be bound by the convention are known as Parties. Although CITES is legally binding on the parties, it does not replace national laws. Rather, it provides a framework to be respected by each party, which must adopt its own (domestic) legislation to ensure that CITES is implemented at the national level.

3.2 The CITES Appendices

Roughly 5,600 species of animals and 30,000 species of plants are protected by CITES against over-exploitation through international trade. They are listed in three CITES Appendices[5] according to how threatened they are by international trade. Appendix I lists species currently threatened with extinction; trade in specimens of these species is permitted only in exceptional circumstances and requires an export and import permit. Appendix II lists species not necessarily threatened with extinction in the immediate term but in which trade must be controlled in order to avoid 'utilization incompatible with their survival'[6]. Appendix III lists species that are protected in at least one country that has asked other CITES parties for assistance in controlling trade in those species[7]. Some of the listings are limited in scope to certain products. These limitations are set out in an annotation; the listing of e.g. *Cedrela odorata* in Appendix III is restricted to logs, sawn wood, and veneer sheets.

Proposals to list a species in CITES can only be made by a Party to CITES. Almost all countries are Parties. For Appendix III, the Party must be a range state and the proposal must be sent to the CITES Secretariat. Proposals for Appendix II can only be approved at a Conference of the Parties (which should take place every two years) and only if two thirds of the Parties present and voting agree.

3.3 CITES export permits

All trade in the species listed in Appendix I of the Convention must be accompanied by a CITES export permit issued by the exporting country and a CITES import permit issued by the importing country. Species in Appendix II must be accompanied by an appropriate CITES export permit issued by the exporting country before entry to the importing country will be allowed. For Appendix III-listed species, an export permit is required for trade from a country that has listed its populations in the Convention. A certificate of origin or a re-export certificate is required for exports from any other country.

[5] See Article II of the convention at http://www.cites.org/sites/default/files/eng/disc/E-Text.pdf.
[6] See Article II 2(a) of the convention.
[7] See Articles II.3 and V of the convention.

3.4 Non-Detriment Finding

Export permits for specimens of Appendix II-listed species must be based on a scientific non-detriment finding (NDF) and, notably, a legal acquisition finding. For timber species, NDF mean that successful implementation will require descriptive knowledge of the species resource base; where it occurs, how much is there, and its ecological role. NDF further require understanding of management practices necessary to promote growth and regeneration toward future harvests and a technical capacity to implement those practices. The mandate for legal supplies means that implementation will require regulatory and enforcement capacity adequate to the task of ensuring compliance with forest legislation; the ability to track legal supplies to separate these from illegal harvests; and clear protocols for handling harvests destined for domestic markets.

Export permits for specimens of Appendix III-listed species (required where the state of export listed the species) need only legal acquisition findings, while certificates of origin require neither NDFs nor legal acquisition findings since those documents only identify the country of export as the country from which the specimen originated. They are not required to include sub-national 'origin' (such as concession of harvest).

3.5 Trade records

Parties must record all trade in listed species and report it annually to the CITES Secretariat. This information is made public through the online CITES trade database, managed by the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). In addition, the parties must designate at least one Management Authority responsible for licensing and at least one Scientific Authority responsible for assessing the effects of proposed and actual trade on the status of the species. In order to authorize the export of a specimen of a CITES-listed species, a national Management Authority must be satisfied that the specimen has been 'legally acquired' and, in the case of species listed in Appendices I and II, that the relevant national Scientific Authority has advised that the proposed export will not be detrimental to the survival of the species.

3.6 Timber species

Initially, commercial timber species were poorly represented in the CITES Appendices; however, in recent years there has been an increased focus on timber. The most recent CITES Conference of the Parties (CoP16), which took place in March 2013, voted to list a number of tropical hardwood species in Appendix II of the convention, including Malagasy ebony (*Diospyros* spp.) and various Rosewood species (*Dalbergia* spp.) from Madagascar, Central and South America and Thailand. Other tropical timber species already listed in CITES include Mahogany or *Swietenia macrophylla*, Ramin or *Gonystylus* spp., Afrormosia or *Pericopsis elata* (all Appendix II) and red cedar or *Cedrela odorata* (Appendix III).

3.7 Inconsistent implementation of Appendix-III timber listings

At its 15th meeting (CoP15, Doha, 2010), the Conference of the Parties discussed the problem of inconsistent implementation of Appendix-III timber listings where only specified national populations are included. It was noted that such listings can cause enforcement problems because, if one population of a species is included in Appendix III and all others are excluded, it is difficult to distinguish specimens that require a CITES permit or certificate from specimens that require none.

In cases where a whole species is included in Appendix III and national populations are also included, the permit requirements vary depending on the country of export. There appears to be a continuing problem of differing interpretations by Parties of the permit requirements for specimens of species, and populations, in Appendix III. These differences have resulted in delays in shipments and in some cases in shipments having to be returned to the country of export.

In the case of *C. odorata*, the whole species is included in Appendix III and one or more Parties have also included their national populations of the species. When a Party includes a whole species in Appendix III, this means that all populations everywhere in the world are included. If other Parties also include their national populations, this changes the permit requirements for export from those States of specimens originating in those national populations.

3.8 Current listing of *Cedrela odorata*

The current listing of *Cedrela odorata* implies that 'usual' listings for the regulation of trade for whole species included in Appendix III should be implemented; i.e.:

a) Export, from the State that included the species in Appendix III (i.e. Brazil, Bolivia, Colombia, Guatemala and Peru) of specimens originating in that State:

   - requires the prior grant and presentation of a CITES export permit that has been issued by the Management Authority of the State of export;

b) Export, from all other range States of the species, of specimens originating in those States (e.g. Guyana):

   - requires a CITES certificate of origin issued by the Management Authority of the range State.

If Guyana decides, based on the outcome of this project (resource assessment and management plan and production and (international) trade in red cedar), that the national population of red cedar should be included on Appendix III, then exports of red cedar logs, sawn wood and veneer sheets from Guyana would fall in category a): i.e., a CITES export permit that has been issued by the Management Authority should be granted prior to export and be presented to the relevant authorities.

4 Red Cedar: Species characteristics

4.1 Taxonomy

Class: Magnoliopsida

Order: Sapindales

Family: Meliaceae

The genus *Cedrela* was first described by P. Browne in 1756. In 1759 Linneaus described *Cedrela odorata* (Patiño, 1997). After revision by Earle Smith (1960) the genus *Cedrela* currently counts nine species, all of them occurring in the Americas (Lamb, 1968). Some authors have considered *C. odorata* only to include those trees originating from the West Indies and others to be of the species *C. mexicana*, but in the revision of *Cedrela* by Earle Smith (1960) *C. mexicana* was recognized as a synonym of *C. odorata*.

4.2 Common names

(Rocas, 2003; Orwa et al, 2009; Patiño, 1997; Lindeman et al, 1963; Mennega et al, 1988)

English: Spanish cedar, cedar, red cedar, cedar wood, American cedar, Barbados cedar, Central American cedar, Honduras cedar, Jamaican cedar, Mexican cedar, Nicaraguan cedar, West Indian cedar, West Indies cedar, Brazilian mahogany, stinking mahogany, cigar-box tree, cigar-box cedar, cigar-box cedrela, cigar-box wood, Mexican boxwood.

French: Acajou amer, acajou-bois, acajou femelle, acajou pays, acajou rouge, acajou senti, acajou á meubles, acajou à planches, cèdre, cedrela, cèdre acajou, cèdre des barbares, cèdre rouge.

German: Cedrela, Westindische Zeder, Westindische Scheinzeder, Zigarrenkistchenholz.

Spanish: cedro, cedro amargo, cedro blanco, cedro caoba, cedro cebolla, cedro colorado, cedro cubano, cedro dulce, cedro del país, cedro español, cedro hembra, cedro hembra del país, cedro macho, cedro mexicano, cedro oloroso, cedro real, cedro rojo, cedro vermelho

Portugese: cóbano, cédre, cédre espagnol, acajú, culche.

Guyana: Red cedar (Creole), Koperi (Akawaio), Kurana (Arecuna), Akuyari (Arawak),Paranka (Macushi), Atoreb (Wapisiana), Parank (Warrau)

Suriname: ceder, sedre

See Pennington (1981) for an extensive list of local names.

4.2.1 Commercial names

English: Central American cedar, South American cedar, Honduras cedar, Spanish cedar, West Indian cedar, Cigar-box cedar

Spanish: Cedro hembra

French: Cedrela, cèdre d'Amérique centrale

4.3 Geographic distribution

Native to the tropical region of America, *Cedrela odorata* is naturally distributed from northern Mexico throughout lowland Central America and South America to northern Argentina and most Caribbean Islands within a latitudinal range of 26°N and 28°S (Pennington, 1981; Cintron, 1990; Rocas, 2003).

Within its native range the species has been reported in: Antigua and Barbuda, Argentina, Barbados, Belize, Bolivia, Brazil, Cayman Islands, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Suriname, Trinidad and Tobago, United States Virgin Islands, Venezuela and British Virgin Islands (UNEP-WCMC CITES, no date). See CITES (2007) for detailed references for each country.

The species has been introduced in American Samoa, the Bahamas, Bermuda, the Cook Islands, the Fiji Islands, southern Florida, Ghana, Micronesia, New Caledonia, Nigeria, Samoa, Sierra Leone, South Africa, Tanzania and Tonga (Betancourt, 1983; CITES, 2007; Little et al, 1967; Webb et al, 1980).

As a well-known plantation tree the species is planted in all tropical regions. Timber plantations have been established in Australia, Côte d'Ivoire, Costa Rica, Ghana, Indonesia, Madagascar, Papua New Guinea, Peninsular Malaysia, the Philippines, Singapore, the Solomon Islands, South Africa, Sri Lanka, Tanzania, Thailand, Uganda and Western Samoa (Chung et al 1995). See CITES (2007) for detailed references for each country.

4.4 Site preferences

In its natural area of distribution *Cedrela odorata* occurs in both primary and secondary, evergreen to semi-deciduous lowland or lower montane rain forest (Pennington, 1981; Chung et al, 1995; Patiño, 1997; Lemmens, 2008; Orwa et al, 2009). In general, it grows in a climate with an annual rainfall between 1,200-2,500 mm at altitudes between 0-1,500 m above sea level (Webb *et al*., 1984; Lemmens, 2008), but in Bolivia it is found up to 3,000 meters above sea level (Lamb, 1968). The temperature ranges are a mean maximum temperature of 27-36°C during the hottest month and a mean minimum temperature of 11-22°C in the coldest month, with a mean annual temperature of 20- 32°C (Webb *et al*., 1984). It prefers well-drained sites on a variety of soils, but is usually more common on limestone-derived soil (Lemmens, 2008). It tolerates variation in pH and requires good levels of light.

C. odorata is most successful in drier closed forest conditions but it is rare in evergreen forest types and prefers sites with a marked dry season (Lamb, 1968). The species tolerates prolonged periods of drought (Lamb, 1968; Salas, 1993) and does not prosper in areas with more than 3,000 mm precipitation. In Central America and Mexico it only occurs on non-flooded sites, often on well-drained limestone, as in the semi-deciduous forests of the Yucatan peninsula (Cintron, 1990; Lamb, 1968). However, in Amazonian Peru and Brazil it is most common on fertile soils which are periodically flooded (Pennington, 2006, cited in CITES, 2007).

In primary forest the species is an emergent or member of the upper canopy. In general individual trees are found in mixed forests dominated by other species. It is very common in secondary forest derived from lowland evergreen rain forest and seasonal rain forest (Pennington, 2006, cited in CITES, 2007).

In Peru, the species is found in sub-humid mountain woods, humid woods in meandering plains and woods in dissected terraces. Individual trees are in general found scattered in mixed semi-evergreen or semi-deciduous forests dominated by other species (INRENA, 2006).

The species occurs scattered in the high dryland forests in Suriname (Lindeman, 1954); especially along the slopes of the hills and is reported to become scarce in ridge forests of the coastal plain (Ostendorf, 1962).

In Guyana, the species is rare to locally occasional in *mora* forest along creeks, seasonal forest and poor types of rain forest (Fanshawe 1961). According to Hohenkerk (1923), the species was very scattered in the easily accessible forests in the early 20th century, except in the North West District and locally in the Rupununi District where it was more abundant.

4.5 Botanical Description

4.5.1 Field characteristics

Cedrela odorata is a (semi-)deciduous, monoecious, medium-sized to large tree up to 30-40(-45) m tall (in Guyana/Suriname) with a straight, cylindrical, branchless bole for up to 20(–25) m, 50-90 (-180) cm in diameter (in Guyana/Suriname), with low, blunt, fairly straight buttresses, 1.5-2.5(-3) x 1-2 x 0.2-0.3 m, branched at base. Bark (dark) reddish-brown especially near the base of the bole, greyish brown higher up, longitudinally fissured or ribbed in a diamond-shaped pattern. Fissures 10-60 x 2-4 x 1-2 cm, 5-8 cm apart. Dead bark 4-10 mm thick, (dark) brown, layered, with some lighter brown layers. Living bark 8-10 mm thick, pink or purplish-red (inner half off-white, when exposed to air discolouring to rusty brown), layered, soft, fibrous, with typical cedar-like scent and taste, sometimes with offensive garlic scent. Crown flat or rounded, light, branches erect to spreading; branchlets finely to conspicuously lenticellate (Lindeman & Mennega, 1963; Polak, 1992; Lemmens, 2008). See Figures 1-3.

Seedlings with epigeal germination and short taproot. Cotyledons are leaf-like, opposite, ovate, c. 3 x 1.5 cm, apex and base rounded. Two first leaves opposite, trifoliolate with entire leaflets; blades of lateral leaflets narrowly elliptic, c. 0.2 x 0.5 cm; blade at middle leaflet rhombic, c. 3 x 1 cm (Polak, 1992; Lemmens, 2008).

4.5.2 Leaves

Twigs round, lenticellate, glabrous. Leaves alternate, paripinnately compound with (5–)6–14(–15) pairs of leaflets; stipules absent; rachis slightly hairy or glabrous, petiolules puberulous when young; petiole 2.5-7.5 cm long, round ; rachis 18-38 cm long , grooved above; petiolules to 2 cm long; leaflets more or less opposite; blades papery or thin-leathery, (narrowly) ovate, often falcate , 5-14 cm long x 3-6 cm wide, glabrous, margin flat, apex slightly acuminate, with obtuse tip, base rounded; primary vein plane above, slightly prominent below; secondary veins 7-12 pairs, loop-forming, with some smaller ones in between, prominent above, moderately prominent below; tertiary venation dense (Polak, 1992; Lemmens, 2008).

Figure 1 a. habit; b. flower; c. flower, longitudinal section; d. dehisced fruit; e. seed; f. trunk base; g seedling. Source: Polak (1992)

4.5.3 Flowers

As a monoecious tree, *C. odorata* has flowers of both sexes in the same inflorescence. The inflorescence is a terminal, much-branched, pendulous panicle, 10-40 (50) cm long, glabrous or puberulous; peduncle 0.5-8 cm long; pedicels 1-2 mm long. Flowers functionally unisexual, but with well-developed vestiges of the opposite sex, male and female flowers very similar in appearance, actinomorphic, pentamerous, greenish-white, subsessile, 6-9 mm long, smelling of garlic; calyx cup-shaped, 2-3 mm long, with 5 short teeth; petals 5 free, imbricate and adnate for ⅓ of their length, forming into a long, columnar androgynophore by a medium carina (therefore preventing their spreading in open flowers); stamens 5, free, 2–3 mm long; ; anthers dorsifixed, opening by longitudinal slits; ovary 5-locular, pubescent; each loculus with 10-14 ovules; style short, stigma discoid (Polak, 1992; Lemmens, 2008; Orwa et al, 2009).

The female flowers open before the male flowers. The reproductive cycle of *C. odorata* is synchronized with the growing season, and thus varies over its range of distribution (Cintron, 1990).

4.5.4 Fruits and seeds

The fruit is a pendulous, woody, oblong-ellipsoid to obovoid capsule, at first green, finally brown-black with numerous lenticels, 3-5 cm long and 2-4 cm in diameter, glabrous, dehiscing with 5 valves, central column with 5 broad wings (Polak, 1992; Lemmens, 2008).

Each fruit contains 13 to 34 developed seeds. The seeds are samaroid, bulky at their apex, 2 to 3 cm long and 5 mm wide (including the wing). The bulky part is oblong, slightly comose, laterally flattened, 7 to 8 mm long, 3.5 to 5 mm wide, and 1.2 to 1.5 mm thick. The seed-coat is light brown to red-brown, rugose, opaque, chartaceous, and expanded at the base on a thin and brittle lateral wing (Rocas, 2003).

Figure 2 Bark of red cedar. Source: Polak (1992)

Figure 3 Leaf and dry fruits of red cedar. Source: Lemmens (2008)

4.6 Natural history and population dynamics

C. odorata is insect-pollinated and has wind-dispersed seed (James *et al.*, 1998; Cintron, 1990). The seeds of *C. odorata* are generally ignored by parrots, in spite of appearing ideally suited for predation. Macaws, however, which specialize in eating unripe seeds and fruits, are known to eat the seeds of *C. odorata* (Matuzak and Dear, 2003). Trees start bearing fruit between the ages of 10 years (Lamb, 1968) to 15 years (Lamprecht, 1989). Flowers appear early in the rainy season and fruits mature during the dry season when the leaves become deciduous.

Flowering and fruiting periods vary throughout the tree's range. In Mexico, it blooms May through August, and the fruits ripen during the dry season from January through March in the following year. As the foliage begins to drop, the fruits dry and open (Rocas, 2003). In Guyana, the species is semi-deciduous, flowers from August to November and fruits from January to March (Polak, 1992). Early height growth of up to 2.3 m per year is possible in favourable conditions (Lamb, 1968).

C. odorata is deciduous; strongly light-demanding, behaves as a long-lived pioneer (Cintron, 1990; Lemmens, 2008), and is often associated with other Meliaceae (*Swietenia* and *Guarea* sp.) and leguminous trees (Pennington, 1981). It can therefore be assumed that *C. odorata* shares life history traits with *Swietenia macrophylla*, which has been more widely studied. *S. macrophylla* is a long-lived, fast-growing, deciduous tree and its seedlings require overhead light for growth but not necessarily for survival (Mayhew & Newton 1998; Pennington 2002). The species is found in both ever-wet and seasonally dry tropical rain forest and it seems to thrive in a very wide range of soil conditions (Mayhew & Newton 1998). The same life history traits would thus apply to *C. odorata.*

In general, the Meliaceae species do not follow the regeneration patterns of the majority of common tropical tree species, that is, those that are present at high density per hectare (Patiño and

Marin, 1991). *Swietenia* and *Cedrela*, are classified as 'rare', but population density varies considerably. Rio San Juan, Nicaragua, has a density of one *C. odorata* tree per 100 ha (Paniagua, no date, cited in CITES, 2007). A density of 2.9 stems of cedar per 100 ha was estimated in the Bladen Reserve of Belize (Johnson and Woods, 1976, cited by Newman, 2004). In Guatemala, average densities of 7.9 trees per 100 ha were recorded in the Peten Biosphere Reserve (Szejner, 2005, cited in CITES, 2007). Brienen & Zuidema (2006b) report an average density of 35 harvestable trees per 100 ha in the northern part of the Bolivian Amazon (Department of Pando). According to Navarro-Cerrillo et al (2013), *C. odorata* density ranges between 0.01 and 4.4 trees per ha in Bolivian forests. From the loggers' perspective, however, Navarro-Cerrillo *et al.* (2013) show that the species should be considered as a typically 'rare' low-density species with average density estimated at 3.3 trees per 100 ha for commercial-sized trees (>60 cm dbh) in Bolivia. In Quintana Roo, Mexico average is 65 trees per 100 ha when considering individuals of 15 cm and up, while for trees between 45 and 65 cm in diameter, 17.5 trees per 100 ha are found (Patiño, 1997). However in some regions, almost pure stands are to be found, such as in successional forests on intermediate-age river terraces of Manu National Park, Peru (Gentry, no date).

In spite of plentiful production of seedlings, natural regeneration of *C. odorata* was reported by Marshall (1939) to be 'extremely scarce' in rainforest conditions, though better in semi-deciduous forest. According to Marshall (1939), good regeneration follows events whereby the canopy has been opened considerably, such as forest fires and hurricanes.

Swietenia macrophylla occurs at high densities within forest stands that have regenerated following severe disturbance (Whitmore 1998); dense patches of mahogany have been found in forests that have been subjected to past fires and hurricanes (Lamb 1966; Snook 1993), gully erosion and log-jam-induced flooding (Gullison *et al*. 1996) as well as on abandoned agricultural fields (Stevenson 1927) and along roadsides (Snook 1993). These disturbances are thought to allow mahogany to regenerate as single-aged cohorts every few decades or centuries (Gullison *et al*. 1996; Snook 1996), which has led to the assumption that mahogany requires catastrophic disturbance in order to persist in forest ecosystems (Brown *et al*., 2003). It is highly likely that population structure and dynamics of *C. odorata* are comparable *S. macrophylla*.

However, it appears that there is a difference in the *C. odorata* (and *Swietenia macrophylla*) population dynamics in Central America compared to South America. In Central America waves of regeneration of these two species are apparently provoked by hurricanes and other catastrophic events, resulting in comparatively high local densities, while in South America, the two species mainly occur in low densities in semi-deciduous forests (Brown *et al*. 2003), forests with rather open canopies along watercourses (Grogan *et al*., 2014; Gentry, no date) and in the transitional zone between evergreen forest and *cerrado* in the Brazilian Amazon (Brown *et al*., 2003). For South America, Brown *et al*. (2003) found no evidence that successful regeneration of mahogany depends on periodic catastrophic disturbances, as suggested by Snook (1996). Instead, gap recruitment is suggested to be the principal driver of mahogany population dynamics in Amazonia (Grogan *et al.*, 2003). Exceptions may occur after mega El Niño Southern Oscillation events which may have given rise to higher than usual regeneration as proposed by Meggers (1994).

C. odorata trees are moderately long-lived. Lamb (1968) gives an example of a tree in Belize with 110 rings. Brienen & Zuidema (2006a) reported on harvested trees in the Bolivian Amazon and found an average diameter of 95 cm and a maximum diameter of 172 cm. Using tree ring analysis, they calculated a mean age of 140 years (range 51-308 years) for their sample of harvested trees. Pennington (2006) suggests that *C. odorata* is a fast growing species, which, under optimal conditions, can reach 1 m in diameter in 50-60 years while Clark & Clark (1992) suggested a diameter growth potential (maximum annual diameter increment) of 3.2 cm/yr. However, Brienen & Zuidema (2006a) report a much lower average growth rate of 0.68 cm/yr. and link this to a strong ontogenetic pattern in growth rates, with relatively low growth rates in the smallest size class and a strong increase (>two-fold) towards larger diameters. This implies that trees can grow 10 cm in diameter within 8 years, but this can also take over 70 years. Using tree ring analysis, Brienen & Zuidema (2006b) found low projected *C. odorata* yields for the second harvest after 20 years (as set by Bolivian regulations); recuperation was less than 30% and it would take 72 years to recuperate 100% of the volume obtained in the initial harvest. There are several reasons why recuperation in South America is this low including a small number of trees present in the lower size classes, and slow growth and high mortality rates of juveniles (Brienen & Zuidema, 2006b; Rozendaal et al, 2010), but the main reason appears to be that many trees of harvestable size at the first harvest have passed the minimum cutting diameter threshold already since many decades (Brienen & Zuidema, 2007). The availability of such old-growth trees of harvestable size at the first harvest is often called the 'Primary forest premium' (Rozendaal *et al*., 2010).

4.7 Other botanical information

The genus *Cedrela* is included in the tribe *Cedreleae* of the subfamily *Swietenioideae,* together with *Toona.* All Old World species of *Cedrela* have been transferred to the genus *Toona*. *Cedrela* differs from the latter by its prominent androgynophore with petals and filaments adnate to it, the cup-like calyx, the bigger and woodier capsule, and seedlings having entire leaflets. The formerly recognized species *C. glaziovii* has recently been found to be identical to *C. odorata* (Chung et al, 1995). The specific name, '*odorata*' is Latin for sweet-smelling, fragrant.

4.8 Wood Properties

C. odorata has lustrous wood of medium density. The heartwood is pale cream in colour immediately after sawing, turning pinkish brown upon exposure; clearly demarcated from the narrow creamy yellow or pale brown sapwood (3-5 cm). The grain is usually straight, sometimes interlocked, sometimes woolly indicating the presence of tension wood, texture moderately fine to moderately coarse; the figure is attractive in flat-sawn boards. Fresh wood has a distinct, lingering, cedar-like scent; this characteristic of the wood makes it a favourite for cigar boxes. It has a bitter, spice-like taste. Sometimes the wood has important resin marks. Growth ring boundaries are distinct, marked by differences in pore size and initial parenchyma (Brunner et al, 1994; Gérard et al, 1996; Miller & Détienne, 2001; Lemmens, 2008). Heartwood is rated as moderately durable and moderately resistant to termites, but the sapwood is susceptible to staining and powder post beetles and is not durable (Orwa et al 2009). Basic specific gravity is low to medium; variable, ranging from 0.25-0.50 (Miller & Détienne, 2001).

4.9 Technological characteristics

The wood is light- to medium-weight, with a green density of density of 0.80 g/cm^3, while air-dry density at 12% moisture content varies according to origin from 0.35 to 0.55 g/cm^3, average 0.44 g/cm^3. Basic specific gravity is low to medium; variable, ranging from 0.25-0.50, on average 0.38. The rates of shrinkage may be low: total tangential shrinkage 6.1 %, total radial shrinkage 3.8 % and total volumetric shrinkage 10.0 %, T/R Ratio: 1.5. (Gérard *et al*, 1996).

4.10 Processing

4.10.1 Workability

The wood is easy to work with both hand and machine tools. It saws, bores, turns and sands without problems and produces a good finish. However, growth stresses may cause severe end-splitting of logs and warping and splitting of the central cant during saw milling (Chung *et al*, 1995). Due to its low density and softness, the wood has a tendency to woolliness, if not machined with sharp cutters; extra sanding up to finer grits may be required to obtain a smooth wood surface. Also, natural gum pockets can remain wet and may ooze out onto the surrounding surface, which can clog and gum up saw blades, and make finishing the wood a challenge. (Gérard *et al*, 1996; The Wood Database, no date).The wood is easy to glue and nails easily with good nail-holding power. Rotary peeling and slicing give good results without pre-treatment, producing attractively figured veneer, but with some tendency for woolly surfaces. (Gérard *et al*, 1996; Lemmens, 2008).

4.10.2 Natural durability

The heartwood is rated durable to moderately durable regarding decay resistance, but only moderately resistant to termites; resistance to insects of dry wood is rated as good; the sapwood is non-durable and susceptible to staining and powder-post beetles; the wood is also reported to have excellent weathering characteristics. (Chung *et al*, 1995; Gérard *et al*, 1996).

4.11 Uses

The timber of *Cedrela odorata* is one of the most widely-used tropical hardwoods both locally in Central and South America and in international trade, second only to true mahogany (*Swietenia macrophylla*). The characteristics which make the timber so prized are the attractive reddish-brown colour, its stability and resistance to fungal and insect attack. It is light in weight, easy to work, aromatic and with an attractive grain which takes a fine polish and is used for furniture, cabinet making, panelling and joinery in general. It is now probably the most widely used timber in houses, hotels and offices in tropical America. It is used on a massive scale locally, especially in Peru and in the forest it is frequently used for canoes and paddles due to its light weight and resistance to decay. (Pennington, 2006, cited in CITES, 2007).

The best known use of the timber of *Cedrela* is for cigar boxes (the fragrant wood is still preferred above all others for lining cigar boxes), but it is also used for light construction, mouldings, cabinets, clothing chests and wardrobes, panelling, boxes, exterior joinery, weatherboards, louvered doors, boat building (hulls of light racing boats), canoes, musical instruments (sounding boards), turnery, matchboxes, household implements, face veneer and plywood. Lower grades are suitable for crates, fencing, and animal pens. The repellent smell of the wood makes it particularly suitable for the manufacture of clothing chests and wardrobes. (Chung *et al*, 1995; UNEP-WCMC CITES, no date)

4.12 Population trends

Although *C. odorata* is widespread, it is seldom common - individuals of this species are few in number and are widely dispersed - and its numbers are being reduced by exploitation without successful regeneration (Cintron, 1990). It has been of great commercial interest for over 200 years and in this time its distribution has been diminished by excessive exploitation over its entire range to the extent that large trees of good form and size are now rarely found (Pennington, 1981).

Already before the 1960s heavy logging had resulted in a reduction in the volume of *C. odorata* timber being cut as reported by Earle Smith (1960) in the West Indian Islands and Mexico and by Standley and Steyermark (1946) in Guatemala.

A trend towards rarity has been reported in several countries and territories, including Argentina, Barbados and Puerto Rico (CITES, 2007). It is threatened in Costa Rica (INBio, 1999), Belize (Cho, Pers. Comm. Cited in CITES, 2007), Bolivia (Killeen, 1997 cited in CITES, 2007), Panama (Condit *et al*, 1996)

In Brazil, Brune and Melchior (1976) reported strong selective cutting for *Cedrela odorata* in the várzea (seasonally flooded lowland by the rivers) of the Amazon. Populations of *C. odorata* remain in Peru, but populations are drastically being reduced (Reynel, 1988). Reynel (1988) notes that *C. odorata* was not under threat in Peru, that populations of the species remain, and that many of the Protected Areas in the country contain individuals of the species. However, the author warns that some populations are drastically being reduced.

4.13 Trade

According to CITES trade data for the period 2001–13, the majority of international trade in red cedar involved sawn wood. The remainder of the trade was in carvings, logs and veneer.

4.13.1 Trading prices

red cedar is considered a commercially valuable species and an important commodity on both the local and export market (CITES, 2007). Information on the value of the species in trade is patchy and reported only at some stages in the supply chain. Data submitted by the Peruvian authorities indicated prices ranging from \$592/m^3 to \$658/m^3 during the period 2000–05 (Ferriss, 2014). Prices reported by ITTO[8] for 2013-2015 for *Cedrela odorata* sawn wood from Peru were in the range of \$911–977/m3 in the North American and Mexican markets; while prices for the Peruvian domestic market were \$296-355/m^3.

Data submitted by the Guyana Forestry Commission indicated export prices ranging from \$360-1,548/m^3 for sawn wood (dressed and undressed lumber) and \$90-155/m^3 for logs during the period 2006-14.

4.13.2 Global trade patterns

The CITES trade database includes details of all export and import permits and certificates issued for CITES-listed species. For this report, data were downloaded from the CITES trade database for the years 2001–13 (2013 being the most recent year for which a complete dataset is available). Only direct trade from the country of origin is considered (i.e., the country of export in which the timber was harvested) to avoid double counting re-exported timber.

[8] ITTO (2013-2015), 'Report from Peru', in Tropical Timber Market Report, Vol. 17, No. 20, 16–31 October 2013 - ITTO Tropical Timber Market Report, Vol. 19, No. 2, 16 – 31 January 2015.

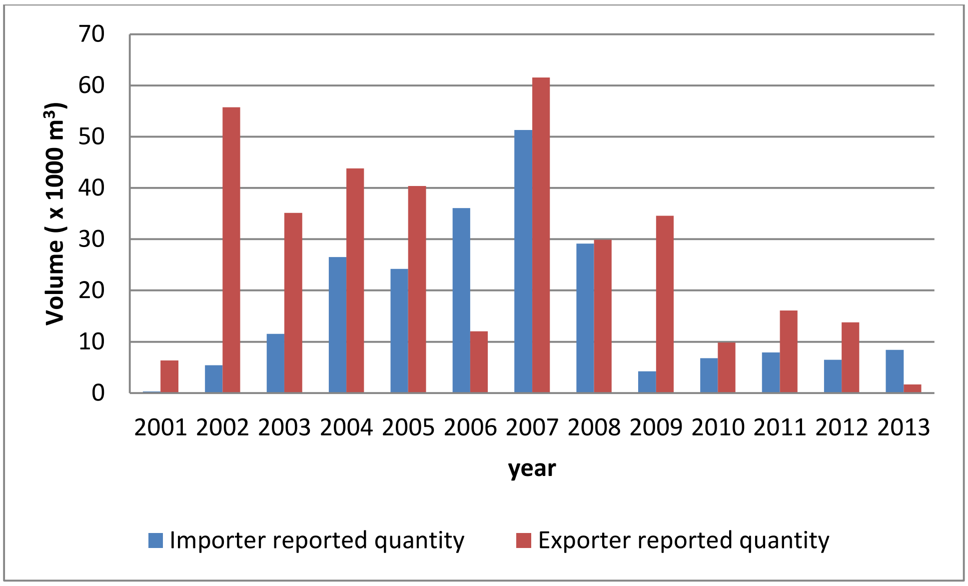

Figure 4 Direct global trade in Cedrela odorata, according to the CITES trade database for 2001–13

According to CITES trade data between 2001 and 2013, the annual level of exports of red cedar as reported by exporters was on average around 28,000 m^3 for sawn wood and logs. Trade in red Cedar peaked in 2002 and 2007, but declined strongly after 2009 (see Figure 4). While the data reported by both exporters and importers for 2009 show a decrease in trade in recent years, the volume, source and destination reported by importers differ from the information reported by exporters; i.e., the average annual of level of imports was around 1,700 m^3 only. The magnitude of the difference between the volumes of trade reported by exporters and importers suggest under and/or misreporting. However, the discrepancy is likely due to inconsistencies in how trade in CITES Appendix III-listed species is reported (Ferriss, 2014). While there is no requirement to report imports of those species and range states that do not list their population on Appendix III are only required to issue a certificate of origin, in practice a number of countries do, including the EU member states and the United States, but not always (Ferriss, 2014). Furthermore, some countries report trade in Appendix III-listed populations (i.e. exports from Bolivia, Brazil, Costa Rica, Guatemala or Peru), while others report trade in all specimens of the species. Guyana, for instance, has never reported any exports, while exports have been substantial (see Table 1).

During the period 2001–13, Peru and Bolivia were the main exporters of red cedar according to exporter reported quantities (annual average of c. 14,700 m^3 and c. 14,150 m^3 respectively), while importer reported quantities indicate only Peru (c. 13,500 m^3 annual average[9]) as main exporter. The United States, Mexico and Argentina were the main importers, while Peru, Japan, Chile, Spain and the Dominican Republic imported significant volumes according to exporter reports.

4.13.3 Export from Guyana

Data submitted by the Guyana Forestry Commission indicated that export volumes from Guyana followed the global decline from 2009 onwards as shown in Table 1 below. The decline is clearly demonstrated for logs, lumber and building components (mainly doors).

[9] For Bolivia, importers reported an annual average volume of c. 850 m^3/yr., while Brazil was the second largest exporter according to importer reports with an average annual volume of c. 1,350 m^3/yr.

Table 1 Export of red cedar lumber, logs, building components, furniture, mouldings and wooden utensils and ornaments from Guyana for the period 2006–14

	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Sawn timber[1] (m^3)	42	585	933	294	115	53	20	19	27	2086
Logs (m^3)	2	2	55		4	3				67
Building Componentry[2] (pcs)		1050	740	421	350	100	20	20		2701
Furniture (pcs)		2	40							42
		2194								2215
Mouldings (pcs)		2			208					1
Wooden Utensils & Ornaments (pcs)							14			14

[1]sawn timber includes both dressed and undressed lumber.

[2]building componentry consists mainly of doors and windows.

Barbados has been the most important market by far for red cedar exported from Guyana with a total volume of exported sawn wood of 1,554 m^3 over 2006-14, followed by the United States of America with a volume of 256 m^3 sawn wood and Trinidad and Tobago with 115 m^3 over 2006-14. Barbados was also the main market for building components (mainly doors), while China was the main importer of red cedar logs (45 m^3 over 2006-14). In terms of export value of all product categories over 2006-14, a value was declared of 2,524,659 US$, with Barbados being the main market in terms of value with a declared value of 1,743,502 US$.

5 Geographic distribution of Red Cedar in Guyana

5.1 Vegetation maps

A vegetation map of Guyana was produced in 2001 by Hans ter Steege (Ter Steege, 2001a) developed from a variety of sources including satellite imagery, a digital elevation model, soil maps, research plots and the FAO-FIDS forest inventory plots and is shown in Figure 5.

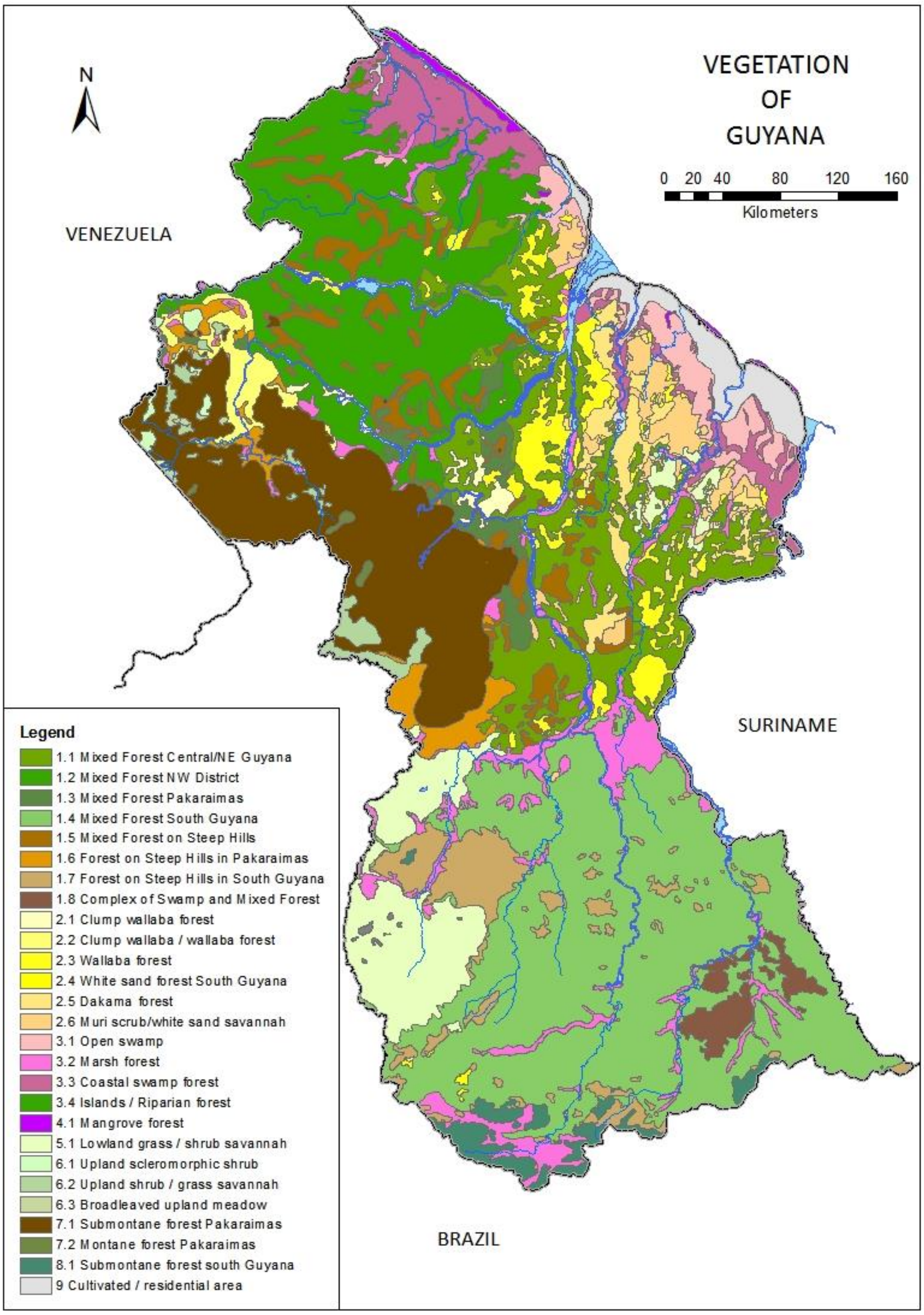

Figure 5 Vegetation map of Guyana (after ter Steege, 2001a)

As part the UN-FAO Forest Industries Development Survey reconnaissance surveys of Guyana during 1968-1973, detailed forest type maps were prepared using aerial photography interpretation (De Milde & De Groot, 1970a-e, g). These maps were digitized into one so-called regional vegetation map in 2000 as part of the DFID Guyana Forestry Commission Support Project. An extract of the FAO-FIDS maps is shown in Figure 6.

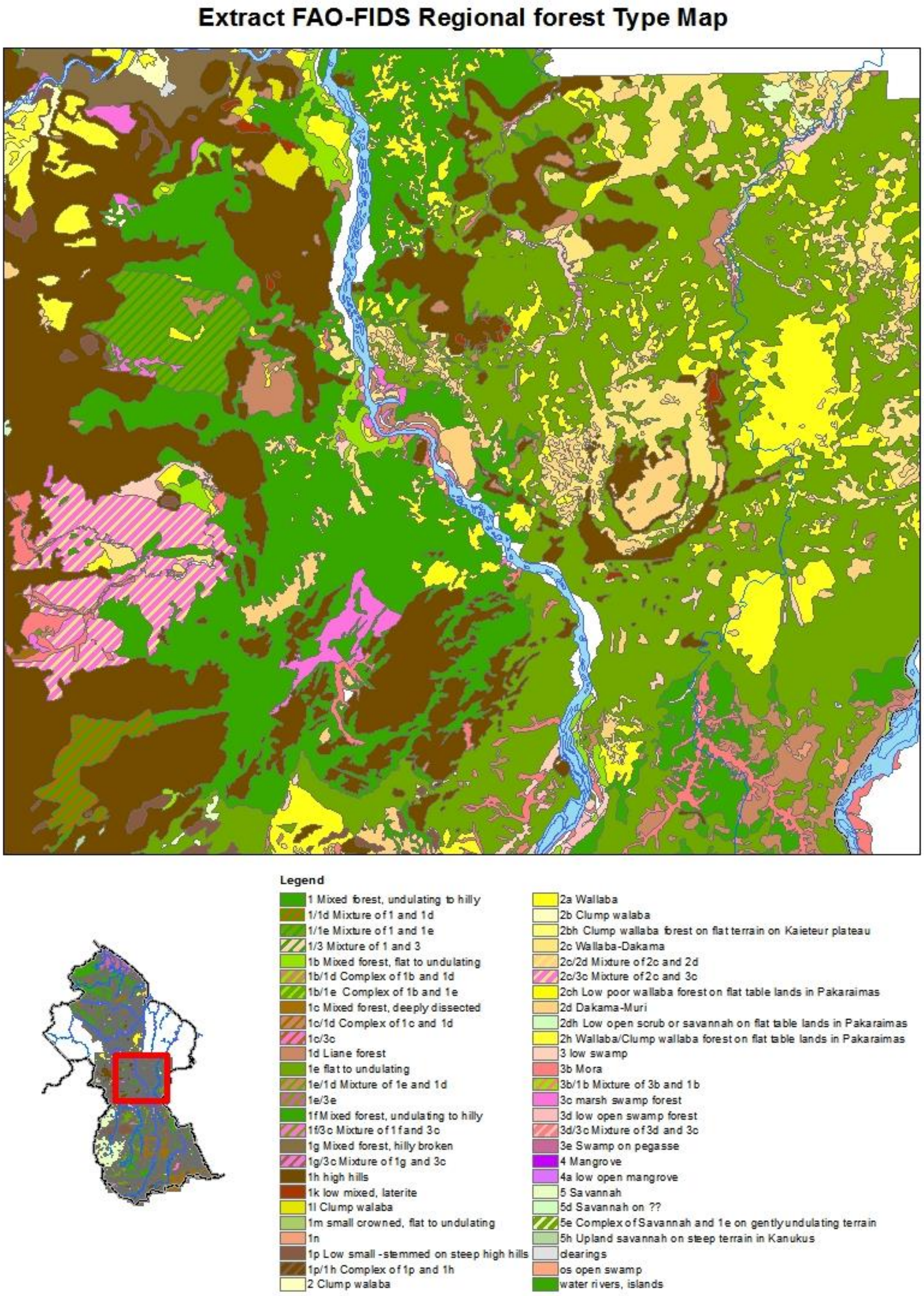

Figure 6 Extract from reconnaissance surveys of the more accessible forest areas, zones 1-5 and the southern part of Guyana (De Milde & De Groot, 1970a-e, and g)

During the same period, even more detailed forest type maps were prepared based on aerial photo interpretation for three at the time untouched areas, two of which were presumed to be well-stocked with greenheart (*Chlorocardium rodiei*); the *Ebini-Itaki* area (De Milde & De Groot, 1970f) and the *Great Falls* area (Welch & Bell, 1971), while the third was prepared for a selected area in the North-West district (De Milde & De Groot, 1971) to assess *Virola surinamensis* (Dalli) and other swamp forest timber resources. Unfortunately these useful forest type maps have not been digitized to date.

5.2 Forest inventories

Wright (1999) has reviewed forest inventories done in Guyana since the 1950's. Prior to World War II the Guyana Forest Department had undertaken numerous valuation surveys in different parts of the accessible forest areas (Fanshawe, 1961). From 1966 to 1975, the FAO-supported Forest Industry Development Survey (FIDS) was undertaken as a national inventory, with most field work from 1969-73. Subsequently, the CIDA-financed Interim Forestry Project (IFP), from 1990-95, undertook a second national inventory. During 2000-2002 the Guyana Forestry Commission developed its own inventory capacity and methodology with support from the UK DFID. The forest inventory methodology was recommended for State Forest Exploratory Permits (SFEPs) and companies conducting management level inventories for their long-term forest management plans. A number of management level inventories (MLIs) have been undertaken by Iwokrama between 2003 and 2012 and by Barama Co. Ltd. of its compartment no. 5 in 2003 and of the 'Barama Housing SFEP 02/04' in 2005. Such MLI was also undertaken in Nagasar Sawh's Ya Ya Concession (TSA Dem 04/90). These MLIs are included in the GEMFORM database of GFC.

Ter Steege (pers. comm., 2001 in Alder, 2008) converted the old IFP and FIDS data files into Access databases, and used them as a resource for biomass studies and the Guyana vegetation map (Ter Steege, 2001a, 2001b) and from 2006 onwards, GFC has been conducting management level inventories (MLI) in State Forest Permits (SFPs) and Small Loggers' Associations (SLAs) to obtain information on the stocking of the areas targeted to guide decisions on their (re)allocation. The data have been processed through GEMFORM (Alder, 2000, 2001, 2008).

MLIs have reportedly been conducted in 70 concessions; 42 SFPs, 24 SLAs, 2 TSAs, 1 SFEP and Iwokrama. GEMFORM database data was available to the consultant for 52 concessions; 31 SFPs, 17 SLAs, 2 TSAs, 1 SFEP and Iwokrama. Not all of Iwokrama's Sustainable Use Area MLI is included in the GEMFORM database when compared with summary data obtained from Iwokrama. Iwokrama itself made results available for red cedar only for the inventories they had conducted; i.e., Sustainable Use Area management level inventory (2003), Annai management level inventory (2007), ITI Pre-harvest (100%) inventory (2010) and Wildlife Preserve biodiversity inventory (2012).

The data in the GEMFORM database at hand includes 4,609 sample plots (Iwokrama: 874 plots, TSAs: 1,420 plots, SFPs/SLAs 1,535 plots and Barama Housing SFEP: 780 plots). The sample plots are circular line plots with lines generally set 1 km apart and sample plots were set 200 m apart. Sample plots consisted of a 0.1 ha circular main plot, where trees of all species from 35 cm dbh are enumerated, and a 0.02 ha nested subplot, where trees of all species between 10 cm and 35 cm dbh are enumerated. The total area covered by these inventories measures 488,564 ha with the Barama

Co. Ltd. inventory of its Compartment no. 5 forming the bulk the inventoried area; i.e. 204,772 ha. The total area of SFPs/SLAs sampled covers 140,951 ha, Iwokrama 69,085 ha and Barama Housing SFEP 47,314 ha. The overall average sampling intensity was 0.09% (TSAs: 0.06%, SFPs/SLAs 0.11%, SFEP 0.16% and Iwokrama 0.13%).

It must be noted that the national inventories cover different time periods (FIDS 1968-73, IFP 1990-94, MLI 2002 onwards) and that they have rather different national coverage, as shown in Figure 7. The locations shown are estimated from place names and descriptions for the FIDS data and in case of the IFP project locations from the consultant's own involvement in the IFP project, as exact georeferences were not recorded. For MLI data, GPS waypoints were recorded for the start of most transect lines but not for the individual plots. Therefore plots are shown as centroids of inventoried areas.

The IFP project did not sample the southern part of the country, and used a point sampling (Bitterlich) design with high Basal Area Count Factors, so that typically only 3-4 trees were sampled per plot. The IFP project covered 32 locations (within 15 concessions) and counted 7,992 plots. IFP point sampling used an average BAF of 6 m^2/ha.

The 1,016 FIDS plots were distributed over 89 locations and consisted mostly of 0.2 ha clusters of 5 × 0.04 ha subplots (De Milde & De Groot, 1970a-e,and g).

5.2.1 *Geographic distribution of red cedar based on national forest inventories*

Plots with red cedar present were identified and overlaid on the national vegetation (Figure 8) and the FAO-FIDS regional forest type maps. Theoretically, it would be possible to intersect the vegetation map and plot locations to determine site preferences for red cedar. However, given the positional estimates for the plot locations, it is more useful to use actual forest types recorded during the inventories. Red cedar was only very occasionally encountered in the sample plots. Only 15 trees showed up in 13 out of the 4,609 MLI sample plots; 5 trees in 5 out of 1,016 FAO-FIDs plots; and 6 trees in 6 out of 7,992 IFP sample points. In case of the Iwokrama inventories 9 trees were found in different plots.

The four different inventory designs used different forest typing designs. The FAO-FIDS inventory obviously links directly to the FAO-FIDS regional forest type map, but this is less the case with the other three inventories. The distribution of plots with red cedar over the different forest types and soil types is shown for each of the four inventory designs in Tables 2-5.

Table 2 Forest and soil types of the plots with red cedar in the FAO-FIDS inventory

Forest type	Soil type			
	brown sand	loam	sand & loam	Total
1 Mixed forest on undulating to hilly terrain	1		1	2
1b Mixed forest flat to undulating W. Guyana			1	1
1e Mixed forest flat to undulating E. Guyana		1		1
1h Mixed forest on steep high hills and mountains			1	1
Total	**1**	**1**	**3**	**5**

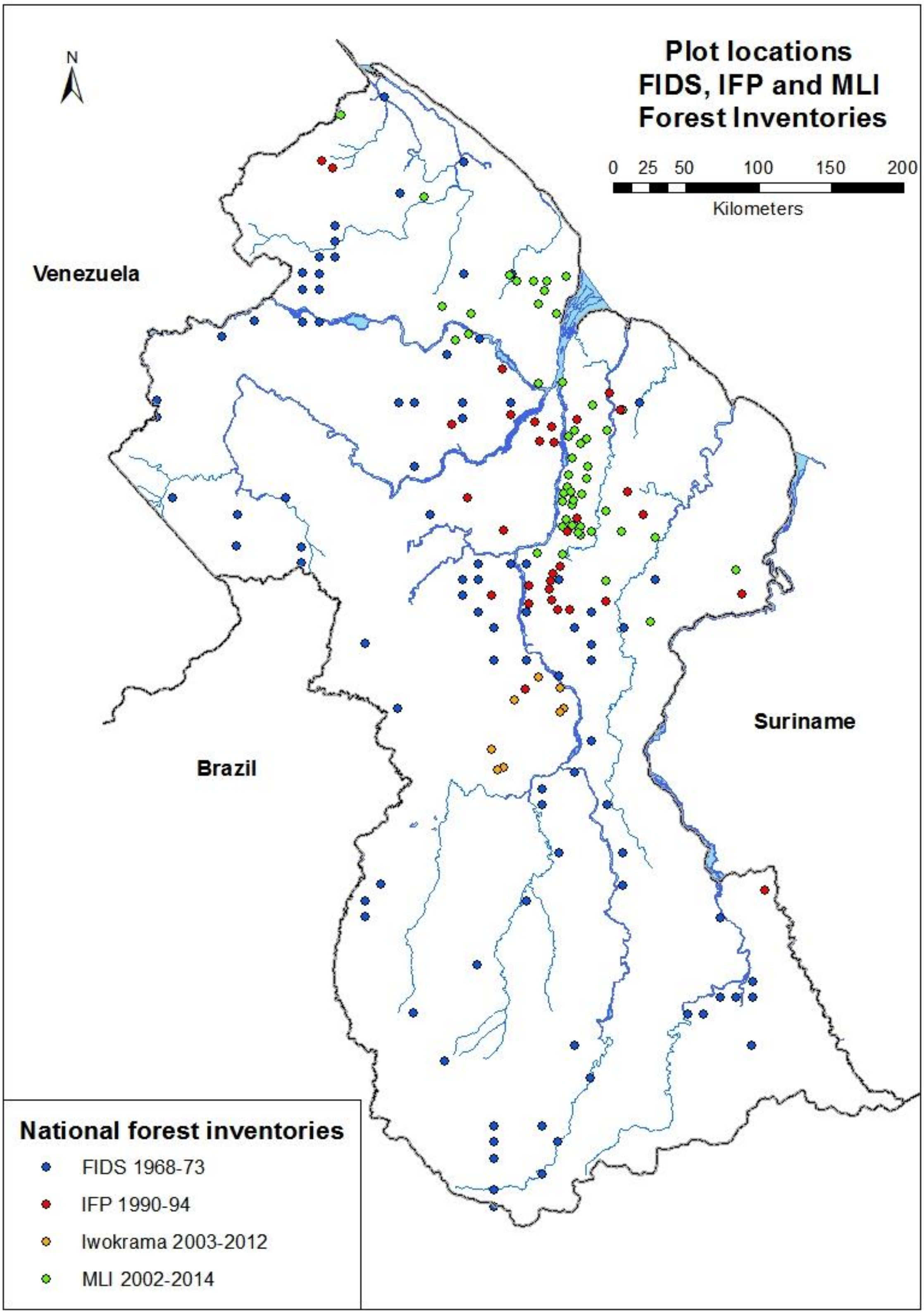

Figure 7 Estimated locations of FIDS (1969-1973), IFP (1990-1994), MLI (2006 to present) and Iwokrama (2003-2012) plots from place names and descriptions for the FIDS data and the consultant's experience with the IFP project. For MLI data, plots are mainly shown as centroids of inventoried areas (SFPs); except for Iwokrama (only plots with red cedar) where locations are more precise.

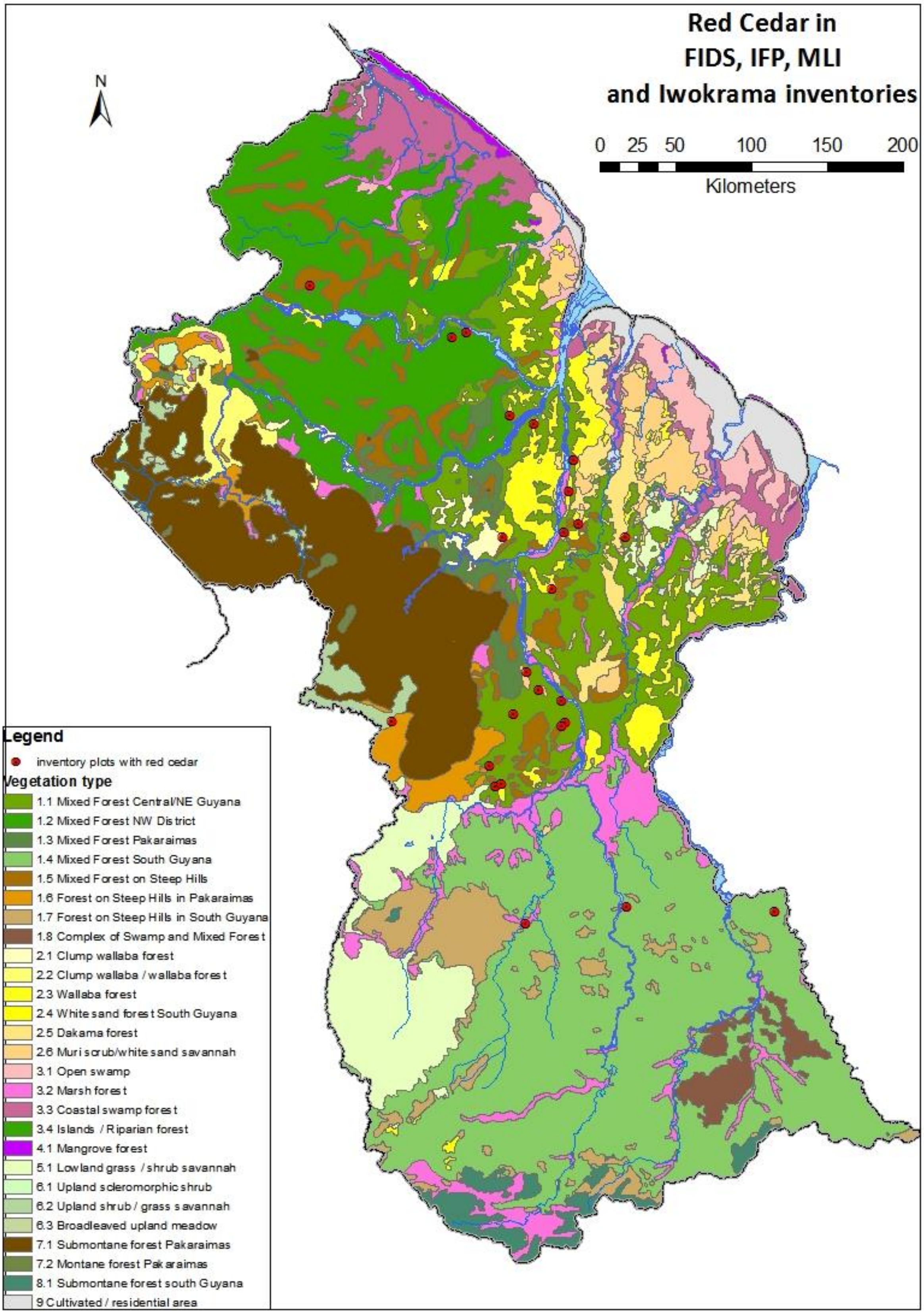

Figure 8 Estimated locations of FIDS, IFP, MLI and Iwokrama inventories plots with red cedar occurring and the national vegetation map

Table 3 Forest and soil types of the plots with red cedar in the IFP inventory

Forest type	Soil type				
	brown sand	clay	flooded	pegasse	Total
Mixed forest	2	1	1		4
Swamp forest			1	1	2
Total	**1**	**1**	**2**	**1**	**6**

Table 4 Forest and soil types of the plots with red cedar in the MLI inventories

Forest type	Soil type					
	brown sand	clay	loam	pegasse	white sand	total
Dakama forest					1	1
Mixed forest	4	1	1	1		7
Mora forest		1				1
Swamp forest				2	2	4
Total	**4**	**2**	**1**	**3**	**3**	**13**

Table 5 Forest types of the plots with red cedar in the Iwokrama inventories

Forest type	Total
Manicole, Kokorite, Soft Wallaba forest	4
Mixed Greenheart, Black Kakaralli, Wamara forest	3
Wallaba forest	1
Mixed Greenheart, Sand Baromalli, Soft Wallaba forest	1
Total	**9**

Based on the four forest inventories, red cedar does not seem to have a clear preference for a specific forest or soil type, but appears to occur on most soil types from pegasse, to loam, to white sand and in most forest types from swamp forest to dakama (*Dimorphandra conjugata*) forest.

5.3 Land use allocation in Guyana

Guyana's land area is divided into State Forest, Amerindian Village Lands and other Private Lands, State Land (mainly Agricultural leases), and protected area reserves, as shown in Figure 9. Roughly 7.1 million hectares of State Forest have been allocated for wood production purposes. The unallocated State Forest area amounts to 5.2 million hectares and is located in the South and the West of the country. 1.16 million hectares are protected areas, including Iwokrama with 371,681 hectares, Kaieteur National Park with 61,091 hectares, and Shell Beach and Kanuku Mountains together covering 730,300 hectares.

The Guyana Forestry Commission (GFC) holds the management rights for all State Forest and issues leases and permits to concessionaires for the commercial harvest of timber. After the lease period the concessions are renewed or returned to the GFC depending on certain factors inclusive of sustainable harvesting levels. There are four types of permit, which include[10]:

[10] Forest Sector Information Report, Annual Review 2014. Guyana Forestry Commission, Georgetown, Guyana.

- *Timber sales agreement* (TSA): concessions of more than 24,281 ha for a duration of 20 years minimum. As per 31st December 2014, 27 TSAs had been allocated covering an area of 4.4 million hectares (63% of the State Forest area that is allocated for production purposes). The average size of TSAs was 123,630 hectares (ranging from 7.5 thousand to 1.6 million hectares).
- *Wood cutting lease* (WCL): concessions between 8,094 and 24,281 hectares and allocated for 3 to 10 years. As per 31st December 2014, there was one licence covering an area of about 21,267 hectares (0.3% of all allocated State Forest).
- *State Forest Permit* (SFP): concessions allowing owners to remove a predetermined quantity (quota) of timber from within the forest concession boundaries. SFPs are valid for a period of 1-2 years and are for area sizes less than 8,093 ha. SFPs are generally issued to small-scale operators and community-based associations. As per 31st December 2014, 525 permits covering a total area of 2.1 million hectares were issued (29% of all allocated State Forest). The average size of SFPs was 3,495 hectares.
- *State Forest Exploratory Permit* (SFEP): a 1-3 yrs. exploratory permit issued for undertaking exploratory operations such as inventories, environmental and social impact assessments and the preparation of management plans. An SFEP holder is allowed to harvest a percentage of its calculated annual allowable cut during the exploratory stage subject to GFC approval. SFEPs are a pre-requirement for new large concessions (TSAs and WCLs). As per 31st December 2014, seven exploratory permits covering an area of 570,302 hectares were in effect (8% of all production area allocations).

WCLs and TSAs are considered 'large concessions' and are required to demarcate their boundaries on the ground, undertake 100% pre-harvest inventories, comply with the Code of Practice of Forest Operations for TSAs and WCLs, and submit a forest management plan and annual operations plan to the GFC before commencement of harvesting operations. The latter specifies the forest blocks to be harvested that year and the volume to be extracted. Volume is calculated based on concession area and felling cycle and tags are issued accordingly. Harvested blocks are inspected by GFC field staff to ensure adherence to the annual operations plan.

'Small concessions' (SFPs) are normally issued for a 2-yr period, which commences in an even year (e.g. 2012-2013). The GFC calculates the Annual Allowable Cut (quota) for SFPs based on the area of the SFP and previous harvesting history. The quota is calculated for either a 12-mo or a 24-mo period depending on the SFP-holder's previous performance and date of issue of the SFP. SFP holders are not required to conduct inventories or to prepare forest plans, but they need to comply with the Code of Practice of Forest Operations for SFPs.

5.3.1 Geographic distribution of red cedar based on stock surveys in TSAs

TSA holders are required to conduct a systematic 100% pre-harvest inventory (stock survey) covering their annual operating area and are obliged to provide this information to the Guyana Forestry Commission (GFC). Stock surveys conducted over the period 2010-2014 were assessed for the occurrence of red cedar. The species was encountered in 11 out of the 23 active TSAs. In total, 393 red cedar trees had been enumerated in 224 blocks; an average of 1.7 trees per block (maximum 7 trees per block).

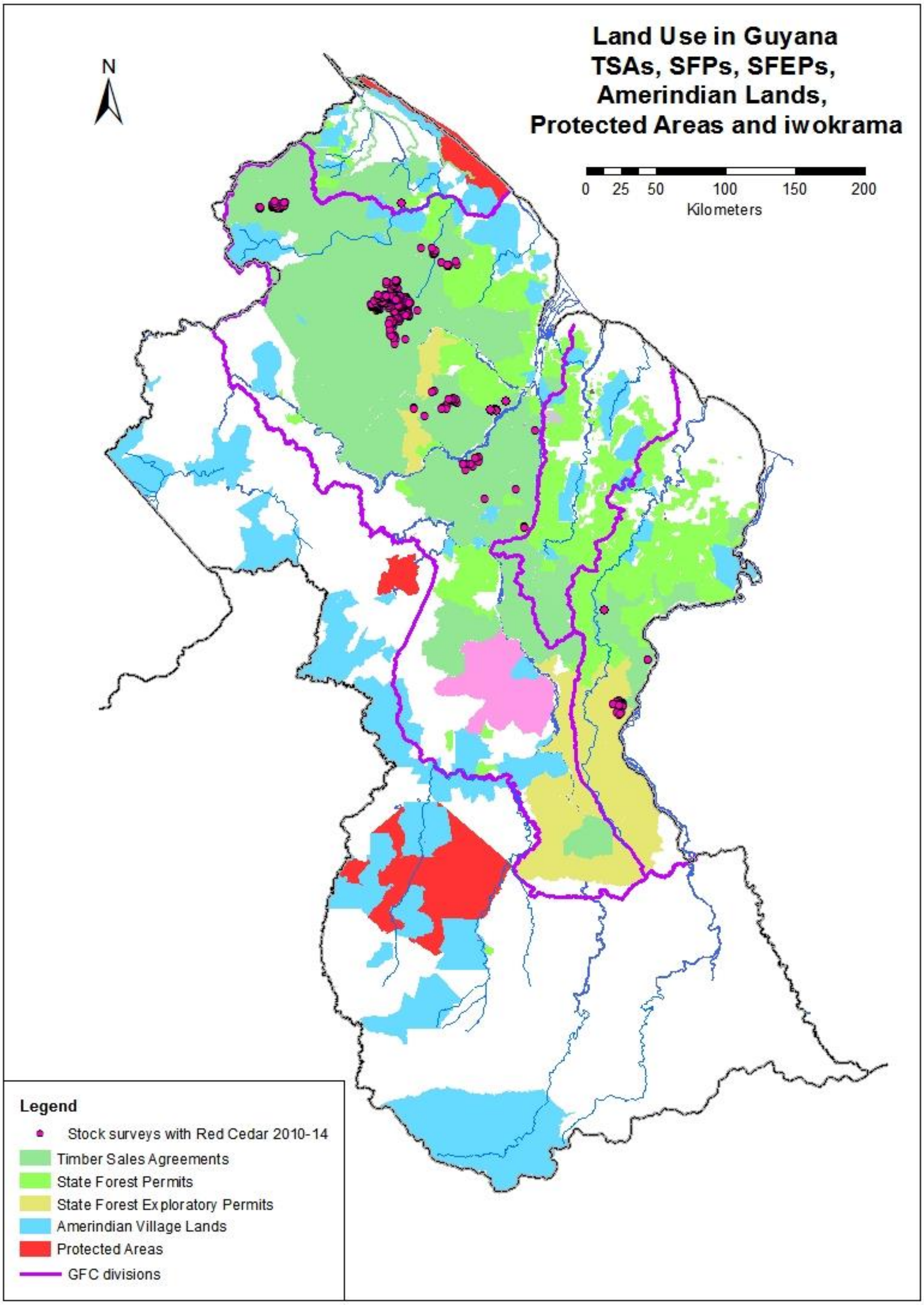

Figure 9 **Land use in Guyana covers TSAs, SFPs, SFEPs, Amerindian Village Lands and protected areas; 100% pre-harvest stock surveys, conducted in TSAs between 2010 and 2014, with red cedar.**

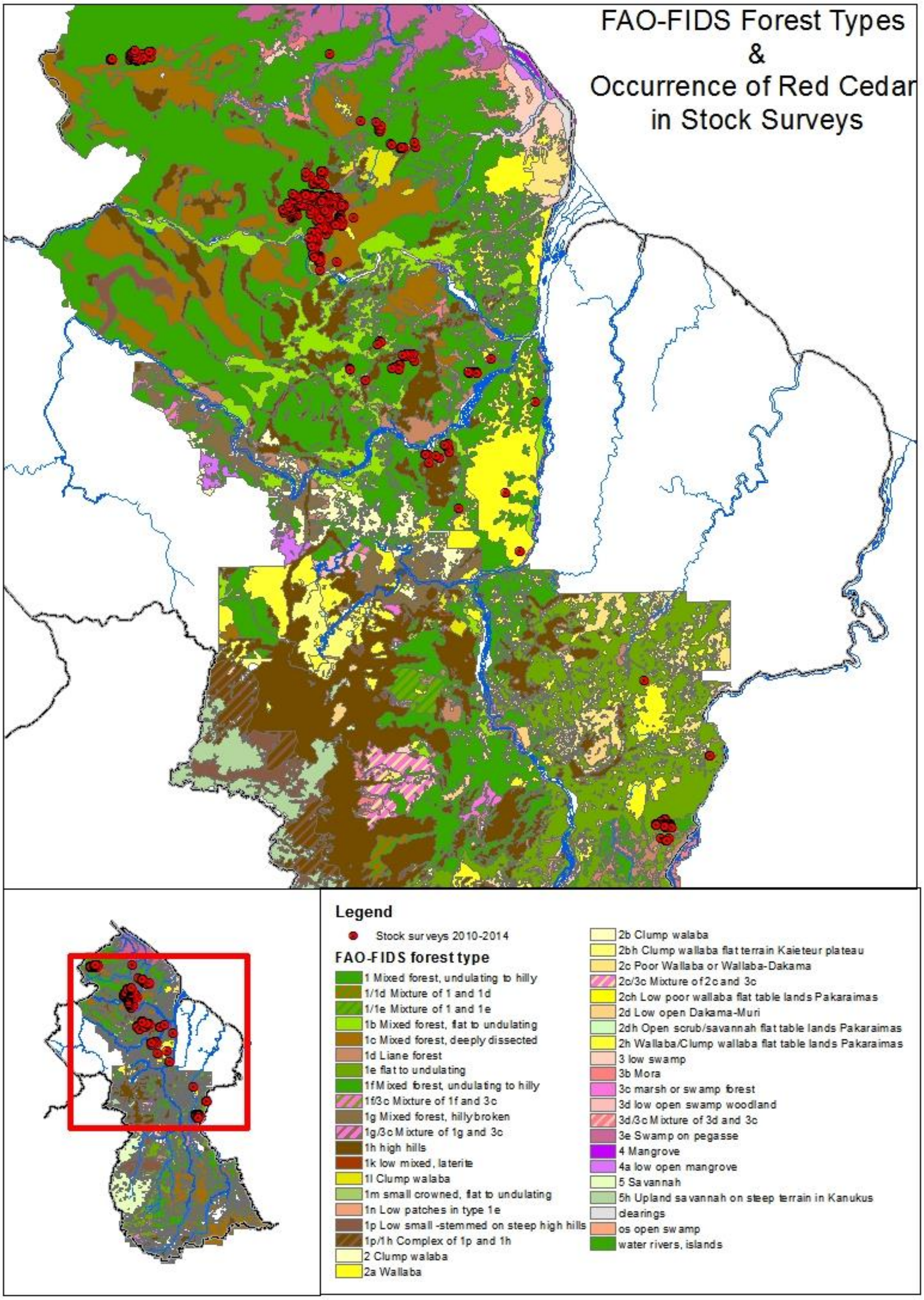

Figure 10 100% pre-harvest inventory blocks with red cedar in Timber Sales Agreements (2010-2014) overlaid on FAO-FIDS regional forest type map

Occurrence of red cedar in stock survey blocks is show in Figure 9. Vegetation types are usually not recorded on a block level, because the forest type usually varies within a 100-ha block. No exact forest type is thus known for the encountered red cedar trees. However, in the case of stock surveys each tree within a block is georeferenced and it may be worthwhile to intersect the vegetation map and tree locations to determine site preferences for red cedar (Figure 10).

Intersection of the FAO-FIDS regional forest type map layer with the layer with the red cedar positions in 100% stock survey blocks was performed with ArcGIS spatial join tool. Results are shown in Table 6. For the national vegetation map results are shown in Table 7.

Table 6 Geographic distribution of red cedar based on stock surveys in TSAs. Distribution of enumerated trees according to FAO-FIDS forest types

Forest type	Number of red cedar trees
1 Mixed forest on undulating to hilly terrain	251
1b Mixed forest on flat to undulating terrain - W. Guyana	8
1c Mixed forest on deeply dissected, steeply sloping terrain	49
1e Mixed forest on flat to undulating terrain - E. Guyana	38
1h Mixed forest on steep high hills and mountains	24
1l Clump Wallaba forest	6
1m Small-crowned forest on flat to undulating terrain	4
2a Wallaba forest	13
Total	**393**

Table 7 Geographic distribution of red cedar based on stock surveys in TSAs. Distribution of enumerated trees according to national vegetation types

Vegetation type	Number of red cedar trees
1.1 Mixed Forest Central/NE Guyana	49
1.2 Mixed Forest NW District	259
1.3 Mixed Forest Pakaraimas	15
1.5 Mixed Forest on Steep Hills	23
2.3 Wallaba forest	47
Grand Total	**393**

Initially, stock survey data had shown that red cedar occurred in the Variety Woods & Greenheart Ltd. concession in the Demerara District and in the W.A.I.C.O., and Haiomarakabra concessions in the Berbice district. Records of red cedar occurrences in these stock surveys were verified on the ground and it appeared that *Apeiba petoumo* (duru), *Bombax* sp. (kamakuti), *Calophyllum lucidum* (kurahara), *Humiria balsamifera* var. *balsamifera* (tauroniro), or *Tabebuia insignis* var. *monophylla* (white cedar) trees had been mistaken for red cedar. Verification of red cedar trees encountered in stock surveys in two blocks in the Barama Co. Ltd. concession and in two blocks in the Vaitarna Holding Private Inc. concession showed that the species were identified properly. Occurrence of red cedar in the Bai Shan Lin SFEP in the Berbice district is unsure because of the misidentifications in the three nearby concessions.

5.4 Geographic distribution of red cedar based on production records

The Guyana Forestry Commission's log tracking system requires that each harvested tree is measured and tagged. These tag numbers with measurements of each tree are reported on removal permits and associated production registers. The log tracking system not only applies to small and large concessions but also to Amerindian lands, which are reported to be important producers of red cedar.

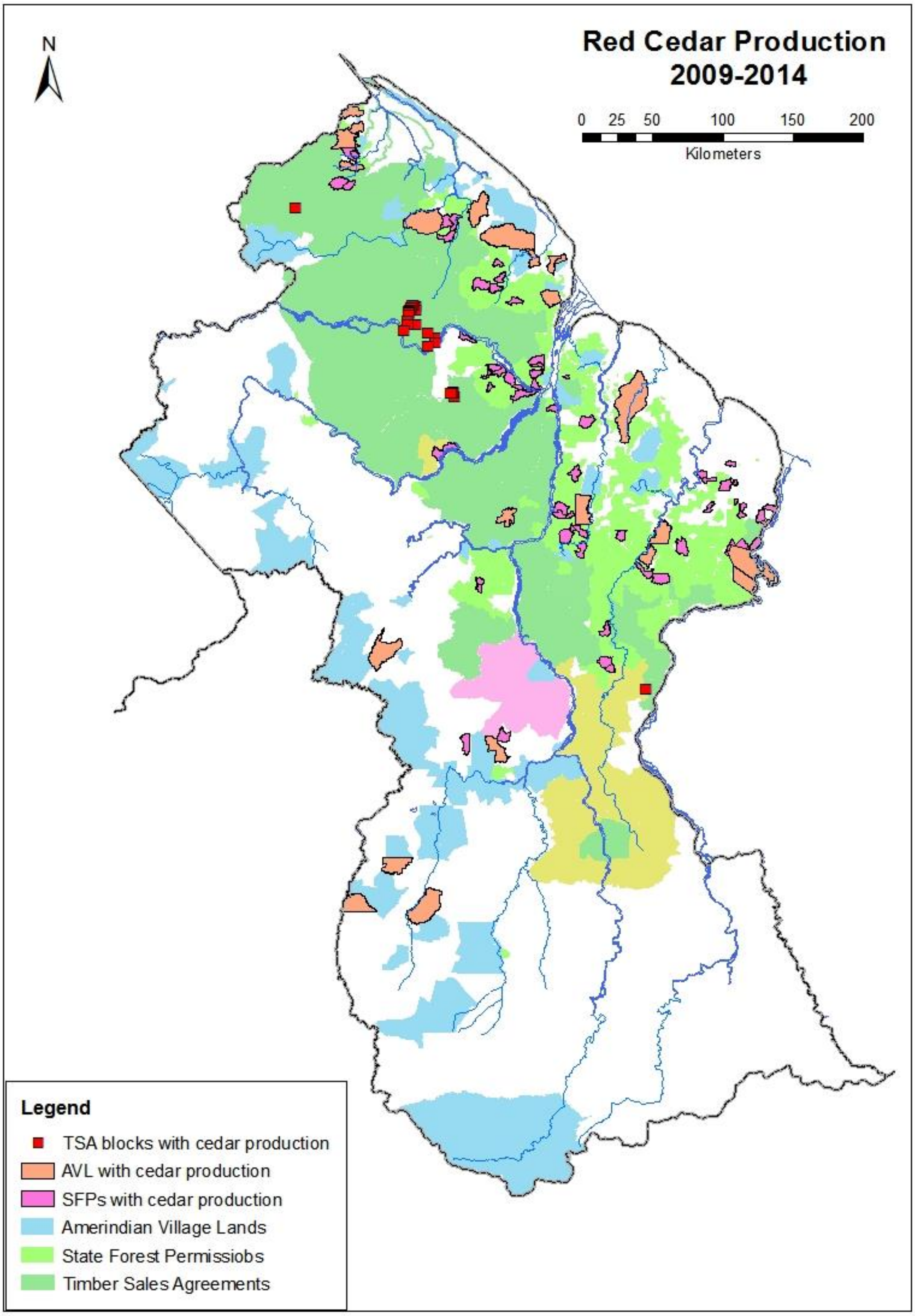

Figure 11 Locations of red cedar production over the period 2009-2014. TSAs: blocks from where the logs originated are shown, while for SFPs and AVLs the locations of the concessions are shown

red cedar production figures for the period 2009-2014 by concession (including Amerindian Village Lands) were scrutinized for red cedar. Since production figures could provide additional information on the distribution of red cedar, in particular where it concerns Amerindian lands and small concessions, an attempt was made to further trace back volumes and source of origin. In case of TSAs, red cedar production can even be traced back to the block. To this end, 'used species reports' for red cedar were requested from the GFC MIS department.

This exercise provided detailed positional information for production from TSAs, while production from SFPs and AVLs can be traced to the individual concession or AVL. The size of SFPs is limited to approximately 8,094 ha and their average size is about 3,500 ha. The average size for the SFPs with red cedar production was 4,315 ha and the maximum size 8,094 ha; the legal maximum limit for SFPs. The average size of the Amerindian Village Lands amounts to 29,073 ha and the maximum size to 620,791 ha for Konashen in South Guyana. The average size for the AVLs with red cedar production was 20,720 ha and the maximum size 63,675 ha for St. Cuthbert's mission.

Origin of red cedar production over 2009-2014 is depicted in Figure 11. For TSAs the blocks from where the logs originated are shown, while for SFPs and AVLs the locations of the concessions are shown.

5.5 Proven and possible geographic distribution of red cedar

Based on the FAO-FIDS, IFP, MLI and Iwokrama forest inventories, red cedar does not seem to have a specific preference for a certain forest or soil type, but appears to occur on all soil types from pegasse, to loam, to white sand and in many forest types from swamp forest to dakama forest. Data from 100% pre-harvest stock surveys in large concessions (Timber Sales Agreements) and production statistics from small concessions (State Forest Permits) and Amerindian Village Lands confirm that the species is found in various forest types; from *mora* forest, to mixed forest on undulating to hilly terrain, on deeply dissected terrain, on steep high hills, and also in *wallaba* forest on white sand soils.

Forest and soil typing of the inventory plots may have been based on the general area, while small-scale ecotope differences, e.g. along seasonal streams, may have been overlooked when assessing the plot characteristics. Within the wallaba and dakama forests on deep, excessively drained white sand soils, small spatially explicit ecotopes may occur along (seasonal) creeks for instance. A general pattern of soil types in the sedimentary plains is that the white sands have an extremely sharp boundary with other soil types (Van Kekem *et al*, 1996). The same, obviously, applies to forest typing based on the FAO-FIDS regional forest type map and national vegetation map, which type is rather course and ignores small-scale ecotope differences.

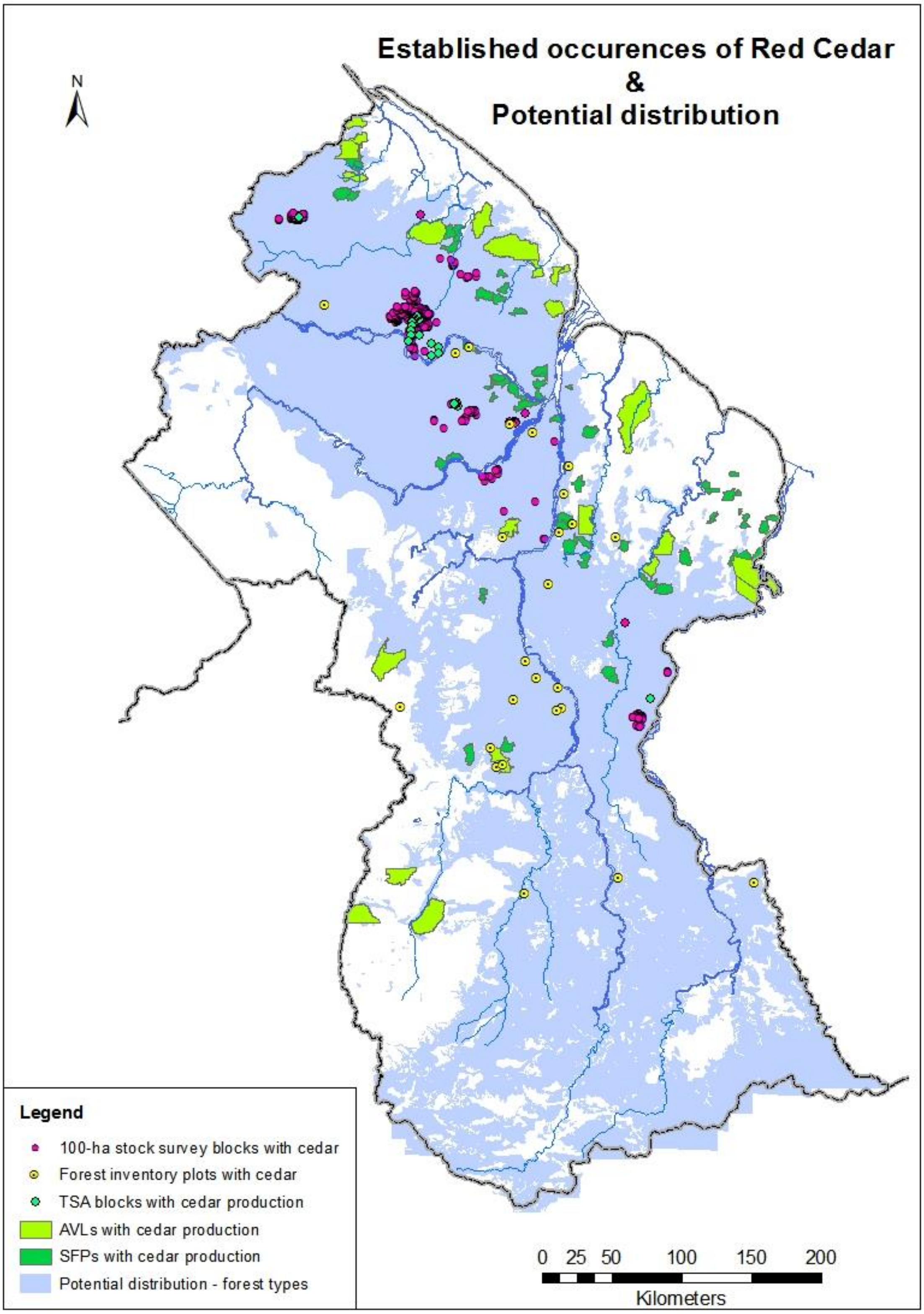

Figure 12 Established occurrences of red cedar in Guyana based on its occurrence in plots of FAO-FIDS, IFP, MLI and Iwokrama forest inventories; and production records from TSAs (block-level), and from SFPs and AVLs (concession/land level). Potential, extrapolated distribution of red cedar in Guyana based on the forest types where the species has been confirmed to occur

In terms of general geographic distribution of red cedar, the national forest inventories show that red cedar occurs in the two most important geomorphological regions of Guyana (Fanshawe, 1952); the Pre-Cambrian Lowland Region and the Sandy Rolling Lands or Berbice formation, but is also likely to occur in the Coastal Plain[11] and Southern Upland Region[12]. Soils pertaining to the Pre-Cambrian landscape are loams and clays and may contain ironstone gravel. Soils pertaining to the Berbice formation are old, infertile and highly acidic. Soil types of the Berbice formation usually correspond closely to geomorphology. An often-observed gradient from watershed to valley bottom is white sands, light brown sands, sandy loam, silty clay, pegasse. Figure 12 shows all locations where occurrence of red cedar is confirmed. The potential geographic distribution has been extrapolated based on the forest types where the species has been confirmed to occur.

5.5.1 Distribution of red cedar at local scale – the ecotope[13] level.

In Amazonian Peru and Brazil, red cedar is most common on fertile soils which are periodically flooded (Pennington, 2006, cited in CITES, 2007), as discussed above in the chapter on the description of the species. In Guyana, according to Fanshawe (1961), the species occurs occasionally in *mora* forest along creeks, seasonal forest and poor types of rain forest. Fanshawe's observations correspond to the observations by Grogan *et al* (2014) for Big-leaf Mahogany in Brazil and Gentry (no date) for red cedar in Peru, that the species tend to regenerate in forests with rather open canopies along watercourses and in the transitional zone between evergreen forest and *cerrado* in the Brazilian Amazon (Brown et al, 2003).

Local distribution of red cedar was examined by plotting red cedar trees that had been enumerated by Barama Co. Ltd. over the period 2010-2014 on 1:50,000 scale topographic map sheets (Figure 13). It appears that the local distribution of the species commonly traces creeks and that many trees are located in flood plains. See Figures 13 and 14 for examples of local distribution of red cedar in two portions of the inventoried area in the Barama Co. Ltd. concession during 2010-14.

Distances from enumerated red cedar trees to the nearest watercourse were computed with ArcGIS Near (Analysis) function. Watercourses shown on 1:50,000 topographic map sheets were traced as line features to this effect.

Table 8 Distribution of distances from enumerated red cedar trees to the nearest watercourse. Trees enumerated in 2010-2014 Barama Co. Ltd.'s stock surveys and watercourses traced as line features from 1:50,000 topographic map sheets. Distances from tree coordinates to nearest line feature were computed with ArcGIS Near (Analysis) function.

	Distance to nearest creek (m)							
	0-25	**25-50**	**50-75**	**75-100**	**100-200**	**200-500**	**>500**	**Grand Total**
No. of trees	28	29	25	24	50	81	12	249
%	11%	12%	10%	10%	20%	33%	5%	100%

It is shown in Table 8 and Figure 14 that 42% of the trees were located within 100 m distance of a creek and 22% within 50 m distance.

[11] Low-lying alluvium, which has either been reclaimed for agriculture or which still carries a complex series of forest, swamp, and marsh communities

[12] Undulating forest land and savannah, generally above 150 m in elevation

[13] The smallest ecologically distinct landscape features in a landscape mapping and classification system; an ecotope represents a relatively homogeneous, spatially explicit landscape functional unit

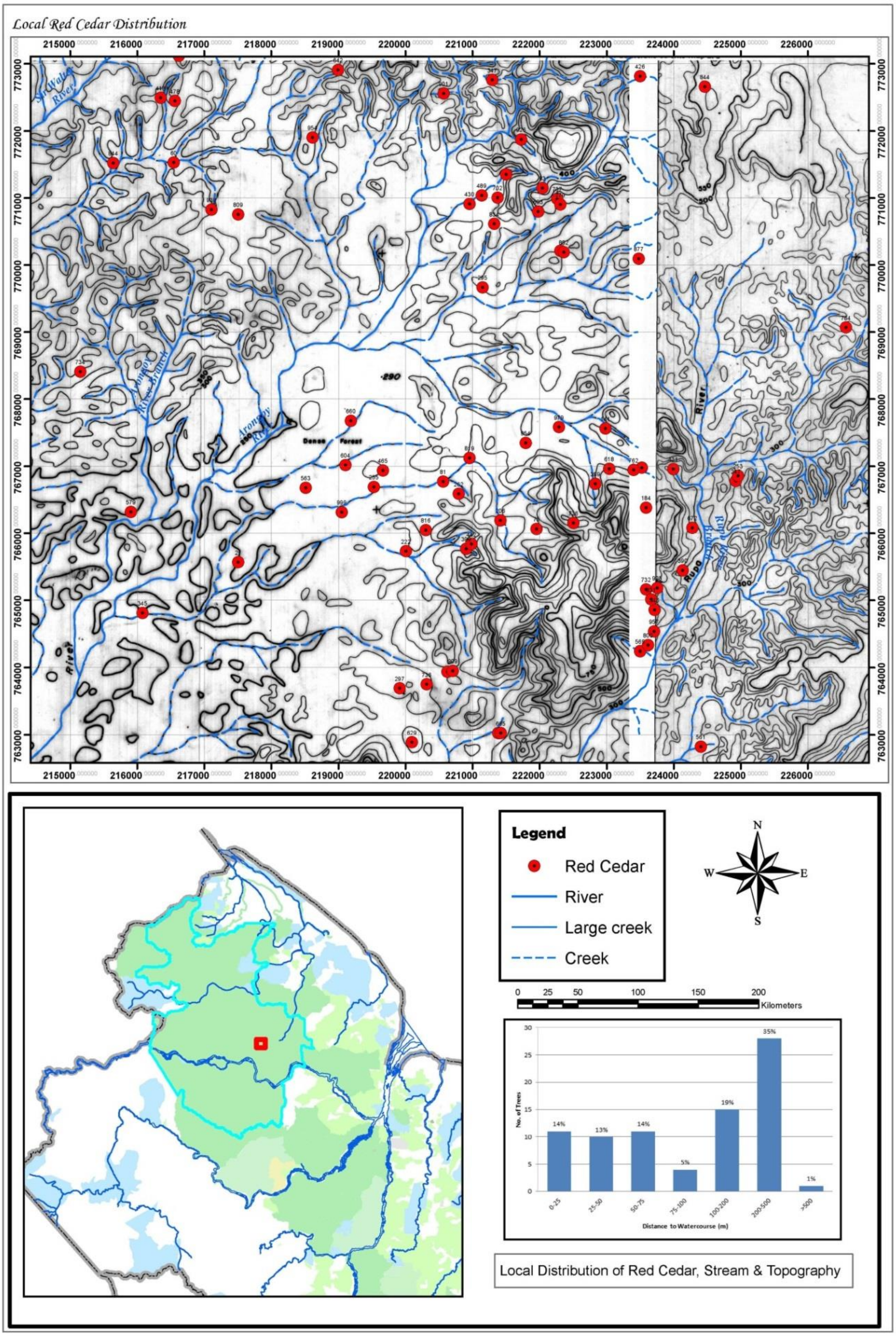

Figure 13 Map of a portion (c. 5000 ha) of the 100% pre-harvest inventory blocks in the Barama Co. Ltd. concession that were enumerated over 2010-14; showing red cedar locations, streams and topography. The smaller rectangle outlines the location of the larger map within the Barama Co. Ltd. concession.

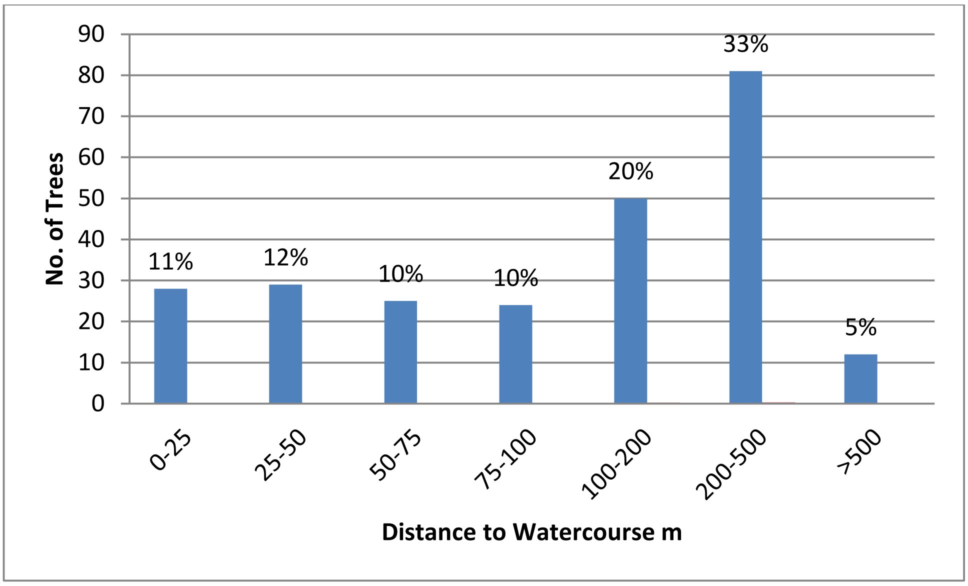

Figure 14 Distribution of distances from enumerated red cedar trees to the nearest watercourse on 1:50,000 maps. Trees were enumerated in 2010-2014 Barama Co. Ltd.'s stock surveys and watercourses are defined as shown on 1:50,000 topographic map sheets. Distances were computed with ArcGIS Near (Analysis) function.

According to Guyana's Code of Practice (2014), no trees may be felled in riparian or streamside vegetated zones (buffer zones). Buffer zone widths depend on the nature and size of the watercourse; rivers (width > 30 m) have a 30 m buffer zone on either side, creeks wider than 10 m a buffer zone of 20 m on either side, creeks narrower than 10 m a buffer zone of 10 m on either side. It can be assumed that most creeks in the surveyed area have widths less 10 m. Given the fact that the distance to the creeks is based on the distance to a linear feature, the width of the creek itself should be taken into consideration to assess whether trees fall within a buffer zone. This suggests that at least 7% of the trees fall within a buffer zone. The depiction of watercourses on the 1:50,000 map sheets are based on aerial photo interpretation (API). Because of the forest cover API results in an approximation of their true course. Moreover, small creeks (< 5 m width) are often not depicted on the map sheets. Examination of the location of the trees on the topographic map sheets further revealed that 52% of the 249 enumerated trees were located in floodplains, whereby a floodplain is defined as being limited by the first contour line from a watercourse on the topographic map sheets.

Another source of information is formed by stock maps that are prepared using 100% pre-harvest inventory tree and terrain data. The tree data in combination with their location allows identification of the forest type as defined by the dominant tree species. It appears that 47% of the 249 enumerated red cedar trees occurred in Mixed Forest, 42% in *mora* Forest, 9% in *wallaba* Forest and 2% in *greenheart* Forest.

Creeks, small streams and gullies are normally mapped during the stock survey exercise. For 23 blocks stock maps were available on which creeks, small streams and gullies were mapped. This not only implies that the location of the creeks can be known more precisely than in case of the topographic map sheets, but moreover that small creeks, (seasonal) streams and gullies are mapped that are not shown on the topographic map sheets. In the 23 blocks 35 red cedar trees were enumerated. Out of these 35 trees 71% were located within 10 m of a watercourse and as much as 94% within 20 m of a watercourse; 20% within 10 m distance from a creek and 51% within 10 m distance from a gully or seasonal stream (see Table 9)

Table 9 Distribution of distances from 35 enumerated red cedar trees to the nearest watercourse in 23 stock survey blocks. Distances from tree coordinates to nearest water feature (creek, gully or ephemeral stream) were taken from stock maps.

	Distance to nearest water feature (m)				
Type of watercourse	**0-9**	**10-19**	**20-29**	**≥30**	**Total**
Creek	7	4			11
Gully	10	2	1	1	14
Seasonal stream	8	2			10
Total	**25**	**8**	**1**	**1**	**35**

In addition, the occurrence of red cedar was verified on the ground in two pre-harvest inventory blocks; block 33-C (South-western corner UTM coordinates X = 221000 m and Y = 783000 m) and block 34-C (UTM coordinates X = 221000 m and Y = 784000 m). Besides confirming that the trees were correctly identified and the inventory concluded reasonably[14] accurately, this revealed that seven out of eight checked red cedar trees were located at close distance to seasonal streams while only one was located on "dryland". The verification exercise took place during a 10% strip sample of sub-adult red cedar trees in the two blocks.

At local scale, red cedar thus appears to occur mainly in mixed or mora forest along watercourses; particularly gullies and seasonal streams. This implies that seed dispersal may be assisted by water flows, similar to the dispersal of *Mora excelsa* seeds. In terms of forest management, an estimated 20% of the red cedar population appears to be excluded from harvesting because they occur in creek buffer zones. In addition, an estimated 50% of the population falls within gully and small stream buffer zones, where felling is allowed but machine access is not. Such trees hence need to be extracted by winching or manually.

[14] Two overlooked red cedar trees were encountered during the verification/sampling exercise

6 Density and size class frequency distribution

6.1 Density in stock surveys and forest inventories

6.1.1 Interim Forestry Project inventory (IFP)

The CIDA-financed Interim Forestry Project (1990-94) covered 32 locations (within 15 concessions) and counted 7,992 sample points. IFP plots were point samples with an average Basal Area Count Factor of 6 m^2/ha and a minimum diameter of 10 cm. Six red Cedar trees were counted among the 7,992 sample points divided over five sampling areas: Camp Jaguar, New River; Wappu compartment in Demerara Timbers Ltd.; 40-mile Linden-Mabura Road; Takatu compartment in Willems Timber & Trading Ltd.; and in Caribbean Resources Ltd. (currently Vaitarna Holding PVT Ltd.).

The average number of stems was estimated using the following equation:

$$N/ha = \frac{k}{n}\sum_{j=1}^{n}\sum_{i=1}^{z_j}\frac{1}{g_{ij}}$$

Where:

N/ha = number of stems per hectare
k = Basal Area (count) Factor (m^2/ha)
n = number of sample points
z_j = number of counted trees at the sample point
g_{ij} = basal area of the counted trees (m^2)

The average number of stems ≥ 10 cm dbh is thus estimated at 0.047 trees/ha, while the density of trees ≥ 35 cm dbh is estimated at 0.009 trees/ha.

6.1.2 Management level inventories (MLI)

The currently available data in the GEMFORM database according to the MLI design include 4,609 sample plots (Iwokrama: 874 plots, TSAs: 1,420 plots, SFPs/SLAs 1,535 plots and Barama Housing SFEP: 780 plots). The sample plots are circular line plots with lines generally set 1 km apart and sample plots were set 200m apart. Sample plots consist of a 0.1 ha circular main plot, where trees of all species from 35 cm dbh are enumerated, and a 0.02 ha nested subplot, where trees of all species between 10 cm and 35 cm dbh are enumerated. The total area covered by these inventories measures 488,564 ha with the Barama Co. Ltd. inventory of its Compartment no. 5 forming the bulk the inventoried area; i.e. 204,772 ha. The total area of SFPs/SLAs sampled covers 140,951 ha, Iwokrama 69,085 ha and the Barama Housing SFEP 47,314 ha. The overall average sampling intensity was 0.09% (TSAs: 0.06%, SFPs/SLAs 0.11%, SFEP 0.16% and Iwokrama 0.13%).

Fifteen red cedar trees were enumerated in the 4,609 sample plots, divided over six sampled concessions: Cleopatra Famey (RB Essequibo river opposite Butukari), Batavia Region 7 CDC (RB Cuyuni River and Oko Mountain), Barama Housing 2005 (RB Cuyuni River and Oko Mountain), Nazim Hussain (RB Demerara River near Ituni), Patrewta Sawmilling & Timber Co. Ltd (RB Essequibo River opposite Omai) and Rockstone Loggers Association (RB Essequibo River near Rockstone). Six out of these 15 trees were below 35 cm dbh and sampled in the subplot (0.02 ha). When considering all sampled areas, the average number of trees per ha is estimated at 0.085/ha; 10-35 cm dbh class: 0.065/ha and ≥ 35 cm dbh: 0.020/ha. This estimate is higher than the one obtained from the stock surveys, but appears to agree with the estimates of stakeholders. It must be realized that the estimates are not reliable minimum estimates and the coefficient of variation is extremely high; i.e. 3920% and 2922% respectively.

6.1.3 FAO-FIDS forest reconnaissance surveys

The FAO-supported Forest Industry Development Survey (FIDS) covered 89 locations and included 1,016 plot clusters with a combined size varying between 0.1 ha and 1 ha, where trees were enumerated from 12 inches up in 4-inch diameter classes. Five red cedar trees were enumerated divided over five sampling areas: Korotoko trail, Buru buru, Essequibo, Kwitaro River and Monkey Mountain. The average number of trees per ha above 12 inches (30 cm) dbh was estimated at 0.017/ha.

6.1.4 100% pre-harvest inventories (stock surveys)

Stock surveys conducted over the period 2010-2014 were assessed for the occurrence of red cedar. The species was encountered in 11 out of the 23 active TSAs. It appeared that a total of 393 occurrences of red cedar were reported in 224 blocks (average 1.7 trees per 100-ha block and a maximum of 7 trees per 100-ha block). During the studied period, 2728 blocks (272,800 ha) were enumerated, suggesting that red cedar occurred in 8% of the blocks that had been inventoried countrywide. It can hence be deducted that the density across all surveyed blocks was only 1 tree per 694 ha or 0.14 trees per 100-ha block.

It should be noted that stock survey information is not as reliable as true forest inventory information. First, it is not known with certainty whether red cedar is included on the species list for all stock surveys or what the minimum diameter for enumeration for the species is. Secondly, results from stock surveys may be biased because of poor species identification and because of rushed execution of some stock surveys. Red cedar is not well-known among tree spotters as shown by verification of red cedar specimens in five blocks in four concessions, which took place in April and in August 2015. In three concessions other species such as *Apeiba petoumo* (duru), *Bombax* sp. (kamakuti), *Calophyllum lucidum* (kurahara), *Humiria balsamifera* var. *balsamifera* (tauroniro), or *Tabebuia insignis* var. *monophylla* (white cedar) trees had been mistakenly identified as red cedar. In four blocks in two other concessions, where three and twelve harvestable red cedar trees respectively were recorded during stock surveys, the species was correctly identified but the verification exercise also showed that two harvestable red cedar trees were overlooked during stock surveys in each concession.

The most reliable stock survey seems to be the one carried out by Barama Co. Ltd., where 249 red cedar trees were found in 142 out of the 1033 blocks (14%) that were surveyed over the period 2010-14; indicating a density of 0.24 tree per 100 ha. As mentioned above, the verification exercise showed that two trees had been overlooked; translating to 14% of the trees. The likely density was therefore adjusted upward and is presumed to be 0.30 trees ≥ 40 cm dbh per 100 ha from this point onwards.

6.1.5 *Estimated density of Red Cedar trees in Guyana*

The estimated average density of red cedar ≥ 10 cm dbh ranges from 1 tree per 60 hectares or 0.017 trees/ha (FAO-FIDS) to 1 tree per 12 hectares or 0.085 trees/ha (MLI) according to the national forest inventories. The estimated density of trees ≥ 35 cm dbh ranges from 1 tree per 118 hectares or 0.009 trees/ha (IFP) to 1 tree per 51 hectares or 0.020 trees/ha (MLI).

Stock surveys conducted between 2010 and 2014 suggest a much lower density of trees with dbh ≥ 40 cm; only 1 tree per 694 ha or 0.14 tree per 100 ha. Given the observation that most stock surveys are unreliable where it comes to red cedar, the corrected estimated based on Barama Co. Ltd's stock survey suggests a density of 0.30 tree ≥ 40 cm dbh per 100 ha. The species is thus definitely rare in Guyana [< 1 tree/ha; *cf* Hubbell & Foster (1986)], and could even be regarded as very rare [less than 1 tree per 100 ha; *cf* Schulze *et al* (2008)] based on the stock surveys that were conducted during 2010-14.

6.2 Size class frequency distribution in stock surveys and forest inventories

The diameter class frequency distributions vary widely between the inventories (Table 10, Figure 15). The size-class structures recorded in the three national forest inventories are all reverse-J-shaped, with progressively lower stem numbers in successive diameter classes indicating a favourable population structure for sustainable forest management.

Table 10 Diameter class frequency distribution in numbers of trees per 100 ha for red cedar in 224 stock survey blocks (blocks with red cedar only) and three national forest inventories

Forest inventory	Diameter class in cm								Totals		
	10-20	20-34	35-44	45-54	55-64	65-74	75-84	85+	10-34	≥ 35	≥ 55
Stock surveys	-	-	0.11	0.43	0.42	0.38	0.17	0.25	-	1.75	1.22
FAO-FIDS[15]	-	-	1.08	0.20	0.20	0.00	0.00	0.20	-	1.67	0.39
IFP	0.00	3.80	0.57	0.00	0.00	0.00	0.15	0.13	3.80	0.85	0.28
MLI	4.34	2.17	0.43	0.65	0.43	0.22	0.22	0.00	6.51	1.95	0.87

In 1898, the French forester de Liocourt observed that the size distribution of stems in an uneven-aged natural forest tended to form a reverse-J curve or negative exponential distribution, in which the ratio of stem numbers in adjacent size classes remains constant, provided the size classes are the same width: n1 /n2 = n2 /n3 = n3 /n4 = . . . This ratio is known as de Liocourt's quotient, q (Vanclay, 1994). According to De Liocourt (1898; in Alder, 1995) numbers in successive diameter classes of a stand table for an uneven-aged forest tend to form a geometric series, such that the ratio between successive classes have the same constant ratio (Q). This ratio (Q) between classes is usually termed the De Liocourt Quotient. Meyer (1933; in Alder, 1995) showed that a diameter class distribution with constant Q-ratio values was mathematically equivalent to an exponential distribution. The exponential distribution for tree numbers with respect to diameter can be expressed as:

$$N_d = N_T \cdot (1 - \exp(-\alpha \cdot (d - d_0))$$

[15] FAO-FIDS reconnaissance survey enumerated trees in 4-inch diameter classes starting from 12 inches. Header row for this inventory reads 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80+, 10-30, ≥ 30, ≥ 50

where, N_d is the total number of trees up to diameter d, N_T Is the total number of trees, d_0 is the lower limit of the smallest diameter class, and α Is an empirical constant. The higher the value of α the steeper is the progressive decline in stem numbers from smaller to the larger diameter classes.

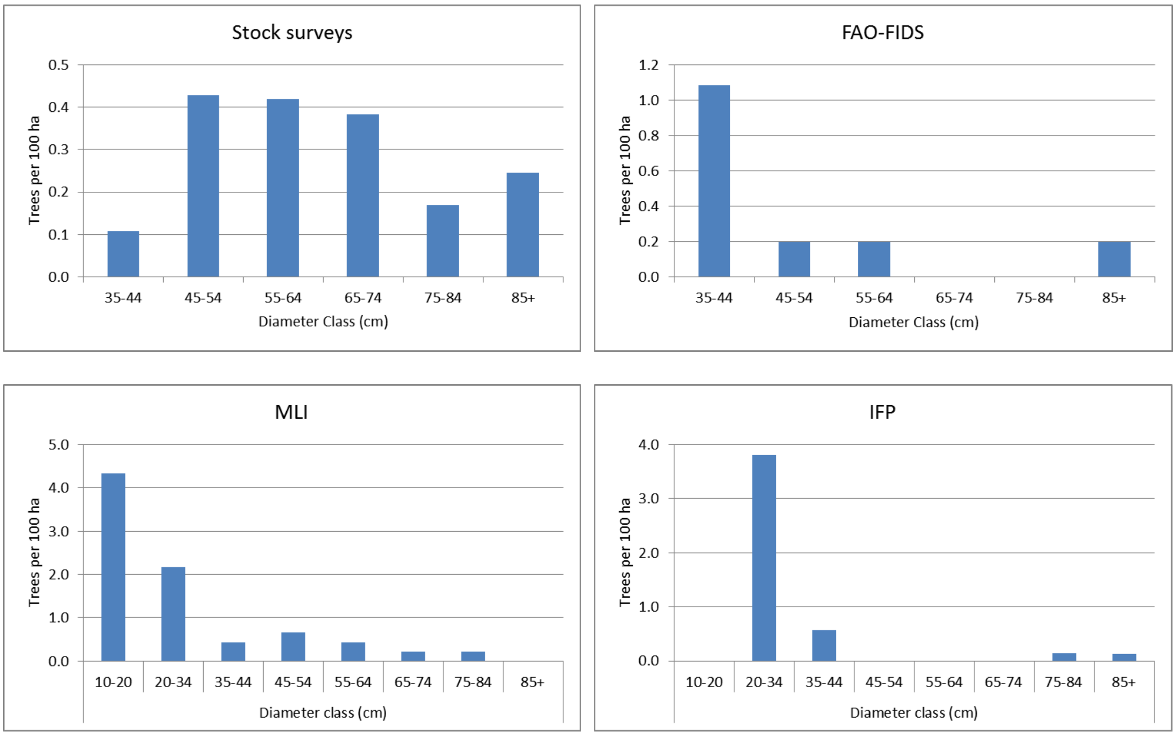

Figure 15 Density of red cedar trees in diameter classes (n/100 ha) in stock surveys (393 trees); and FAO-FIDS (5 trees), IFP (6 trees) and MLI (15 trees) inventories (note different Y-axis scales).

The diameter class distributions found for the national inventories (pooled plots) do not deviate from an exponential (De Liocourt) distribution, but the distribution according to the stock surveys (pooled blocks) does (Table 11). It must be realized that in mixed tropical stands the premise of a constant De Liocourt Quotient generally does not hold well and many commercially valuable species are likely to have an irregular distribution (Alder 1995).

Table 11 De Liocourt ratios for red cedar in the three national inventories an stock surveys, constant α in exponential distribution equations, Chi-square statistic and probability of deviation from expected distribution with given value α ; distributions found for the national inventories (pooled plots) do not deviate significantly from an exponential (De Liocourt) distribution, but the distribution according to the stock surveys (pooled blocks) does.

	Mean 'De Liocourt' - ratio	Value of α	$\chi^2_{0.05}$ -value	Degrees of freedom	Probability
Stock surveys	1.53	0.026	250.37	12	<0.001
FAO-FIDS[16]	-	0.048	1.49	7	0.91
IFP	-	0.051	9.16	5	0.24
MLI	1.40	0.059	4.71	7	0.69

A depression in the 35–45 cm class and increasing densities again towards larger size classes are shown for the MLI inventories; depressions in the 65-84 cm classes in the FAO-FIDS surveys and 45-

[16] Average De Liocourt ratio not available due to zero values in one or more diameter classes.

74 cm classes in the IFP point samples. Such depressions could coincide with the size at which the trees reach their maximum growth rates, and may thus be caused by faster growth through these size classes followed by accumulation at larger size classes with lower growth rates. However, it must be realized that the trees in the size-class structures in Figure 15 belong to different populations and, moreover, are based on very small numbers of trees.

The size-class structure shown for the combined stock survey shows the opposite with fewer juveniles than adults and no depressions in the mid-size classes, but with a depression in the 35–45 cm class just like observed in the MLI inventories. This depression could be due to minimum diameter that was stipulated for the stock survey, which could be higher than 35 cm dbh in certain stock surveys. To further analyse the population structures, stock surveys within some concessions were studied separately.

Four out of five size-class structures of the five geographically separated red cedar 'populations' show lower frequencies in the 40-49 cm class than in the 50-59 class (Figure 16). The population at Bai Shan Lin (East-Guyana) shows deficiency in all lower diameter classes (40-69 cm). Based on the records it can safely be assumed that these stock surveys used a minimum diameter limit of 40 cm; only three trees below 40 cm were recorded. None of the size-class structures is reverse-J-shaped; i.e., fewer juveniles than adults were recorded indicating an unfavourable population structure for sustainable forest management.

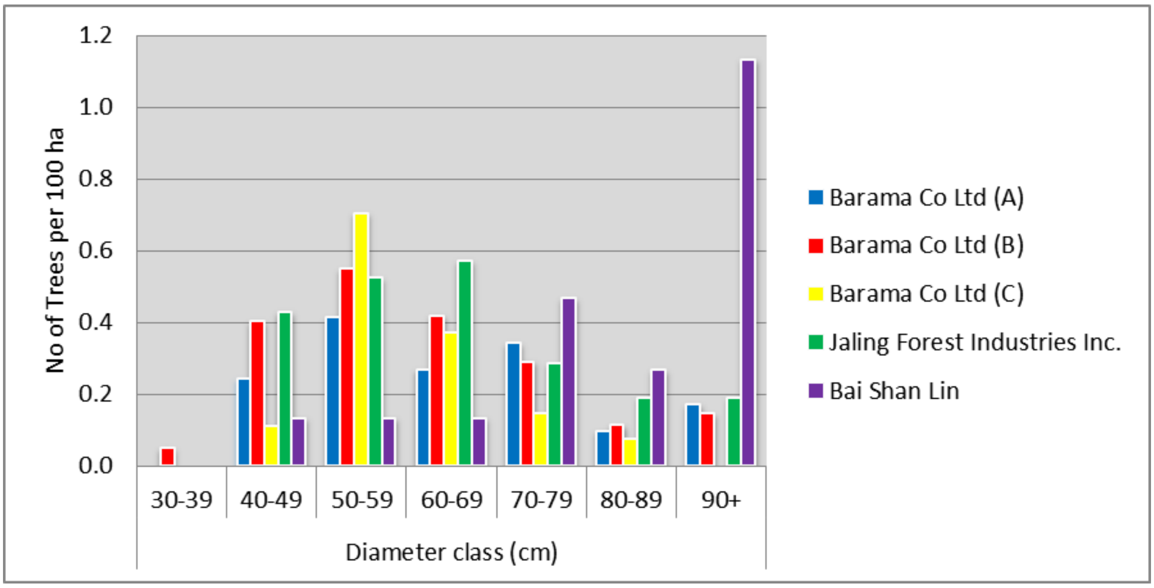

Figure 16 Size-class structures of five geographically segregated red cedar 'populations'. Barama Co Ltd (A) - covers 41 blocks situated between UTM X = 203060, Y = 763021 and X = 221290, Y = 774053 (18 x 11 km); Barama Co Ltd (B) - 62 blocks situated between UTM X = 216075, Y = 756398 and X = 236180, Y = 773470 (20 x 17 km); Barama Co Ltd (C) - 27 blocks situated between UTM X = 215680, Y = 738650 and X = 227960, Y = 757754 (12 x 19 km); Jaling Forest Industries Inc. - 21 blocks situated between UTM X = 123302, Y = 836044 and X = 142108, Y = 840800 (19 x 5 km); Bai Shan Lin - 15 blocks situated between UTM X = 376880, Y = 473257 and X = 383825, Y = 483305 (7 x 10 km)

Records on juveniles (dbh < 35 cm) are only available from national forest inventories and are basically inconclusive; being based on 11 records only.

10% strip samples were conducted in April 2015 and August 2015 in four 100% pre-harvest inventory blocks that were surveyed in 2014, two of these blocks were in the Barama Co. Ltd. concession and two in the Vaitarna Holding PVT Ltd. concession. The blocks in the Barama Co. Ltd. concession were not harvested yet, implying that sub-adult red cedar trees had not suffered any logging damage or might have been overlooked due to felling gaps. The strip sample consisted of 5 equally spaced strips in the 4 blocks, resulting in a sample of 20 strips in all. The centre line of each 20-m wide strip coincided with a central strip line established by companies in order to save time. The first line was randomly selected (central line of either strip 1 or strip 2) and subsequent lines were spaced 200 m apart. Trees would be included in the sample if their centre was located within 10 m of either side of the centre line.

Only one sub-adult tree with a diameter of 39 cm dbh was recorded in the sample resulting in an estimated mean density of sub-adults of 5 trees per 100-ha for the Barama Co. Ltd. concession. The sample was relatively small and the statistical error in the reported mean density is rather great; the 95% confidence interval of the mean is 5 ± 11 trees per 100-ha.

6.3 Volumes of red cedar in stock surveys and forest inventories

6.3.1 Volumes in national forest inventories

In the Management level inventories (MLI) surveys, nine harvestable red cedar trees ≥ 35 cm dbh were enumerated in the 4,609 sample plots, divided over four of the sampled concessions. When considering all sampled areas, the average volume per ha is estimated at 0.08 m^3/ha.

During the Interim Forestry Project (1990-94) three red cedar trees ≥ 35 cm dbh were counted at the 7,992 sample points divided over three sampling areas. The average volume is estimated using the following equation:

$$V/ha = \frac{k}{n}\sum_{j=1}^{n}\sum_{i=1}^{z_j}\frac{v_{ij}}{g_{ij}}$$

Where:

V/ha = volume per hectare
k = Basal Area (count) Factor (m^2/ha)
n = number of sample points
z_j = number of counted trees at the sample point
g_{ij} = basal area of each counted tree (m^2)
v_{ij} = volume of each counted tree (m^3)

The average volume was thus estimated at 0.028 m^3/ha.

Three red cedar trees ≥ 16 inch dbh were enumerated during the FAO-supported Forest Industry Development Survey (FIDS). The average volume per ha above 40 cm dbh was estimated at 0.024 m^3/ha.

6.3.2 Volumes in 100% pre-harvest inventories

A total volume of 1,121 m^3 was reported for the 224 blocks where red cedar was encountered during 2010-14 with and a maximum of 37.9 m^3 per 100-ha block. As mentioned before, 2728 blocks (272,800 ha) had been enumerated during the period, implying that red cedar occurred in 8% of the blocks that had been inventoried countrywide. It can hence be deducted that the average volume for all blocks that were surveyed during 2010-14 amounted to 0.4 m^3 per 100-ha block. This estimate is more than 10 times less than the one found based on the MLI inventories.

As mentioned in section 6.1.4, many stock surveys did not prove to be reliable where it concerns enumeration of red cedar trees and the most reliable stock survey seems to be the one by Barama Co. Ltd. The 249 red cedar trees that were enumerated in that concession over the period 2010-14 had a total volume of 629.5 m^3; indicating a volume of 0.61 m^3 per 100 ha. Based on the assessment that also in those stock surveys some trees were overlooked, the estimate is adjusted upwards to 0.76 m^3 per 100 ha.

The estimated volume of red cedar ≥ 35 cm dbh thus ranges from 2.4 m^3 per 100 ha (FAO-FIDS) to 6.0 m^3 per 100 ha (MLI) according to the national forest inventories. Stock surveys conducted between 2010 and 2014 suggest a much lower volume; i.e., 0.76 m^3 per 100 ha.

7 Regeneration dynamics and sustainable harvest levels

7.1 Growth and yield of red cedar in Guyana

Permanent sample plots have been the single most important source of tree growth data of tropical trees. Data from permanent plots are used to project tree growth over long time spans and calculate timber yields with growth models (e.g., Alder, 2000, 2001, 2008). In Guyana, PSP data are available for two locations; the Tropenbos Pibiri plots established in the Demerara Timbers Ltd concession in Central Guyana in 1993 and plots established by the Edinburgh Centre for Tropical Forests (ECTF) in 1993 in the North-West District near Port Kaituma in Barama Co. Ltd.'s Compartment 1.

A classical method to estimate (stand) growth is diameter class or stand table projection, which is one of the oldest techniques used to determine the future composition of uneven-aged forests, with numerous examples in the literature and in standard textbooks (e.g. Husch et al. 1982, Vanclay 1994, Alder 1995). The basic concept of the classical diameter class projection model is that the forest is represented as a stand table of tree numbers classified by diameter classes; usually of equal width (e.g. 10–19, 20–29, …, 100+ cm dbh). The method predicts the future stand table from the present stand table by adjusting each entry in the table with the estimated diameter increment and mortality for that class; calculated over an interval of for instance 5-10 year using periodic increment data. The revised table is then used as the starting point to repeat the calculations. Increment, mortality and ingrowth observations made from PSPS or from literature may be used to estimate growth over a full felling cycle or rotation, which may be 25 years or more. It is often difficult to compile outgrowth rates directly from PSP data and it will need to be estimated from mean increment for a diameter class. Such approach assumes that trees in each diameter class are uniformly distributed through the class and that each tree grows at the average rate; the so-called Uniform Distribution, Mean Increment assumptions (Alder 1995). For each class, a 'movement ratio' is then determined from the class width and average increment, and this indicates the number of trees moving to the next class (Vanclay 1994, Alder 1995).

According to Alder (2000), three red cedar specimens occurred in the PSPs mentioned earlier. Average diameter increment of the three red cedar trees averaged 0.82 cm/yr. (SE% 42.2%). Because the increment and mortality data for red cedar in Guyana are so limited, it is decided to revert to data from Brienen & Zuidema (2006a, 2006b) from Bolivia to estimate the time needed to recuperate harvested volumes. Based on tree ring analysis for red cedar, Brienen & Zuidema (2006a) found the longest passage time in the smallest size class (0–10 cm diameter). This is most likely caused by low growth rates because of limiting light availability in the understorey. Species such as red cedar are thought to require releases from understorey light levels by canopy disturbances (e.g. tree and branch falls) to enable them to reach the canopy. Brienen & Zuidema (2006a) accounted for mortality using an annual rate of 2%. Mortality rates are highest in the smallest diameter class due to the longer time of passage and decrease in subsequent diameter classes due to increasingly shorter times of passage.

7.2 Stand table projection without intervention based on MLI inventory

A simple stand table projection model was constructed based on Uniform Distribution, Mean Increment assumptions (Husch *et al*. 1982, Alder 1995) and published data from Brienen & Zuidema (2006a), which are shown in Table 12. The Inventory data for the original stand table is taken from the pooled MLI inventory data (4,609 plots of 0.1 ha). Initially, recruitment into the smallest diameter class (10-20 cm dbh) was emulated in a way to achieve a constant ingrowth (see Table 13 and Figure 17).

Table 12 Median time of passage and mortality through 10-cm diameter classes for red cedar according to Brienen & Zuidema (2006a)

Diameter class (cm)	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	≥100
Time of passage	16	12	9	7	7	9	12	12	12	n/a
Increment cm/yr	0.63	0.83	1.11	1.43	1.43	1.11	0.82	0.82	0.82	0.63
Outgrowth %/5-yr	31.3%	41.7%	55.6%	71.4%	71.4%	55.6%	41.0%	41.0%	41.0%	0.0%
Mortality % / time of passage	27.6%	21.5%	16.6%	13.2%	13.2%	16.6%	21.8%	21.8%	21.8%	n/a

Table 13 Stand table projection for red cedar without intervention; initial stand structure based on the pooled MLI inventory data; stem numbers as recorded in all MLI plots (460.9 ha), expressed per 100 ha

Projection year	Diameter class (cm)										Total
	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	≥100	
0	**4.3**	**2.2**	**0.2**	**0.7**	**0.4**	**0.2**	**0.2**	**0.2**			**8.5**
5	4.3	2.4	0.9	0.3	0.5	0.4	0.2	0.2	0.1		9.2
10	4.4	2.5	1.4	0.1	0.4	0.5	0.2	0.2	0.1		9.9
15	4.6	2.6	1.1	0.8	0.1	0.6	0.4	0.2	0.2		10.6
20	4.3	2.6	1.6	0.9	0.5	0.3	0.6	0.2	0.1	0.1	11.1
25	**4.3**	**2.7**	**1.6**	**0.9**	**0.8**	**0.2**	**0.6**	**0.3**	**0.1**	**0.1**	**11.6**
30	4.3	2.6	1.7	1.0	0.8	0.6	0.3	0.4	0.1	0.2	12.1
35	4.3	2.6	1.8	0.8	0.9	0.9	0.4	0.5	0.2	0.2	12.5
40	4.3	2.6	1.6	1.2	0.8	1.0	0.6	0.4	0.2	0.2	12.9
45	4.3	2.6	1.6	1.0	1.0	1.1	0.9	0.2	0.3	0.3	13.3
50	**4.3**	**2.6**	**1.6**	**1.0**	**1.1**	**0.9**	**1.0**	**0.4**	**0.3**	**0.3**	**13.6**

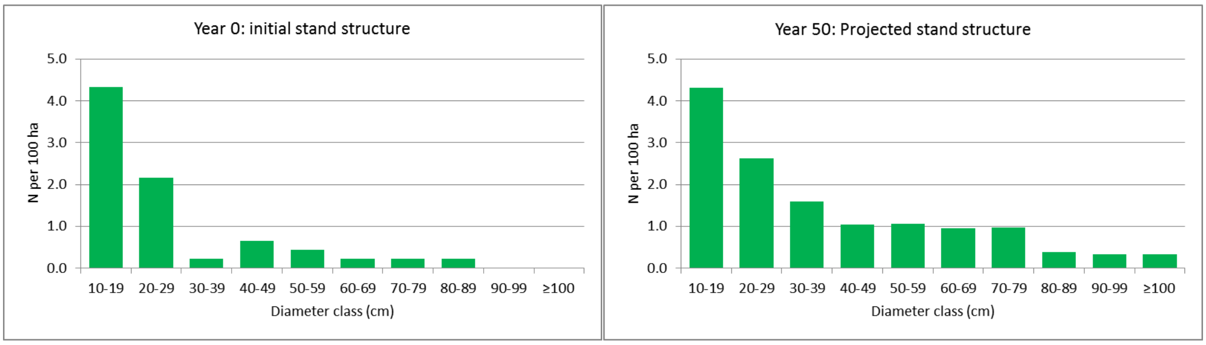

Figure 17 Initial size-class structure of red cedar (left) and projected size-class structure after 50-yr with no intervention (right). Initial size-class structure is based on pooled MLI inventory data; stem numbers expressed per 100 ha; growth and yield projection is based on time of passage and mortality figures from Brienen & Zuidema (2006a); stem numbers expressed per 100 ha.

Size class projection based on the increment and mortality data in Table 12, while maintaining a constant level of recruitment and without intervention, results in a strong increase in adult stems after 50 years and hence does not reflect the stand structure found for the larger trees in the pooled MLI inventory plots or the pooled stock surveys. The encountered stand structure can be attained by applying a lower recruitment rate or an increased mortality rate. Unfortunately, data relating to the 0-10 cm diameter class are non-existent in Guyana while data relating to the diameter classes 10-39 cm are very limited. Densities in the 10-39 cm size classes are therefore inferred based on the increment and mortality rates published by Brienen & Zuidema (2006a). Recruitment into the 10-19 cm size class is set at such a constant rate (0.1 stem/100-ha/yr.) that the total number of trees ≥ 40 cm dbh remains stable. Ignoring the inventory results and constructing the stand table based on this recruitment rate and the parameters published by Brienen & Zuidema (2006a) results in a stable stand structure as portrayed in Figure 18.

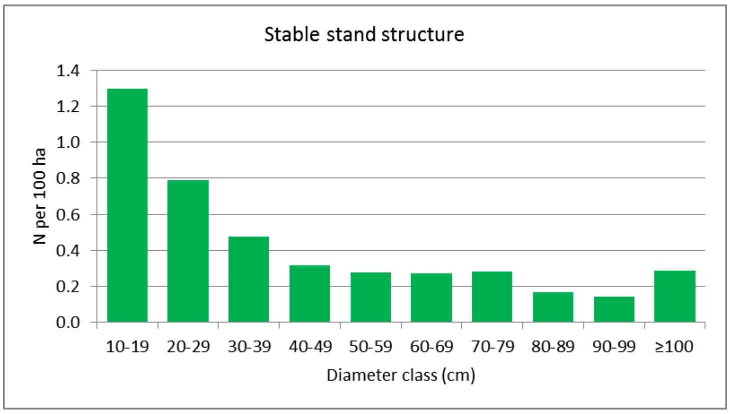

Figure 18 Stable size-class structure of red cedar after 100-yr projection without any intervention. Initial size-class structure set at zero density for all size classes; annual recruitment set at 0.1 stems/100-ha; stem numbers expressed per 100 ha; growth and yield projection is based on time of passage from Brienen & Zuidema (2006a); stem numbers expressed per 100 ha.

7.3 Stand table projection without intervention based on 100% pre-harvest inventory

The size-class structure of the pooled MLI inventory data is based on scarce data with a high sampling error (see section 6.1.2). The size-class structure suggested by the MLI inventories yields a greater number of harvestable red cedar trees (assumed to be ≥ 40 cm dbh for practical purposes) as the stock surveys where red cedar was encountered (Table 14 and Figure 19). The stock surveys cover a much larger area and therefore provide a better estimate of the stand structure, but do not provide information on the size classes < 40 cm dbh. Densities in these size classes were emulated based on De Liocourt Quotients of the stable stand structure in Figure 18. Recruitment into the 10-19 cm size class was set at a constant rate in such a way that the total number of trees ≥ 40 cm dbh remained stable.

Table 14 Stand table projection for red cedar without intervention; initial stand structure based on the pooled stock survey data. Stand table projection is based on time of passage and mortality figures from Brienen & Zuidema (2006a). Stem numbers are expressed per 100 ha.

Projection year	Diameter class (cm)										Total
	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	≥100	
0	**0.17**	**0.10**	**0.06**	**0.04**	**0.08**	**0.06**	**0.05**	**0.02**	**0.02**	**0.02**	**0.63**
5	0.16	0.10	0.06	0.04	0.05	0.08	0.06	0.03	0.02	0.02	0.63
10	0.17	0.10	0.07	0.03	0.03	0.07	0.07	0.04	0.02	0.03	0.63
15	0.17	0.10	0.05	0.05	0.03	0.05	0.08	0.04	0.02	0.03	0.63
20	0.16	0.10	0.06	0.04	0.04	0.04	0.08	0.05	0.03	0.03	0.62
25	**0.16**	**0.10**	**0.06**	**0.04**	**0.04**	**0.04**	**0.06**	**0.06**	**0.03**	**0.04**	**0.62**
30	0.16	0.10	0.07	0.04	0.04	0.04	0.04	0.07	0.04	0.04	0.62
35	0.16	0.10	0.07	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.62
40	0.16	0.10	0.06	0.04	0.03	0.04	0.04	0.04	0.05	0.06	0.62
45	0.16	0.10	0.06	0.04	0.04	0.04	0.04	0.03	0.05	0.07	0.62
50	**0.16**	**0.10**	**0.06**	**0.04**	**0.04**	**0.04**	**0.04**	**0.03**	**0.03**	**0.08**	**0.62**

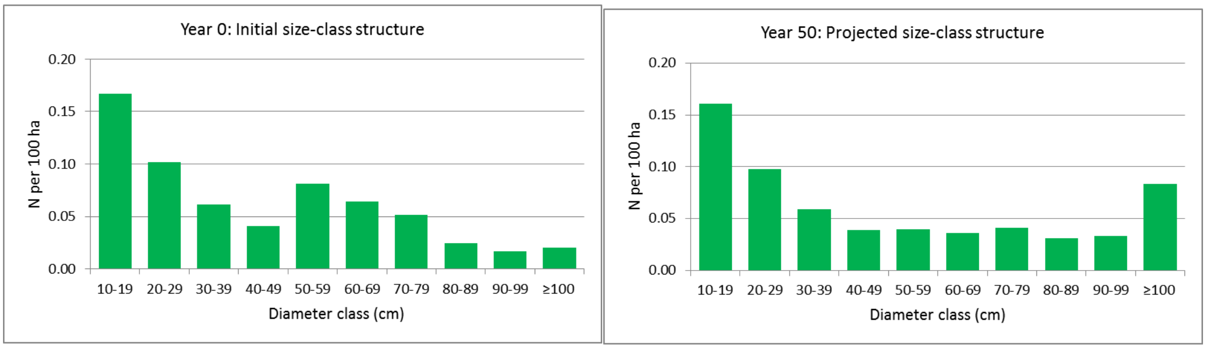

Figure 19 Initial size-class structure of red cedar (left) and projected size-class structure after 50-yr without intervention (right). Initial size-class structure is based on pooled stock survey data; stand table projection is based on time of passage and mortality figures from Brienen & Zuidema (2006a). Stem numbers are expressed per 100 ha.

7.4 Stand table projection of harvested stands

Stand table projection of harvested stands applied a minimum cutting diameter limit of 40 cm (set 6 cm above the legal minimum cutting diameter limit for practical purpose), assumed no trees are defective, assumed no logging or natural damage inflicted to red cedar trees, and a cutting cycle of 25 years. Recruitment into the 10-19 cm class was reduced in proportion to the reduction in trees ≥ 20 cm diameter in each subsequent modelling interval, but because the time of passage through the 0-10 cm size class is estimated at 20 years (Brienen & Zuidema 2006a) this reduction is applied starting from year 20. This implies that the impact of harvesting all trees ≥ 40 cm at first harvest on recruitment is deferred by 20 years. The impact of removing parent trees on the recruitment after the second harvest will therefore not be as big as the effect after the third harvest after 50 years.

Progressive reduction in recruitment after year 20 and a slow transition into the 40-49 cm dbh size class implies that the volume taken at the first harvest cannot be sustained with the given recruitment, increment and mortality rates. The pooled stock surveys would yield an estimated harvest of 0.30 red cedar stem ≥ 40 cm dbh per 100-ha at first harvest. The simple model suggests that only 40% of this initial harvest (0.12 stem/100-ha) would recuperate after one logging cycle of 25 years (Table 15 and Figure 20). After a third harvest after 50 years, 35% of the initial harvest (0.10 stem/100-ha) would still be available, but harvests would dwindle afterwards because of the progressive decline in recruitment. Stand table projection with the given assumptions indicates that the maximum size a tree (of 39 cm dbh) can attain within one cutting cycle of 25 years is 71 cm dbh.

Application of a net form height factor of 12.61 (Alder 2000) yields an initial volume at first harvest (MCDL =40 cm dbh; Year 0) of 1.49 m^3 per 100 ha. At the second harvest (year 25) the volume will have declined to 0.38 m^3/100-ha (26% of the initial harvest volume), at the third harvest (year 50) to 0.34 m^3/100-ha, at the fourth harvest (year 75) to 0.28 m^3/100-ha and at the fifth harvest (year 100) to 0.17 m^3/ha. The strong reduction in volume after the first harvest is associated with the presence of large (dbh ≥ 70 cm) old-growth trees at the first harvest ('primary forest premium'). Brienen & Zuidema (2006b) also found that projected yields for a second harvest after 20 years in Bolivia were much lower than initial harvests (recuperation of less than 30%). The further reduction after the third harvest in year 25 is due to a reduction in recruitment into the 10-20 cm size class which is caused by the first harvest in year 0.

Table 15 Stand table projection for red cedar with complete harvest of all stems ≥ 40 cm dbh in years 0, 25 and 50; initial stand structure based on the pooled stock survey data; densities shown in red italic are the trees that are harvested. Stem numbers are expressed per 100 ha.

Projection year	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	≥100	Total
0	**0.17**	**0.10**	**0.06**	***0.04***	***0.08***	***0.06***	***0.05***	***0.02***	***0.02***	***0.02***	**0.63**
5	0.16	0.10	0.06	0.03							0.36
10	0.17	0.10	0.07	0.04	0.02						0.38
15	0.17	0.10	0.05	0.05	0.03						0.40
20	0.16	0.10	0.06	0.04	0.04	0.03					0.42
25	**0.16**	**0.08**	**0.06**	***0.04***	***0.04***	***0.04***	***0.01***				**0.42**
30	0.13	0.09	0.06	0.03							0.30
35	0.11	0.09	0.05	0.03	0.02						0.30
40	0.09	0.10	0.04	0.04	0.03						0.31
45	0.08	0.07	0.06	0.03	0.03	0.02					0.31
50	**0.09**	**0.06**	**0.06**	***0.03***	***0.03***	***0.03***	***0.01***				**0.30**

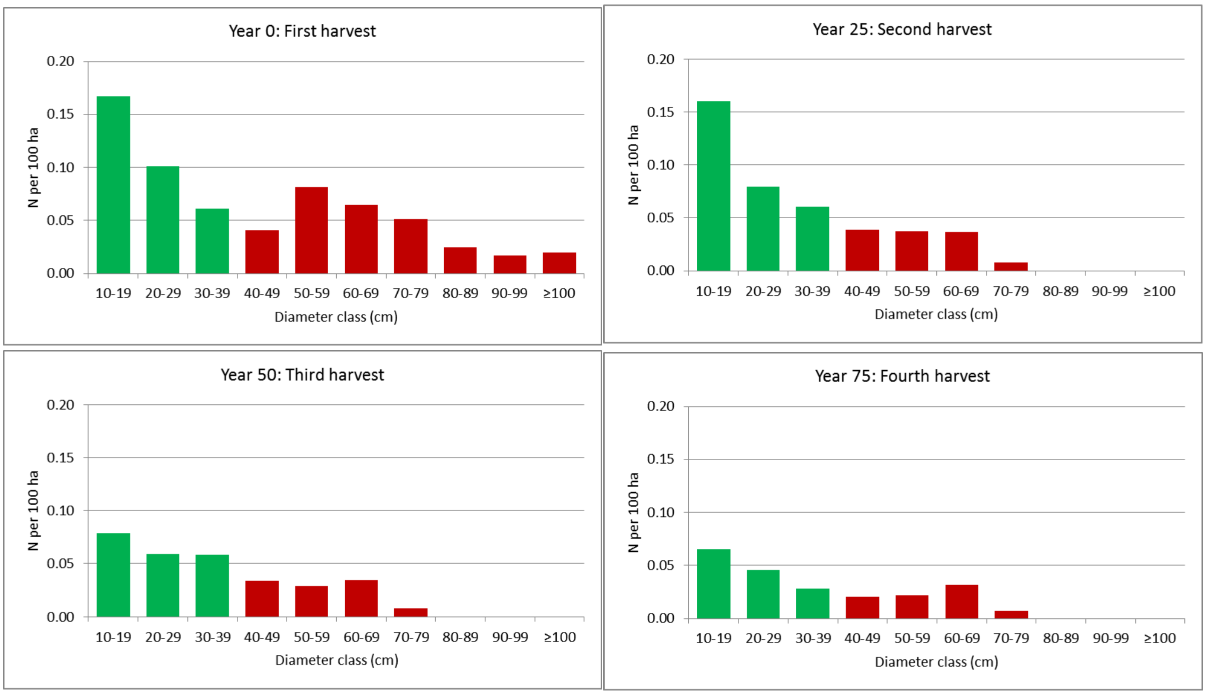

Figure 20 Size-class structure of red cedar at first harvest (top-left), projected size-class structure at second harvest after 25-yr. (top-right), third harvest after 50-yr (bottom-left), fourth harvest after 75 yr. (bottom-right). Red bars indicate harvestable trees and green bars unharvested trees. Initial size-class structure is based on the average structure found in stock surveys; stem numbers expressed per 100 ha; growth and yield projection is based on time of passage and mortality figures for each 10-cm diameter class from Brienen & Zuidema (2006a).

The result is strongly influenced by the assumption that the level of recruitment is reduced in direct proportion to the reduction in the number of trees ≥ 20 cm dbh at each 5-year modelling interval, no logging or natural damage is inflicted to red cedar trees, and no trees are defective. The model shows the importance of knowledge about recruitment and about differences in increment and mortality rates among diameter classes. As previously postulated by Alder (2002) availability of data down to a 10-cm diameter limit (e.g. by subsampling during 100% stock surveys) would provide data that can be used for management and projection with a much higher degree of confidence and utility.

7.5 Forest management and yield regulation in Guyana

Yield regulation in Guyana is based on a stipulated maximum annual allowable cut of 20 m^3/ha over a 60 year cutting cycle for all merchantable species combined (*i.e.* assuming a mean annual volume increment of the entire species group of ⅓ m^3/ha/yr.). The stipulated AAC is not generally achieved due to limited availability of marketable species of minimum size and quality and the concessionaire can opt for a lower AAC. The majority of large concessionaires apply a 25-year cutting cycle instead of a 60-year cycle and therefore apply a prorated maximum allowable cut of (25 × 0.33 =) 8.33 m^3/ha. The smallest forest management unit is a 100-ha block (the same unit as used for the 100% pre-harvest inventory). The allowable cut is determined and monitored for each individual block based on the 100% pre-harvest inventory. The Maximum Allowable Cut is the lower volume figure of the (prorated) AAC and the Inventoried Volume. Based on the allowable cut a number of log tags to be issued is computed to monitor the log quota for each block.

The annual log quota for SFP holders are determined by the GFC on a case by case basis for the entire SFP (hence not for individual 100-ha blocks), based on the 20 m^3/ha over a 60-year cutting cycle and an assumed 80% net productive forest area. SFP holders receive a fixed number of tags per year based on the quota calculation. SFP holders are thus not required to conduct a pre-harvest inventory or prepare any management or operational plans. They are required to tag logs and stumps according to the log-tracking system.

7.5.1 Effect of retention of buffer zone trees on sustainable yield

According to Guyana's Code of Practice (2014), no trees may be felled in riparian or streamside buffer zones. The prescribed buffer zone widths depend on the type of protected area or watercourse; i.e., 30 m on either side of rivers, 20 m on either side of creeks wider than 10 m, 10 m on either side of creeks less than 10 m wide, and no machine access 10 m on either side of gullies although felling is allowed along gullies. As shown in section 5.5.1, an estimated 20% of the red cedar trees occur in creek buffer zones and would therefore be excluded from harvesting.

Stand projection was carried out whereby buffer zone trees were excluded resulting in a reduction of the allowable yield by 20%. It is assumed that seeds from retained trees in the buffer zone are also dispersed beyond the buffer zone borders and that recruitment originating from buffer zone trees takes place outside the buffer zone. This improves sustainability of the harvestable volume in future cutting cycles; at the first and second cut the harvested volume is reduced to 80% compared to a complete harvest of all available stems (i.e. 0.24 and 0.10 stem per 100 ha), but afterwards the size of the harvest starts to approach levels achieved with all stems harvested due to improved regeneration levels; at the fourth and fifth cut the proportions available will be 86% and 91% (0.07 and 0.05 stems per 100-ha) compared to a harvest of all available stems (Table 16 and Figure 21). At the first harvest the volume will be 1.20 m^3/100-ha, but at the second harvest (year 25) the volume will have declined to 0.31 m^3/100-ha, at the third harvest (year 50) to 0.28 m^3/100-ha, at the fourth harvest (year 75) to 0.24 m^3/100-ha and at the fifth harvest (year 100) to 0.16 m^3/ha. Although this harvesting regime still does not result in truly sustained yields, it forms a substantial improvement compared to the situation whereby all available stems are being harvested. Moreover, retention of 20% of the red cedar trees in buffer zones protects the species from becoming in a position where its continued existence is being threatened.

Table 16 Stand table projection for red cedar with harvest of stems ≥ 40 cm dbh in years 0, 25 and 50; following the GFC regulation that bans harvesting from buffer zones; initial stand structure based on the pooled stock survey data; trees within buffer zone retained and outside buffer zone harvested; densities shown in red italic are the trees that are harvested. Stem numbers are expressed per 100 ha.

Projection year	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	≥100	Total
0 – harvested				*0.03*	*0.07*	*0.05*	*0.04*	*0.02*	*0.01*	*0.02*	**0.24**
0 – retained	**0.17**	**0.10**	**0.06**	*0.01*	*0.02*	*0.01*	*0.01*	*0.00*	*0.00*	*0.00*	**0.39**
5	0.17	0.10	0.06	0.03	0.01	0.02	0.01	0.01	0.00	0.00	0.41
10	0.17	0.10	0.07	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.43
15	0.18	0.10	0.05	0.05	0.03	0.01	0.02	0.01	0.00	0.00	0.45
20	0.17	0.10	0.06	0.04	0.04	0.03	0.02	0.01	0.01	0.00	0.47
25 - harvested				*0.03*	*0.03*	*0.03*	*0.01*				**0.10**
25 - retained	**0.17**	**0.09**	**0.06**	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.00*	**0.37**
30	0.14	0.09	0.06	0.03	0.01	0.01	0.01	0.01	0.01	0.00	0.37
35	0.12	0.10	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.37
40	0.12	0.10	0.04	0.04	0.03	0.01	0.01	0.01	0.01	0.01	0.38
45	0.11	0.08	0.06	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.38
50 - harvested				*0.03*	*0.02*	*0.03*	*0.01*				**0.09**
50 - retained	**0.10**	**0.07**	**0.06**	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	**0.29**

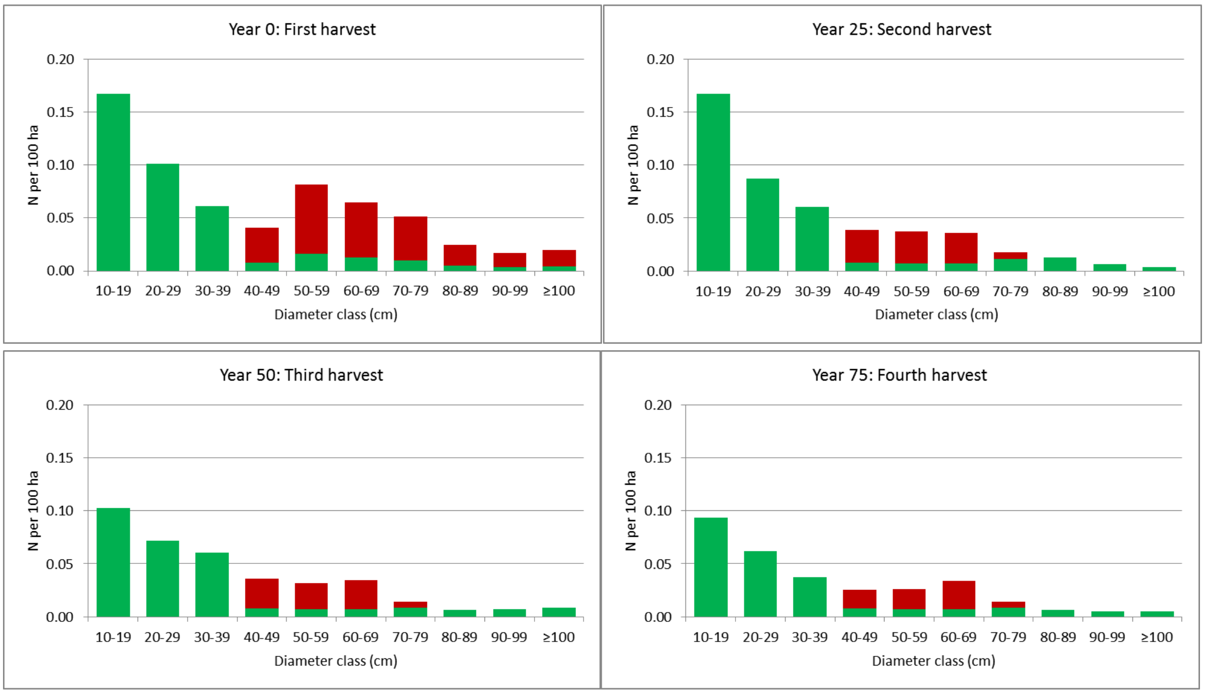

Figure 21 Size-class structure of red cedar following the GFC regulation that bans harvesting from buffer zones; at first harvest (top-left), projected size-class structure at second harvest after 25-yr. (top-right), third harvest after 50-yr (bottom-left), fourth harvest after 75 yr. (bottom-right). Red bars indicate harvestable trees and green bars retained trees.

7.5.2 Effect of raising the minimum cutting diameter limit

The legal minimum cutting diameter limit for red cedar in Guyana is 34 cm dbh and there are no requirements to leave any seed trees. In Bolivia, a minimum cutting diameter 60 cm is prescribed, a cutting cycle of at least 20 years, and a maximum harvest intensity of 80% of the trees of harvestable size (leaving the remaining 20% as seed trees) for each species (Brienen & Zuidema, 2006b). Current harvest regulations in Brazil prescribe a 50 cm minimum diameter cutting limit, a 20% commercial-sized tree retention rate, a minimum 3 commercial-sized trees per 100 ha retained after harvest as seed trees and a 30-year cutting cycle (Schulze *et al*, 2008). In Peru, minimum diameter cutting limit is 65 cm.

The maximum harvest intensity of 80% of the trees of harvestable size (leaving the remaining 20% as seed trees), as stipulated in Bolivia and Brazil, is guaranteed in Guyana by default because of the harvesting ban for riparian buffer zones combined with the observation that 20% of red cedar trees appear to grow in such buffer zones. As mentioned in the previous section a maximum harvesting intensity of 80% ensures the continued existence of the species but does not result in a truly sustained yield if a minimum cutting diameter limit of 34 cm dbh is applied as required by the Forest Act and its subsidiary Forest Regulations in Guyana.

Periodic diameter increment rates of juvenile red cedar trees are reportedly low and mortality of juveniles high. The species requires releases from low understorey light levels by canopy disturbances to enable them to reach the canopy (Brienen & Zuidema, 2006a). Periodic diameter increment rates (PAI) increase with increasing diameter and peak in the 40-50 cm and 50-60 cm diameter classes. Periodic increment rates are almost 30% higher in these two classes than in the 30-40 cm and 60-70 cm diameter class (see Table 12). From a silvicultural point of view, the optimum minimum cutting diameter would therefore rather be close to 60 cm dbh, because the mean annual increment (MAI) rate would peak after the tree has reached this size. The effects of a shift in the MCDL on sustainable yield were modelled for MCDLs of 50 cm and 60 cm.

Raising the MCDL to 50 cm dbh, while excluding buffer zone trees, further improves sustainability of the harvestable volume in future cutting cycles; at the first cut the harvested number of stems is reduced to 86% compared to a MCDL of 40 cm while excluding buffer zone trees (i.e. 0.21 stem per 100 ha), to 88% at the second harvest (i.e. 0.08 stem per 100 ha), but increased to 103% at the fourth cut (Figure 22). At the first harvest the volume will be 1.13 m^3/100-ha (95% compared to a MCDL of 40 cm), at the second harvest (year 25) the volume will have declined to 0.35 m^3/100-ha (116%), at the third harvest (year 50) to 0.33 m^3/100-ha (118%), at the fourth harvest (year 75) to 0.31 m^3/100-ha (129%) and at the fifth harvest (year 100) 0.21 m^3/ha (134%). Although this harvesting regime still does not result in strictly sustained yields, it forms a substantial improvement compared to the situation whereby all available stems outside buffer zones are being harvested. Of the original 0.63 tree ≥ 20 cm dbh per 100 ha 0.10 stem is preserved after 100 years, if all trees are allowed to be harvested, compared to 0.21 stems when harvesting in buffer zones is excluded and 0.25 stems, if, in addition to buffer zone exclusion, the MCDL is raised to 50 cm.

If the MCDL is further raised to 60 cm dbh as would be advisable based on the fact that periodic increment rates are highest in the 40-50 and 50-60 cm diameter classes, sustained yield levels are being approached (Figure 23). At the first harvest the volume will be 0.94 m^3/100-ha (78% compared to a MCDL of 40 cm), at the second harvest (year 25) the volume will have declined to 0.52 m^3/100-ha (169%), at the third harvest (year 50) to 0.37 m^3/100-ha (132%), at the fourth harvest (year 75) to 0.36 m^3/100-ha (149%) and at the fifth harvest (year 100) to 0.28 m^3/ha (176%). Ignoring the fifth harvest a sustained yield level of 0.36 m^3/100-ha seems achievable. Of the original 0.63 tree ≥ 20 cm dbh per 100 ha 0.30 stem is preserved, if, in addition to buffer zone exclusion, the MCDL is raised to 60 cm.

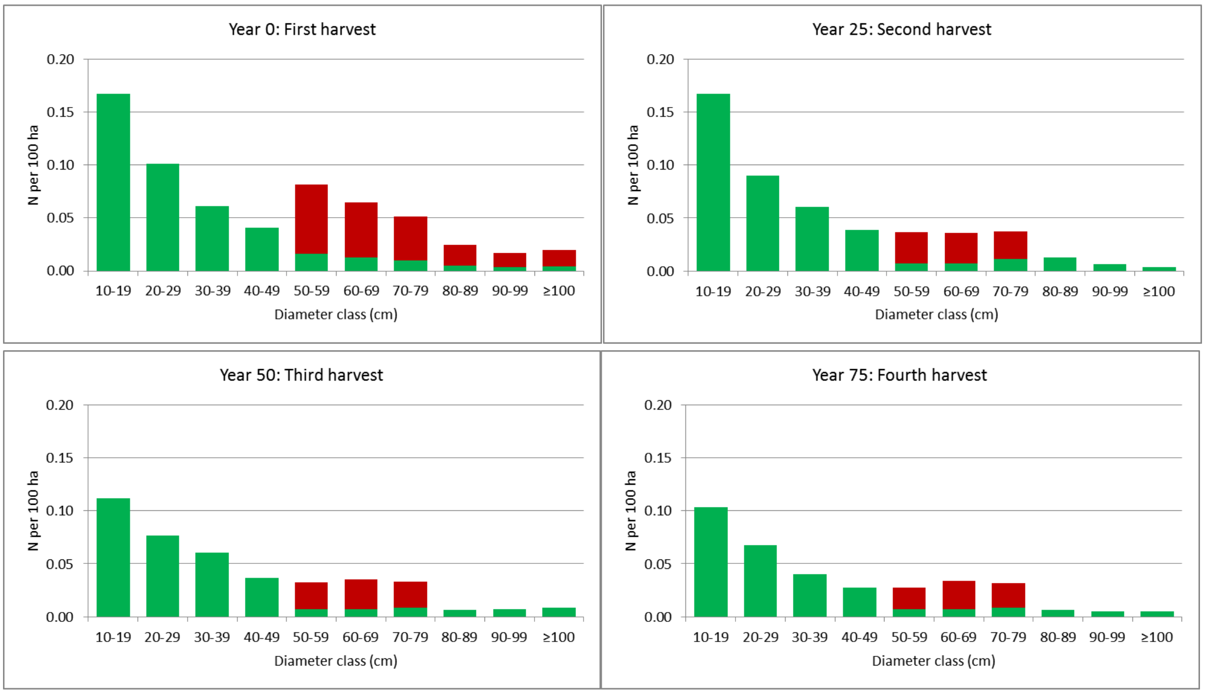

Figure 22 Size-class structure of red cedar banning harvesting from buffer zones and applying a minimum cutting limit of 50 cm dbh; at first harvest (top-left), projected size-class structure at second harvest after 25-yr. (top-right), third harvest after 50-yr (bottom-left), fourth harvest after 75 yr. (bottom-right). Red bars indicate harvestable trees and green bars unharvested trees.

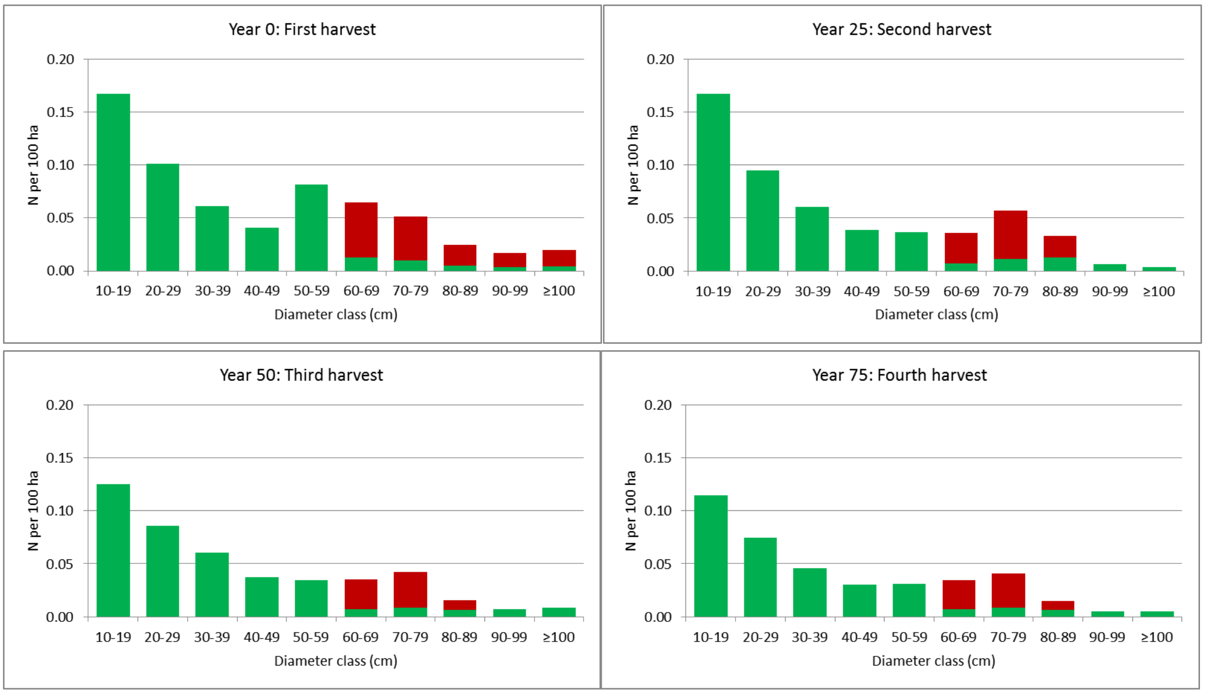

Figure 23 Size-class structure of red cedar banning harvesting from buffer zones and applying a minimum cutting limit of 60 cm dbh; at first harvest (top-left), projected size-class structure at second harvest after 25-yr. (top-right), third harvest after 50-yr (bottom-left), fourth harvest after 75 yr. (bottom-right). Red bars indicate harvestable trees and green bars unharvested trees.

Figure 24 shows that the yield at first harvest decreases by raising the MCDL but that the yield at subsequent harvests increases. If the yields for the hypothetical harvesting regime whereby all red cedar trees above the legal MCDL including trees in buffer zones can be harvested are ignored, it appears that the total accumulated yield after five consecutive harvests is highest when the MCDL is set at 60 cm.

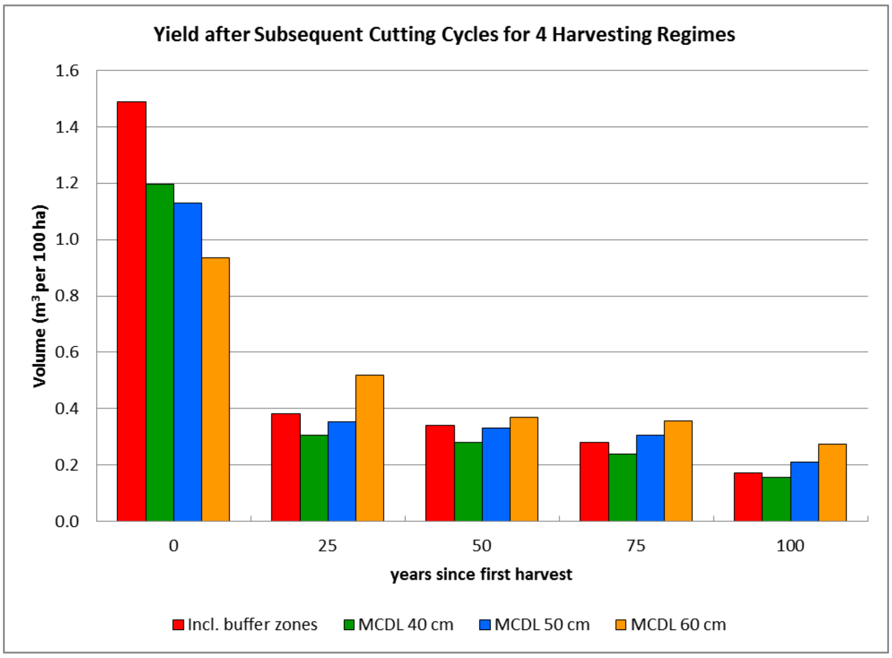

Figure 24 Forecasted yield of red cedar at subsequent cuts with complete harvest of all available stems ≥ 40 cm dbh (red bars); and banning harvesting from buffer zones and applying a MCDL of 40 cm dbh (green bars), a MCDL of 50 cm dbh (blue bars) and a MCDL of 60 cm dbh (yellow bars); assuming recruitment into the 10-19 cm class in proportion to the reduction in trees ≥ 20 cm diameter at each 5-yr modelling interval; and initial stand structure based on the pooled stock survey data.

Figure 25 shows that standing volume at each subsequent is increased if the MCDL is increased, but that the total standing volume diminishes after east harvest. This is due to the applied decrease in recruitment into the 10-19 cm class in proportion to the reduction in trees ≥ 20 cm diameter at each successive 5-year modelling interval. This implies that a stand table projection using time of passage and mortality figures from Brienen & Zuidema (2006a) combined with the assumption that regeneration (recruitment) diminishes after each harvest will not result in sustained yield after the fourth harvests, neither if the MCDL is raised to 60 cm dbh.

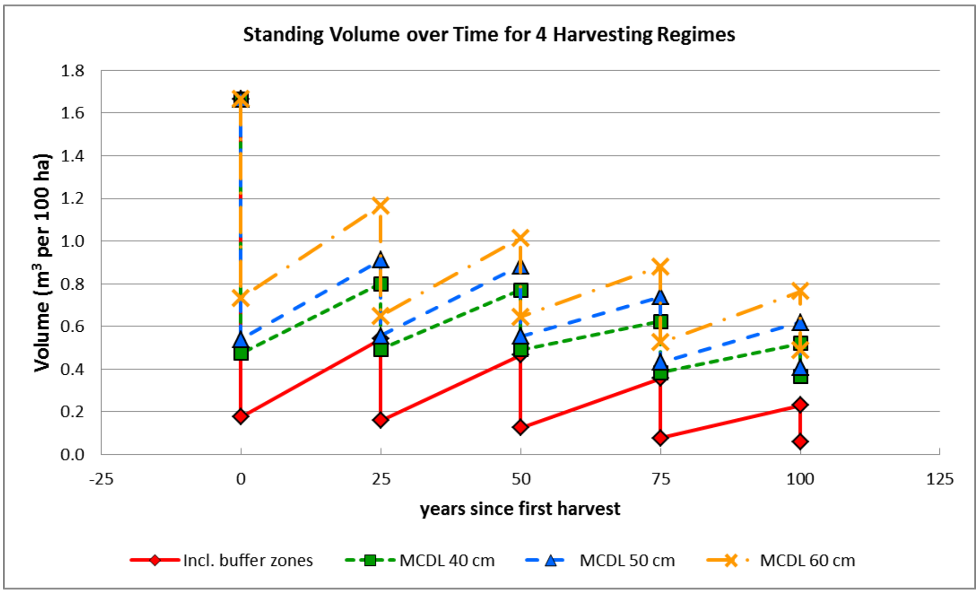

Figure 25 Development of standing red cedar volume (diameter ≥ 10 cm dbh) according to stand table projection with a cutting cycle of 25 years: for complete harvest of all available stems ≥ 40 cm dbh (red line); and banning harvesting from buffer zones and applying a MCDL of 40 cm dbh (green line), a MCDL of 50 cm dbh (blue line) and a MCDL of 60 cm dbh (purple line); initial stand structure based on pooled stock survey data; time of passage and mortality figures from Brienen & Zuidema (2006a); and recruitment into the 10-19 cm class in proportion to the reduction in trees ≥ 20 cm diameter at each 5-yr modelling interval.

7.5.3 Effect of recruitment rate assumptions

Knowledge on regeneration of red cedar in Guyana is limited, but red cedar reportedly starts bearing fruit at an early age under plantation conditions (Lamb, 1968; Lamprecht, 1989) and it was therefore assumed that the species start reproducing at a diameter of 20 cm. In the previous sections it was assumed that recruitment in the 10-19 cm diameter class would diminish in proportion to the number of stems that remain after each logging cycle. However, the species is strongly light-demanding and regarded as a 'long-lived' pioneer (Cintron, 1990; Lamprecht, 1989; Lemmens, 2008). It regenerates well in forest clearings, on abandoned agricultural plots and following disturbances such as forest fires and hurricanes (Lamprecht, 1989; Marshall, 1939). According to Lamprecht (1989) natural regeneration can be encouraged by removing the canopy around seed trees. This may indicate that fecundity would increase after logging. Therefore, the stand projection model was also run assuming that recruitment rates would remain constant. Under this assumption, sustained yields would be possible and stable sustained production rates would be achieved after two 25-year cutting cycles (Figures 26 and 27).

Ignoring the hypothetical harvesting regime whereby all red cedar trees above the legal MCDL may be harvested also buffer zones, it appears that the total accumulated yield after five consecutive harvests is still highest when the MCDL is set at 60 cm. The differences between the three MCDL scenarios are however smaller when assuming constant recruitment rates in comparison with recruitment being directly related to the number of trees retained after harvest.

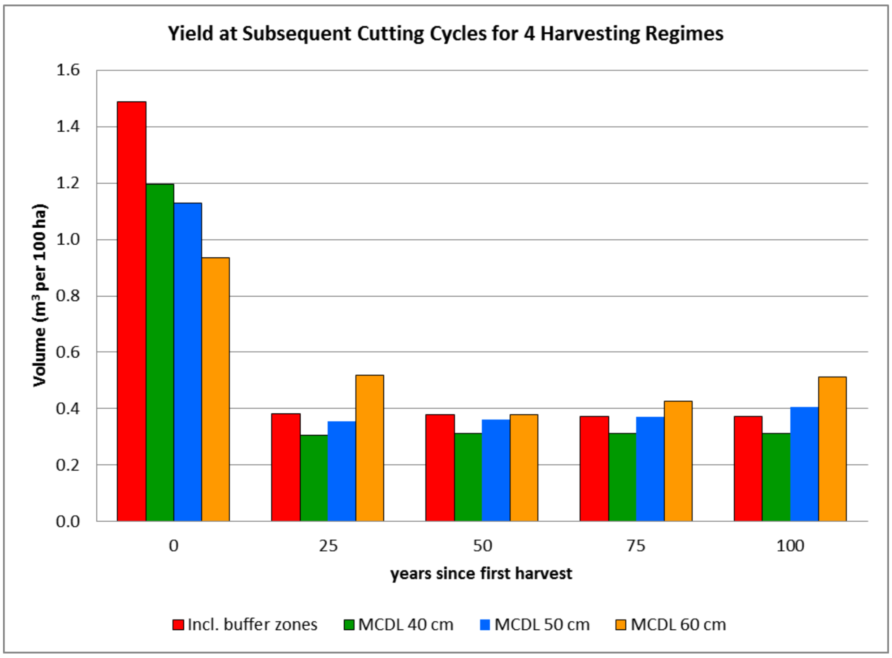

Figure 26 Forecasted yield of red cedar at subsequent cuts with complete harvest of all available stems ≥ 40 cm dbh (red bars); and banning harvesting from buffer zones and applying a MCDL of 40 cm dbh (green bars), a MCDL of 50 cm dbh (blue bars) and a MCDL of 60 cm dbh (purple bars); assuming a constant recruitment rate; and initial stand structure based on the pooled stock survey data (224 km^2).

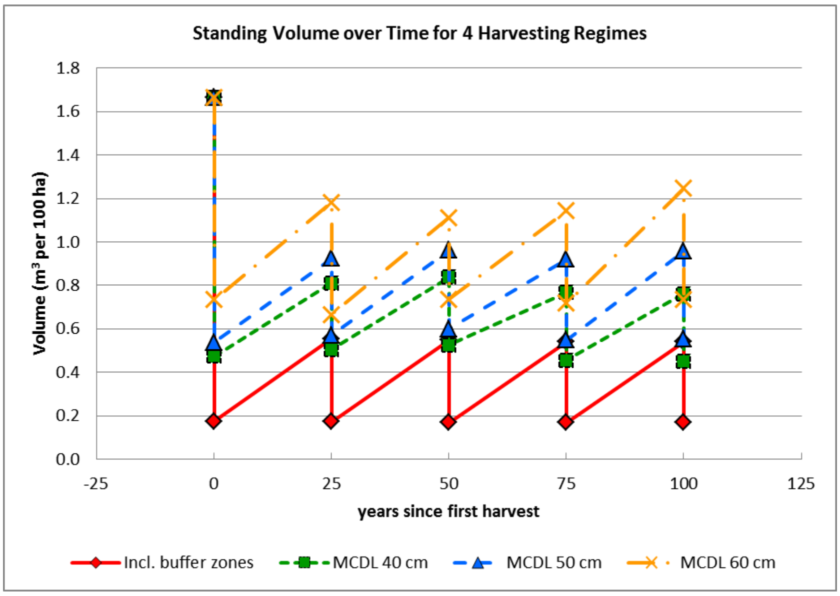

Figure 27 Development of standing red cedar volume (diameter ≥ 10 cm dbh) according to stand table projection with a cutting cycle of 25 years for: complete harvest of all available stems ≥ 40 cm dbh (red line); and banning harvesting from buffer zones and applying a MCDL of 40 cm dbh (green line), a MCDL of 50 cm dbh (blue line) and a MCDL of 60 cm dbh (purple line); initial stand structure based on pooled stock survey data (224 km2); time of passage and mortality figures from Brienen & Zuidema (2006a); assuming a constant recruitment rate.

In point of fact recruitment rates will lie somewhere between a constant rate and a proportionately decreasing rate. Sustained yield levels in a 25-year cutting cycle, as determined by the yield after the third cutting cycle when the modelled stand structure stabilizes, would therefore lie somewhere between 0.24 and 0.31 m^3 per 100 hectare in case of a MCDL of 40 cm dbh (implemented starting from the first harvest), between 0.31 and 0.37 m^3 per 100 hectare in case of a MCDL of 50 cm dbh and between 0.36 and 0.43 m^3 per 100 hectare in case of a MCDL of 60 cm dbh.

8 Sustainable yield

8.1 Density and sustained yield of red cedar

This study produced variable estimates of the density of harvestable red cedar trees; varying from 0.9 trees ≥ 35 cm dbh per 100 ha according to the CIDA-IFP inventories (1990-95), 1.7 trees ≥ 30 cm dbh per 100 ha recorded in the FAO-FIDS reconnaissance survey (1969-73) and 2.0 trees ≥ 35 cm dbh per 100 ha according to the MLI inventories (2006-present).

The most widespread source of information was formed by 100% pre-harvest inventories in large concessions which indicated an average of 0.14 trees ≥ 40 cm dbh per 100 ha. However, red cedar was only reported in 8% of all 100% pre-harvest inventories that were undertaken during 2010-2014. It should be noted that stock survey information is not as reliable as true forest inventory information. Neither concessionaires nor their inventory teams are familiar with the species. Not all concessionaires include the species on their species list for 100% pre-harvest inventory, while many inventory crews do not recognize the species. The latter was clearly indicated by a small verification exercise of seven blocks in five large concessions. In three concessions other species such as *Apeiba petoumo* (duru), *Bombax* sp. (kamakuti), *Calophyllum lucidum* (kurahara), *Humiria balsamifera* var. *balsamifera* (tauroniro), or *Tabebuia insignis* var. *monophylla* (white cedar) trees had been mistakenly identified as red cedar. In four blocks in two other concessions, where three and twelve harvestable red cedar trees respectively were recorded during stock surveys, the species was correctly identified but the verification exercise also showed that four harvestable red cedar trees had been overlooked during stock surveys. The most reliable stock survey seems to be the one carried out by Barama Co. Ltd., where 249 red cedar trees were found in 142 out of the 1033 blocks (14%) that were surveyed over the period 2010-14; indicating a density of 0.24 tree per 100 ha. As mentioned above, the verification exercise showed that two trees had been overlooked; this may suggest that the species density is about 22% higher. Given the general uncertainty regarding the reliability of 100% pre-harvest inventories, a likely density of 0.30 tree ≥ 40 cm dbh per 100 ha is presumed and, for that matter, 0.26 tree ≥ 50 cm dbh and 0.18 tree ≥ 60 cm dbh per 100 ha.

In terms of volume, estimates vary from 2.8 m^3 per 100 ha according to the CIDA-IFP inventories (1990-95), 2.4 m^3 per 100 ha recorded in the FAO-FIDS reconnaissance survey (1969-73) and 8.2 m^3 per 100 ha according to the MLI inventories (2006-present). Based on the stock surveys, a volume of only 1.49 m^3 per 100 ha is indicated. Application of a MCDL of 50 cm dbh would suggest a harvestable volume of 1.41 m^3 per 100 ha, while a MCDL of 60 cm would suggest a harvestable volume of 1.16 m^3 per 100 ha.

According to Guyana’s Code of Practice (2014), no trees may be felled in streamside buffer zones. An estimated 20% of the red cedar trees occur in such buffer zones and would therefore be excluded from harvesting. This would imply that of 0.24 tree ≥ 40 cm dbh per 100 ha would be actually available for harvesting, while this would be 0.21 tree ≥ 50 cm dbh and 0.14 tree ≥ 60 cm dbh per 100 ha. The actually harvestable volume is therefore estimated at 1.20 m^3 per 100 ha. Application of a MCDL of 50 cm dbh would result in an estimated harvestable volume of 1.13 m^3 per 100 ha and a MCDL of 60 cm in an estimated harvestable volume of 0.94 m^3 per 100 ha.

Stand table projection with a 25-year cutting cycle based on the stock survey results suggests long-term sustainable yields between 0.24 and 0.31 m^3 per 100 hectare in case of a MCDL of 40 cm dbh, between 0.31 and 0.37 m^3 per 100 hectare in case of a MCDL of 50 cm dbh and between 0.36 and 0.43 m^3 per 100 hectare in case of a MCDL of 60 cm dbh.

In terms of annual sustainable yield these figures translate to 0.010-0.013 m^3 per 100 hectare per year in case of a MCDL of 40 cm dbh, 0.012-0.015 m^3 per 100 hectare per year in case of a MCDL of 50 cm dbh and 0.014-0.017 m^3 per 100 hectare per year in case of a MCDL of 60 cm dbh.

8.2 Allocated State Forest area and annual coupe

8.2.1 Occurrence of red cedar in concessions

In section 5.5 it was shown that red cedar does not seem to have a specific preference for a certain forest or soil type, but appears to occur on all soil types from pegasse, to loam, to white sand and in many forest types from *mora* forest, to mixed forest on undulating to hilly terrain, on deeply dissected terrain, on steep high hills, and also in *wallaba* forest on white sand soils. At a local scale, red cedar appears to occur mainly in mixed or *mora* forest along watercourses; particularly along gullies and seasonal streams. For the assessment of the annual sustained red cedar yield it is therefore assumed that red cedar occurs in all forest concessions.

8.2.2 Large concessions

Twenty-six large concessions (25 TSAs and 1 WCL) have been issued with a total area of roughly 4.4 million hectares. Assuming the net productive forest area is 80% of the concession area, the total net productive area would amount to 3.5 million ha. Most of these large concessions are managed at a 25-year cutting cycle. The total annual coupe for the large concessions would therefore amount to roughly 140,000 ha. An operator's annual quota is calculated based on the chosen cutting cycle, the annual coupe calculated for the concession and the results of the 100% pre-harvest inventory in case of large concessions. The quota is equated to the number of standing trees which will yield the volume and the number of trees computed indicates the number of tags to be issued. The block and log quota system applied to large concessionaires ensures that the concessionaire adheres to the allowable harvest intensity and the cutting cycle, because harvesting outside of those blocks is not permitted.

Stand table projection with a 25-year cutting cycle under the current forest management regulations with a practical MCDL of 40 cm and prohibiting harvesting in riparian buffer zones suggests long-term sustainable yields between 0.24 and 0.31 m^3 per 100 hectare. In case a MCDL of 50 cm dbh would be applied sustainable yield would lie between 0.31 and 0.37 m^3 per 100 hectare and in case a MCDL of 60 cm dbh would be applied sustainable yield is estimated between 0.36 and 0.43 m^3 per 100 hectare. Based on the stand projection model, the estimated readily available volume of red cedar in the State Forest allocated as large concessions would amount to 140,000 ha ÷ 100 × 1.2 m^3 = 1,680 m^3 per year, under provision that the annual coupe consists entirely of primary forest. The long-term annual sustained yield for large concessions, however, would lie somewhere between 350 and 450 m^3 per year. Application of a MCDL of 50 cm dbh would result in a readily available yield 1,582 m^3 per year (providing all is primary forest), while the long-term annual sustained yield lie between 450 and 500 m^3 per year. Raising the MCDL to the silviculturally desirable 60 cm dbh would result in a readily available yield 1,316 m^3 per year (providing all is primary forest), while the long-term annual sustained yield would be between 500 and 600 m^3 per year.

8.2.3 Small concessions and Amerindian reservations

The total area allocated as small concessions (State Forest Permits) amounts to about 2.0 million ha. Small concessions are managed by the GFC who issues log tags based on predetermined log quota. The GFC computes the log quota on a case by case basis for the entire SFP, whereby the basic maximum 20 m^3 harvest intensity and a cutting cycle of 60 year are applied and allowance is made for non-productive areas; i.e. 80% of the area is assumed to be accessible for harvesting. Small concessions do not have an annual coupe in terms of area but a log quota.

For practical purpose the estimation of the annual sustained red cedar yield from SFPs follows the same approach as the one that was used for large concessions. In lieu of log quota, the annual coupe for small concessions is suggested to be roughly 64,000 ha. Under the current forest management regulations with a practical MCDL of 40 cm and prohibiting harvesting in riparian buffer zones, long-term annual sustained yield for small concessions would lie somewhere between 150 and 200 m^3 per year. Application of a MCDL of 50 cm dbh would result in a long-term annual sustained yield between 200 and 250 m^3 per year. Raising the MCDL to the silviculturally desirable 60 cm dbh would result in a long-term annual sustained yield of between 250 and 300 m^3 per year. The majority of SFPs have been logged previously and estimates of the readily available yield would be definitely less than the volumes quoted for large concessions, where primary forest is still largely available.

Produce stemming from Amerindian Reservations and Private Properties is not subject to maximum cut restrictions because these lands do not form part of the State Forest Estate and are not managed by the GFC. About 3.5 million hectares have been formally gazetted as Amerindian Reservations and roughly 2.6 million hectares of these lands are forested. Sustained yield for the Amerindian reservations is estimated at 200-250 m^3 per year.

8.2.4 Total sustainable yield

The total area of available productive forest - both allocated State Forest and Amerindian reservations - is roughly 9.0 million hectares. Applying a 25 year cutting cycle this would produce a theoretic national annual coupe of 288,000 hectares. Under the current forest management regulations with a practical MCDL of 40 cm and prohibiting harvesting in riparian buffer zones for State Forest and assuming similar practices in Amerindian reservations, long-term annual sustained yield would lie between 700 and 900 m^3 per year. Application of a MCDL of 50 cm dbh would result in a long-term annual sustained yield between 900 and 1,050 m^3 per year. Raising the MCDL to the silviculturally desirable 60 cm dbh would result in a long-term annual sustained yield between 1,050 and 1,250 m^3 per year.

8.2.5 Red cedar production 2007-14 in comparison to sustainable yield

Red cedar production is dealt with in detail in report no. 2 'Reporting Framework for CITES timber exports'. In summary, the average total red cedar production (felled roundwood equivalent) from State Forest fluctuated around 555 m^3/yr. over the period 2007-14; ranging from around 172 m^3/yr. to 1,750 m^3/yr. The majority of the red cedar production from State Forest was sourced from small concessions with an average yearly production of 500 m^3; this production was composed of 150 m^3 logs and 350 m^3 primary (chainsaw) lumber. Yearly production from large concession was limited to 55 m^3; ranging from 21 m^3 to 140 m^3; this production was nearly completely composed of logs.

Average yearly production over the period 2009-2013 originating from Amerindian Village Lands amounted to 86 m^3; ranging from 0 m^3 to 238 m^3.

The total production thus amounts to 641 m^3 per year on average and is thus 92% of the lower estimate of the sustained yield of 700 m^3 per year and 71% of the higher estimate of the sustained yield of 900 m^3 per year. Red cedar is principally sourced from small concessions where harvests are three times the lower sustained yield estimate and 2.5 times the higher estimate. Large concessions harvest only 12-16% of their sustained yield levels, while production from Amerindian Village Lands does not exceed 34-43% of the estimated higher and lower sustained yield levels. Sustainable management of red cedar hence does not appear to be threatened under current forest regulations and harvesting practice in large concessions and Amerindian reservations, but is possibly being in small concessions. There appears to be scope for intensification of production from large concessions.

8.2.6 Other considerations

A point of concern relating to sustainable management of red cedar in Guyana is that the species mainly occurs along watercourses. Small-scale gold mining in and along watercourses is widespread in Guyana, particularly to the West and South-West of the Essequibo River. These destructive mining practices may undercut established forest management measures to safeguard the species.

Given the assumption that the periodic annual increment is greatest for the 40-49 cm and 50-59 cm size classes, higher sustained yield levels would be attained if the minimum cutting diameter limit would be raised to 60 cm dbh. Such increase would compromise the yield at the first harvest, but indicates a substantially higher countrywide sustained yield of about 1,150 m^3 per year instead of 800 m^3 per year under current regulations. In addition, stand table projection indicates that successful regeneration is guaranteed when applying a MCDL of 60 cm dbh, while this is questionable when applying lower MCDLs.

9 Conclusion

In 1998 *Cedrela odorata* was assessed as globally Vulnerable in the IUCN Red List and it has been listed in Appendix III of CITES since 2001. The species was subsequently proposed for listing in Appendix II of CITES in 2007. Appendix II listing would require non-detriment findings (NDF) to ensure that export will not be detrimental to the survival of the species being traded. NDFs should be based on a comprehensive review of available information on the population status, distribution, population trend, harvest, and other biological and ecological factors, as appropriate, and trade information relating to the species concerned. Because such information was lacking for nearly all range states, CITES adopted an Action Plan in 2007 to complete knowledge on the status of conservation of, trade in and sustainable use of *Cedrela odorata.* Although the proposal to list the species in CITES Appendix II was unanimously opposed by all 30 Range States and subsequently withdrawn in 2013, Range states were urged to consider the inclusion of their populations of *Cedrela odorata* in Appendix III and to ensure the implementation and enforcement of CITES rules with regard to that Appendix. It is against this background that this report has been prepared.

This report aimed to review the available information on *Cedrela odorata* in Guyana using existing, available information sources on the distribution, population structure and production. The main sources of information are formed by national forest inventories and forest inventories (through sampling) and 100% stock surveys carried out by forest concessionaires. Another source of information is formed by production records.

Findings

- In Guyana, red cedar occurs widely from the North West to the South East of the country. Its potential geographic distribution covers about three quarters of Guyana's territory with the exception of the coastal lowlands, the Rupununi and other savannahs and the Pakaraima mountain region based on the geographic distribution of the forest types in which it appears to occur.
    - The species does not appear to have a specific preference for a certain forest or soil type; it is reported to occur on many soil types from pegasse, to clay, to brown sand and white sand and in many forest types such as swamp forest, mixed forest on flat to undulating, undulating to hilly, deeply dissected terrain and steep high hills, and in *wallaba* forest on white sand soils.
    - At a local scale, the species occurs mainly in mixed or *mora* forest along watercourses; particularly gullies and seasonal streams, but also along larger creeks. It is estimated that 20% of the trees are within a 10 m distance of a creek and another 10% within a 20 m distance, while 63% grow within 20 m of a gully or seasonal stream.
- According to the national forest inventories, red cedar is rare in Guyana (< 1 tree/ha), but according to stock surveys the species is very rare (< 1 tree per 100 ha). According to three nation-wide inventories the estimated density of red cedar trees ≥ 10 cm dbh varies from 1.7 to 8.5 trees per 100 ha, while the estimated density of harvestable trees (≥ 35 cm dbh) ranges from 0.9 trees to 2.0 trees per 100 ha. According to 100% pre-harvest inventories in

large concessions the average density amounts to 0.3 tree ≥ 40 cm dbh per 100 ha (in the concessions where the species was reported).

- Red cedar was only reported in 8% of the blocks that were surveyed during 2010-2014, but the fact that a species is not recorded in a certain concession does not necessarily mean that the species does not occur in that concession. Neither concessionaires nor their inventory teams appear to be familiar with the species. Not all concessionaires include the species on their species list for 100% pre-harvest inventory, while some inventory crews do not recognize the species.
- The estimated volume of red cedar ≥ 35 cm dbh ranges from 2.4 m^3 per 100 ha (FAO-FIDS) to 6.0 m^3 per 100 ha (MLI) according to the national forest inventories. An upwards adjusted average volume of 1.5 m^3 per 100-ha block (maximum of 37.8 m^3 per 100-ha block) was reported for the 2728 100-ha blocks that where were surveyed by large concessionaires during 2010-14.

- Guyana's Code of Practice (2014) prescribes that trees may not be felled in streamside buffer zones. As shown above, an estimated 20% of the red cedar trees occur in such buffer zones and should therefore be excluded from harvesting. Stand table projection of harvested stands applying a minimum cutting diameter limit of 40 cm, excluding trees in buffer zones and assuming a progressive reduction in recruitment into the 10-19 cm class in proportion to the reduction in trees ≥ 20 cm diameter in each subsequent 5-year modelling interval results in a volume at the first harvest of 1.49 m^3/100-ha, reducing to 0.38 m^3/100-ha at the second harvest (year 25) and eventually to 0.17 m^3/ha at the fifth harvest (year 100). The strong reduction in volume after the first harvest is associated with the presence of large (dbh ≥ 70 cm) old-growth trees at the first harvest ('primary forest premium').

    - The legal minimum cutting diameter limit (MCDL) for red cedar in Guyana is 34 cm dbh. From a silvicultural point of view, the optimum minimum cutting diameter would rather be close to 60 cm dbh, because the mean annual increment rate of the species is reported peak after the tree has reached this size. If the MCDL is raised to 60 cm dbh the volume at the first harvest will be reduced to 0.94 m^3/100-ha (78% compared to a MCDL of 40 cm), but harvests will be higher at the second harvest (year 25) estimated at 0.52 m^3/100-ha (169%), and eventually yield 0.28 m^3/ha (175%) at the fifth harvest (year 100).
    - Red cedar is strongly light-demanding, regenerates well in forest clearings and following disturbances such as forest fires and hurricanes and is regarded as a 'long-lived' pioneer. It is therefore plausible that recruitment does not decrease proportionately after removing parent trees at each harvest. Stand table projection assuming that recruitment rates remain constant suggests that stable sustained yields can be achieved after only two 25-year cutting cycles.

- Recruitment rates will probably lie somewhere between a constant rate and a proportionate rate. Sustained yield levels in a 25-year cutting cycle, as determined by the yield after the third cutting cycle when the modelled stand structure stabilizes, would therefore lie somewhere around 0.28 m^3 per 100 hectare in case of a MCDL of 40 cm dbh and 0.40 m^3 per 100 hectare in case of a MCDL of 60 cm dbh.

- Based on the observation that the species occurs in all forest types along watercourses; particularly along gullies and seasonal streams it can safely be assumed that the species occurs in all forest concessions and overall sustained yields can be computed using the annual coupe for the concessions:
  - The annual coupe of all large concessions (TSAs and WCLs) amounts to roughly 140,000 ha and the long-term annual sustained yield for these concessions would therefore be close to 400 m^3 per year.
  - Small concessions (SFPs) are managed per log quota and not per an annual coupe. For the purpose of assessing sustained yield levels, the annual coupe for small concessions is estimated at roughly 64,000 ha in lieu of log quota. The long-term annual sustained yield for small concessions would lie somewhere between 150 and 200 m^3 per year.
  - Produce stemming from Amerindian Reservations and Private Properties is not subject to maximum cut restrictions because these lands do not form part of the State Forest Estate and are not managed by the GFC, but sustained yield for the Amerindian reservations is estimated at 200-250 m^3 per year.
- The total area of available productive forest - both allocated State Forest and Amerindian reservations - is roughly 9.0 million hectares. Applying a 25 year cutting cycle this would produce a theoretic national annual coupe of 288,000 hectares. Under the current forest management regulations with a practical MCDL of 40 cm and prohibiting harvesting in riparian buffer zones for State Forest and assuming similar practices in Amerindian reservations, long-term annual sustained yield would lie close to 800 m^3 per year. Raising the MCDL to the silviculturally desirable 60 cm dbh would result in a long-term annual sustained yield of 1,150 m^3 per year.
- Over the period 2007-14, total red cedar production amounted to 641 m^3 per year on average and appears to be only 20% of the lower estimate of the sustained yield of 3,150 m^3 per year and 12% of the higher estimate of the sustained yield of 5,200 m^3 per year. Red cedar is principally sourced from small concessions and amounts there to between 43% and 71% of the higher and lower sustained yield estimates. Large concessions harvest only 2-4% of their sustained yield levels, while production from Amerindian Village Lands does not exceed 6-10% of the estimated higher and lower sustained yield levels.

In conclusion

- Although red cedar is very rare in Guyana, current harvesting regimes (and export levels) do not appear to be detrimental to the survival of the species, because a considerable proportion of the population (20%) occurs along streamside buffer zones, where logging is prohibited in Guyana, and trees are protected. Secondly, harvest levels, about 640 m^3 per year on average, are below the estimated national sustained yield level, which lies close to 800 m^3 per year.
- Under the current forest management regulations and harvesting practice there appear to be no clear grounds for including Guyana's red cedar population in CITES Appendix III.

- Production of red cedar from large concessions is low and there appears to be an opportunity to expand production from these concessions. This is likely related to poor knowledge of the species among concessionaires and inventory teams. Large concessionaires do not seek specialty markets for red cedar but are reported to sell the species as mixed hardwood; i.e. below its intrinsic value. Better promotion of possibly attractive markets for the species and training of inventory teams in identification of the species are recommended.
- Finally, red cedar is reported to attain maximum diameter increment rates through the diameter class 40-60 cm dbh. Sustainable yield levels can therefore be increased by raising the minimum cutting diameter limit (MCDL) to 60 cm dbh; long-term annual sustained yield is currently estimated to lie close to 800 m3 per year with a MCDL of 40 cm, while with a MCDL of 60 cm dbh a long-term sustained yield of around 1,150 m3 per year seems achievable.

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11 Glossary

In this glossary explanations are given for the technical terms used in the botanical description.

actinomorphic	having its petals arranged in a radially symmetric fashion.
acuminate	having a gradually diminishing point
adnate	linked or fused to something unlike itself
alternate	inserted at different levels along the stem , not opposite (leaves or branches)
androecium	the set of a flower's stamens.
androgynophore	a stalk bearing both the androecium and the gynoecium of a flower above the level of insertion of the perianth.
anther	part of a stamen containing the pollen
apex	tip
bark	the phloem tissue formed on the outside by the cambium
blade	limb of a leaf
bract	small leaf subtending the flower stalk
buttress	flattened outgrowth of the trunk, connected for its entire length with the trunk, usually triangular in side view
calyx	outer whorl of perianth leaves (sepals), often green
cambium	layer of cells between the xylem and the phloem that is responsible for the secondary growth of roots and stems; often difficult to see in a slash
capsule	dry fruit which splits open (dehisces) to release the seeds
carina	part of a flower consisting of two petals, commonly united, which encloses the organs of fructification.
chartaceous	resembling paper or parchment; papery.
comose	bearing a tuft of soft hairs or down
corolla	inner whorl or perianth leaves (petals), often coloured
cotyledons	seed-lobes, first leaves of the embryo
cracked	with fine, shallow grooves (see 'fissured')
dbh	diameter at breast height (1.30 m)
dead bark	the outer part of the bark in which no living tissue is present any more
deciduous	falling off eventually (tree standing leafless part of the year)
dehiscent	splitting up, opening (fruit)
dioecious	with male and female flowers on different plants
discoid	shaped like a disc
dorsifixed	said of anthers that are attached to the filament somewhere along their back.
endemic	occurring in a restricted area
epigeal germination	cotyledons of the germinating seed expand, throw off the seed shell and become photosynthetic above the ground
ellipsoid	having the tridimensional shape of an ellipse rotated on its long axis.
falcate	sickle-shaped
fibrous	containing, consisting of, or resembling fibres
filament	stalk of a stamen
fissure	coarse, deep groove in bark
fissured	with coarse, deep grooves; in fact a further developed stage of 'cracked', and therefore not strictly separated from it; actual sizes should therefore be given

foliolate	with a particular number of leaflets
glabrous	smooth, without hairs or scales
gynoecium	the pistils of a flower considered as a group
imbricate	overlapping
inflorescence	arrangement of the flowers on a plant
lateral	to the side; of or pertaining to the side
leaflet	the ultimate unit of a compound leaf
lenticel	small, oval, rounded spots upon the twig, fruit, stem or branch of a plant, from which the underlying tissues may protrude
lenticellate	with lenticels
living bark	the inner part of the bark; bark recently formed by the cambium which still contains living tissue
locular	having a loculus or compartment.
loculus	one of the compartments of a several-celled ovary
monoecious	having the male and female reproductive organs on different parts of the same plant
oblong	rectangle-shaped (2:1 - 3:1); narrowly oblong (6:1 - 3:1); transversely-oblong (2:3 -1:2); narrowly transversely-oblong (1:3 -1:6)
obovate	shaped like an egg, with the broad extremity located away from the base.
obovoid	approximately obovate in shape.
obtuse	blunt or rounded at the base or apex, at an angle of more than 90 degrees
opaque	not reflecting light
ovary	part of a carpel containing the ovules and eventually becoming the fruit
ovate	egg-shaped (of a flat surface), greatest width below the middle (2:1 - 3:2); depressed-ovate (2:3 -1:2)
ovoid	egg-shaped (three-dimensional)
panicle	inflorescence , in which the main axis bears several side branches with several flowers
paripinnate	compound leaf with pinnate leaflets, without a terminal one
pedicel	stalk of a single flower
peduncle	stalk of an inflorescence
pendulous	hanging or bending downwards; drooping or weeping
pentamerous	in five parts; made up of five parts.
perianth	flower leaves (tepals; sepals and petals)
petals	corolla leaves: inner whorl of often coloured perianth leaves
petiole	leaf stalk
petiolule	the stalk (petiole) of a leaflet of a compound leaf
phloem	living vascular tissue that carries organic nutrients (known as photosynthate), in particular, sucrose, to all parts of the plant where needed. In trees, the phloem is the innermost layer of the bark
photosynthate	compound that is a product of photosynthesis; process by which plants generate carbohydrates and oxygen from carbon dioxide, water, and light energy
pinna(e)	yoke(s) of a compound leaf
pinnate	with leaflets arranged along both sides of a common rachis

puberulous	beset with soft, short, erect hairs
rachis	main axis of inflorescence or compound leaf
rhombic	rhomb-shaped (2:1 - 3:1); narrowly rhombic (6:1 - 3:1); transversely-rhombic (2:3 - 1:2); narrowly transversely-rhombic (1:3 - 1:6)
ribbed	with ridges or raised markings.
rugose	having a rough, wrinkled surface
samara	winged indehiscent fruit of trees
samaroid	resembling a samara, or winged seed
sepals	calyx leaves: outer whorl of usually green perianth leaves
sessile	without stalk (flower, leaf)
slash	cut blaze: the surface that becomes visible after a piece of bark has been chopped off
stamen	male reproductive organ of a flower, consisting of a filament and an anther
stigma	sticky part of a flower that receives pollen during pollination
stipule	leaf-like or scar-like appendage of a leaf, usually at both sides at the base of the petiole
style	mostly elongate part of a carpel at apex of ovary
subsessile	not quite sessile
taproot	main root of a primary-root system, growing vertically downward. From the taproot arise smaller lateral roots (secondary roots)
tepals	perianth leaves, not distinguishable as either a sepal or a petal
terminal	proceeding from or belonging to the end or apex
trifoliolate	(of a compound leaf) having three leaflets.
valves	pieces into which a capsule naturally separates at maturity
vein	thickened portion of the leaf containing the vascular bundle
venation	pattern of veins or vein-like structures
vestige	rudimentary or degenerate, usually non-functioning, structure that is the remnant of an organ or part that was fully developed or functioning in a preceding generation or an earlier stage of development
xylem	living vascular tissue responsible for the distribution of water and minerals taken up by the roots; also the primary component of wood
yoke	a pair of opposite leaflets