The establishment of long-term forest monitoring plots in Southeast Cameroon.

Report to CARPE, November 2006

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EXECUTIVE SUMMARY

A forest monitoring partnership for timber certification was established in 2006 between the Smithsonian Institution (CTFS), WWF-CARPO and the SEFAC timber company in the Jengi Project Area of the Sangha Tri-national Landscape, following the model created last year by CTFS, WWF and the Groupe Decolvenaere timber company for the implementation of IR 1.2.

This report describes the creation of long-term forest monitoring plots, part of a larger program for sustainable timber harvest through timber certification. The work focuses on CARPE IR 1.2 (sustainable management plans within forestry concessions), IR 3 (monitoring the state of the basin), and also contributes to IR2 through training and capacity building for forest monitoring.

Funding was provided by CARPE, through CTFS and WWF, who each contributed about half of the field costs, while logistical support was provided by the timber company. This is a good example of the type of partnership we are trying to establish through CARPE for monitoring and sustainable forest management across the Congo Basin.

Four geo-referenced plots, each 1.0 hectare, were established in two logging concessions. 11,461 trees 2.0 cm or more in diameter were recorded. Two plots were sited in previously logged forest in the southern concession (UFA 10-012), with two more in unlogged forest in the northern concession (UFA 10-008). This project significantly expanded the network of 1.0 ha monitoring plots in the Jengi Project Area and in the semideciduous forest zone of central Africa.

We have created a well-trained field team in the Jengi Project Area that can establish permanent forest monitoring plots using a standard method. Hiring some of the workers trained during last year's program we were able to field two enumeration teams and support them in the field using the CTFS CARPE field vehicle.

The results showed a forest moderately rich in tree diversity and varying quite a lot in structure and species composition between plots. A total of 292 species were found in four hectares, averaging 161 species per hectare.

For tree populations, the canopy dominants, including the important timber species, appear to be regenerating poorly, suggesting that conditions for regeneration in the forest were very different in the past (probably a few hundred years ago) when the present canopy was establishing as seedlings and saplings. Our results also suggest that as the current canopy trees die naturally or are harvested, they will be replaced by different species. These results support previous findings from several researchers that the semi-deciduous forests of the landscape are secondary and represent a successional stage between an earlier, more open forest or even grassland and a more mature closed-canopy forest.

Results were obtained relevant to the logging of the forest that support our findings from 2005. For the economically important species that currently comprise much of the canopy, the forest contains sufficient volume for another harvest. However, the smaller size classes are very sparse, and, as far as we can tell, the current canopy species are

replacing themselves poorly in the forest understory. Naturally, the forest will assume a very different species composition and structure in future. Rather surprisingly, opening larger gaps in the forest canopy through logging did not result in increased regeneration of the canopy species, suggesting that in future, stocks of these species will need to be maintained through intensive silviculture. Developing programs in the area focused on enrichment planting of the important timber species should to be a priority for sustainable forest management.

In the final section, we discuss our results including the contribution of our work to CARPE IR's 1, 2 and 3 and the value to CARPE of our standard methodology. Our plans for future work in the landscape include replicating the partnership model with other timber companies; expanding the number of 1.0 ha monitoring plots; obtaining data from pre-exploitation timber cruising surveys in the landscape; re-measuring two plots post-logging; establishing new control plots; developing biodiversity inventory; making the data that we have obtained so far easily available to other researchers and forest managers.

INTRODUCTION

1. Forest management and timber certification

Cameroon produces about three million m^3 of roundwood logs per year, which makes the nation a major producer of tropical hardwood logs. Close to 70% of this annual production comes from the forests in the southeast of the country. Harvesting is conducted by concessionaires, while the granting of licenses, partitioning and enforcing of forest management regulations are the responsibility of the state. The regulations are aimed at ensuring sustainable exploitation the resource, an objective attainable only when management is based on sound forest ecology. The WWF-CARPO program, supported by CARPE, seeks to establish such sustainable management in the Jengi Project Area of southeastern Cameroon, including national parks, logging concessions and other zones.

CARPE established IR 1 in the Revised Performance Management Plan of February 2005, which focuses on the sustainable management of natural resources. To achieve this IR, IR level indicator 2 addresses the creation of sustainable management plans within forest concessions, national parks and other landscape zones. This has culminated in WWF CARPO's increased interest to collaborate with logging companies operating in forest concessions in South East Cameroon, particularly those soliciting for FSC timber certification. The FSC was designed as non-state, multi-stakeholder, and market driven approach for encouraging sustainable forest management. Since the creation of this pioneering program, forest certification has gained considerable attention on the part of environmental groups, trade associations, forest companies, forestry professionals, policy makers, and academic institutions and think tanks. Certification systems have been developed in response to different forest types, land ownership patterns, and historical, cultural, and legal traditions. Long term goals for timber concessions include sustainable timber harvest and the conservation of wildlife and natural values. Several collaborative activities have been identified among which the establishment of long-term plots to monitor the dynamics of the forests is a priority.

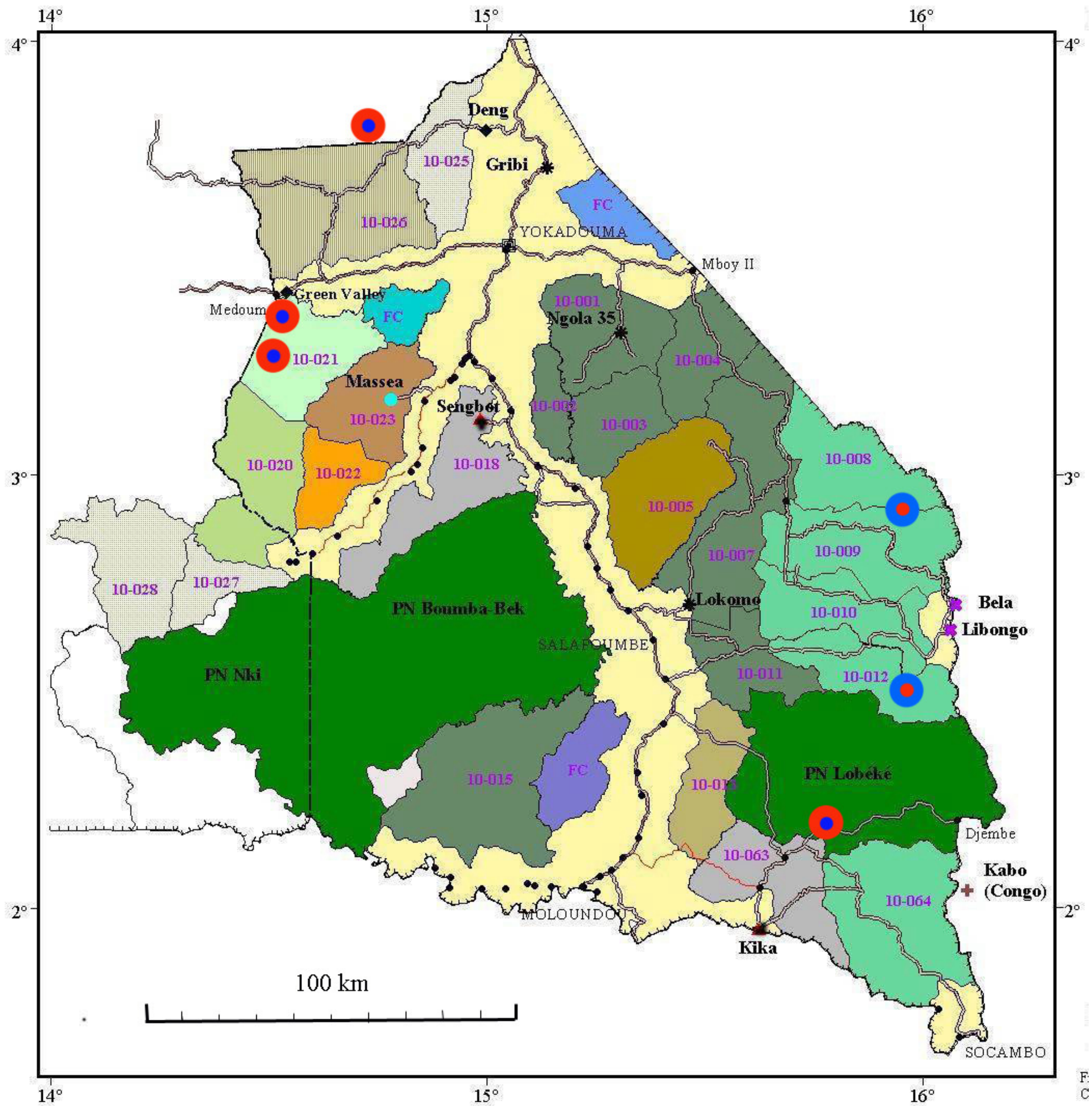


Figure 1. *Land-use and logging concessions in the Jengi Project Area showing the locations of the eleven 1.0 ha permanent forest monitoring plots established by CTFS and WWF-Cameroon in 2005 and 2006. The 2006 plots are shown as blue circles with red centers, two plots per circle. They are located in the pale blue SEFAC logging concessions center/right.*

2. Forest monitoring plots

Good management plans will guarantee sustainable use of the existing forests. For the preparation and revision of these management plans, appropriate knowledge on the resource is very vital. Forest monitoring underlies all planned forest management. In the absence of monitoring, there is no information on how the forest is responding to logging and silviculture, and it is hard to tell whether or not the management objectives are being met. Long-term forest plots are one of the most important tools for monitoring forest vegetation. CTFS is establishing a network of permanent long-term monitoring plots across central Africa.

Long-term plots make it possible to collect base-line information, which provides a measure of what is present at the outset of a management initiative. Since natural change also is occurring, sometimes at a rapid rate, we need to monitor natural rates of change as well so that they will not be mistaken for those caused by human disturbance, especially by logging. Both natural change and human disturbance must therefore be studied if the impacts of logging or other anthropogenic disturbances are to be successfully separated from natural dynamic processes.

A number of crucial questions underlie forest management in SE Cameroon, and the answers to these questions greatly affect the way the landscape is managed and conserved, and the effectiveness with which IR 1.2 is achieved:

a) What are the natural dynamics of the forests (measured directly by 1.0 ha control plots)?
b) Are tree species compositions stable, or are they undergoing long-term changes? Specifically, does it appear that canopy species will replace themselves through processes of natural regeneration (measured directly by 1.0 ha monitoring plots)?
c) Is timber exploitation sustainable in the long term? What logging practices or silvicultural interventions are needed to ensure the regeneration and sustainable harvest of exploited species (results of forest monitoring provide important information)?
d) How does forest biodiversity and wildlife habitat change over time following logging (directly measured by 1.0 ha monitoring plots)?
e) What additional changes do we see when human disturbance patterns are superimposed on natural disturbance regimes (measured directly)?

These questions can be answered by studying vegetation plots, looking at forest structure and diversity, and following growth, recruitment and mortality over time. In particular, this information tells us the likely species and timber volume that will be available for future harvest, and also the effects of forest management on other biodiversity.

3. Roles of SI, WWF and timber companies

Because of our specialized expertise in biodiversity and forest monitoring, CTFS has developed partnerships for forest management programs. In 2004/2005 we found what we believe to be an ideal partnership in the Jengi Project Area, involving CTFS as technical experts, and WWF as the NGO partnered with the Government of Cameroon to implement landscape level planning, conservation and development, and through them, partnerships with the timber industry.

Our main objectives are to:

a) Establish a long-term partnership between WWF, CTFS and timber companies for vegetation monitoring in the Jengi forests Project area in SE Cameroon.

b) Train local inventory teams capable of implementing appropriate field methodologies with minimal oversight.

c) Establish a network of permanent forest monitoring plots to study forest structure, diversity and tree populations, and responses to harvest, over time.

d) Re-census the plots for forest dynamics in future, to obtain growth rates, recruitment and mortality for trees in the canopy and understory, and to study forest regeneration under selected logging regimens and in controls.

e) Evaluate rates of natural change, logging impacts, regeneration, and assess the needs, methods and potential impacts on the ecosystem of silviculture practices, especially enrichment planting for important timber species.

4. CARPE Intermediate Results

As a follow up of last year's work, the current phase is also at both the landscape level and at the regional cross-cutting level, and is therefore relevant to I.R.1 (natural resources managed sustainably) and I.R.3 (natural resources monitoring institutionalized).

At a landscape level, our work is especially relevant to I.R. 1.2 (number of different use-zones within landscapes with sustainable management plans), which contributes directly to the sustainable management of timberlands, through the certification of timber companies. This work establishes permanent forest monitoring plots that can be used to assess the impacts of logging on forest structure, biodiversity and productivity.

At a cross-cutting level, our work is relevant to I.R. 3.1 (number of landscapes or other focal areas with forest cover assessments). In FY06, we created four georeferenced permanent forest monitoring plots that provide ground-truthing for vegetation cover maps based on satellite images. Our plot links information on diversity, forest structure, biomass and ecological processes to mapped vegetation cover types. Together with the plots from FY05, we now have established 11 forest monitoring plots in the Jengi Project Area, with over 35,000 trees and saplings from more than 300 species.

Also at the cross-cutting level, our work is relevant to I.R. 3.3 (content/quality analysis of annual "State of the Congo Basin Forest" report). Within a reasonable time-frame (5 years), we will measure change in forest structure, diversity and productivity and predict future patterns.

Our work also relates indirectly to I.R. 3.2 (assessment of capacity of Congo Basin institutions to collect and analyze information of adequate quality for decision making). Although we did not conduct a formal assessment of capacity, our training resulted in an increase in the regional capacity to establish monitoring programs through the training of individuals and the involvement of their institutions. In particular, we have created the local capacity to maintain a forest monitoring program and to rapidly evaluate the results of the monitoring in relation to forest change.

METHODS

1. Selection of methods and sites

We decided that the best use of the available resources was to build on our achievements from FY05 and expand our collaboration to include partnership with a second timber company (SEFAC) and establish four permanent forest monitoring plots within their concessions. We used the same monitoring units as last year, 1.0 ha plots with all trees over 2.0 cm diameter measured, mapped and identified to species. We were not able to conduct the proposed post-logging recensus of two plots from FY05, since these plots had not yet been logged. Consequently, we decided to create an additional new plot (for a total of 4 instead of the proposed 3), and postpone the post-logging recensus until FY07.

In collaboration with WWF and SEFAC, we selected sites for two plots in each of two concessions (Figure 1). Two plots were located in forest that has been logged several times, most recently in early 2006 (UFA 10-012), while two plots were sited in forest block in UFA 10-008 that is currently unlogged, but will be logged in 2006/07. For logged plots, stumps served as indicators of logging intensity; we selected areas with 3-4 stumps per hectare, which is an average level of exploitation for these forests. To further reduce the sources of variation in the data, we selected sites on the extensive plateau at about 500 m elevation that dominates the topography of the region and on which most of the timber production is concentrated. We avoided areas of steep slopes and wetlands for this survey.

We previously adapted the CTFS large-plot methods for use in the smaller 1.0 ha monitoring plots when we established a single monitoring plot in the Monts de Cristal, Gabon in April 2004. The method was further refined for the Jengi project area in March 2005, when a 1.0 ha plot was established in the Lobeke National Park and six others in the GD concessions. The following modifications to the basic CTFS method were maintained for the SEFAC plots: (1) minimum diameter is 2.0 cm; (2) we decided to allow the clearing of herbaceous vegetation along survey lines; (3) we excluded lianas (vines) from the survey.

2. Field supplies, teams and training

Standard CTFS field supplies were used for the survey, some borrowed from our project in Korup, some purchased for this work by both WWF and CTFS. 15,000 tree tags were produced locally from aluminum roofing sheets by our local team based in Mundemba. Metal rebar rods, 50 cm long with the looped top painted yellow, used for plot demarcation were made locally in Yakadouma (see Figure 2). Other equipment included a theodolite (Figure 2) metric staff and pole cutters, relevant record sheets, calipers, diameter tapes, measuring tapes, nylon string and rope, nails, red paint, botanical supplies and a 7-m aluminum ladder for measuring diameter of high and buttressed stems (Figure 2).

Plot demarcation was carried out in July 2006 by a team of four: two survey technicians and two assistants (Figure 2). Plot enumeration was carried out during July and August

2a: Metal corner post for plot demarcation.

2b: Plot demarcation in progress

2c: Measurement of a buttressed stem

2d: Enumeration team at work

Figure 2. *Plot enumeration in progress*

2006 by two six-person teams, each with a data recorder (team leader) an assistant to place the aluminum tags, one person to measure the tree diameters, and two or three assistants to measure the exact location of each tree within the plot. There was also a botany team for species identification, composed of a botanist and two assistants. Two additional assistants were given rotating assignments, to supplement team strength as needed (Appendix 1).

Most of the field staff were recruited from the villages and camps around Libongo, the SEFAC base. Training was conducted by the CTFS Korup team, and consisted of training in plot demarcation, plot enumeration and botanical specimen collection. The field guide that was prepared and translated into French by Zacharie Nzooh for use by the field teams in 2005 was also used by the SEFAC teams. The result of this training was the formation of a cadre of skilled CTFS/WWF vegetation monitoring technicians for the Jengi project area, able to conduct sophisticated vegetation inventories. We will continue to use this monitoring capacity in future.

3. Plot demarcation and enumeration

Demarcation and enumeration followed standard protocols for permanent monitoring plots describe in Condit 1998, *Tropical Forest Census Plots*. During plot demarcation, each 1.0 ha plot was subdivided into 25 20m x 20m quadrats, whose corners were marked with painted metal posts (Figure 3A) and to be replaced with permanent concrete pillars. During the enumeration, each 20m x 20m quadrat was subdivided into 16 5m x 5m subplots, using temporary markers at 5m intervals, and nylon rope around each 5m x 5m subplot.

All standing stems of tree species of minimum dbh 2.0 cm were measured, tagged, and located (x and y coordinates within the 5m x 5m subplot). Diameter measurements were taken at 1.3m above the ground where possible, and where this was not possible (Figure 1B), alternative points of measurement followed standard CTFS rules and the measurement point was painted to facilitate future re-censuses. Calipers were used for diameters under 6 cm, and diameter tapes for larger diameter. Each stem was measured to the nearest millimeter. A numbered tag was attached to each tree, using nylon string for smaller stems and aluminum roofing nails for larger ones. The location of each tree was determined by measuring the distance to the west and south sides of the 5m x 5m subquadrat (demarcated with nylon rope) and recorded to the nearest centimeter.

4. Data Processing

Data entry was conducted in Buea using Excel spreadsheets. The spreadsheets were then extensively checked and cleaned for data analysis. The datasets included a file of the tree data (example in Table 1), a species list (Appendix 3), and a metadata file containing plot information (Appendix 2).

Botanical methods followed the standard CTFS procedures developed in Korup and during the enumeration of the 1.0 ha monitoring plots in the Groupe Decolvenaere (GD) concessions last year (2005). The key to successful plant identification is the collection of large numbers of voucher specimens in the field and for that reason; herbarium specimens were collected from many of the individuals enumerated within the plots, except for species that were already well known. In all 246 samples were collected in three duplicates per individual. Both fertile and voucher specimens were collected.

plot	tag	sp	diam	code	gx	gy
1	1	DIOS1	37	.	1.4	0.09
1	2	ANTMA	96	M	1.45	0.38
1	3	SLOUS	28	.	1.1	2.84
1	4	DIOS1	72	L	3.8	4.3
1	5	THOM	85	L	3.76	5.54
1	6	SLOUS	20	A	0.35	7.45
1	7	DESDE	103	MLQ	1.28	8.39

Table 1. *Part of the final SEFAC dataset listing the number for the 1 ha plot (1-4), the tree tag number, code for the species, diameter at breast height, codes for abnormalities, and the exact location of each tree in the plot in meters from the west side (gx) and from the south side (gy). The dataset contains details of 11,461 trees of 292 species.*

Specimens were pressed and dried using a gas dryer in the field and hot box oven at the Life Science Laboratory of the University of Buea. Subsequent identification was carried out in the field, at the WWF Herbarium in Yokadouma, and at the National Herbarium in Yaounde by Sainge Nsanyi Moses. Two different stages were involved in the identification. The first was morphospecies matching, which was carried out in the field. Morphospecies is the general name for species lacking full scientific determination, and identified by a field code name. All the specimens were sorted and resorted, until multiple specimens belonging to the same morphospecies were grouped together. The specimen numbers were recorded, and then the surplus material discarded, keeping only the best specimens of each morphospecies.

sp	family	genus	species	author
AFRLE	Huaceae	Afrostyrax	lepidophyllus	Mildbr.
AFZ1	Fabaceae	Afzelia	bella	Harms
AFZPA	Fabaceae	Afzelia	pachyloba	Harms
ALB1	Fabaceae	Albizia	zygia	(DC.) J.F.Macbr.
ALBH	Fabaceae	Albizia	adianthifolia	(Schum.) W.F Wight
ALLAF	Sapindaceae	Allophylus	africanus	P. Beauv.
ALSBO	Apocynaceae	Alstonia	boonei	De Wild.
AMPPT	Fabaceae	Amphimas	pterocarpoides	Harms
ANGPY	Fabaceae	Angylocalyx	pynaertii	De Wild.
ANIAL	Sapotaceae	Pouteria	altissima	(A. Chev.) Baehni

Table 2. *Part of the final species list for the SEFAC plots. This dataset is linked to the tree dataset (Table 1) by the column "sp".*

The second stage was to identify the morphospecies to species with scientific names, using standard herbarium practices. Ten days were spent at the National Herbarium in

Yaounde (October 3rd - October 12th) to properly identify the sorted specimens. Species that could not be matched were listed as indeterminate. A total of 292 species were recorded from the four plots in the two UFAs. Further identification of critical specimens, including rare, difficult, and new species, will be conducted by taxonomic specialists and the specimens will be distributed top them.

RESULTS

1. Tree Diversity

We measured tree diversity at SEFAC as the number of tree species over 2 cm diameter in 1.0 ha and in 2.0 ha, and compared this with diversity from elsewhere in the Jengi area (Green Valley) and with other African sites with comparable datasets (Table 3, Figures 3, 4). Semideciduous forests like those at SEFAC have the appearance of secondary forest, as noted both from our previous fieldwork and from the literature, and some stands may be of relatively recent origin. Consequently, we were expecting to find low species richness relative to wetter, less disturbed sites such as Korup and Ituri. Our findings are that the SEFAC sites are less species rich than last year's Green Valley sites to the east, which in turn are lower than wetter CTFS sites in central Africa. Larger-sized samples are needed to confirm this difference. There was quite a lot of variation in the species-richness between the four SEFAC plots, 141-172 species per hectare.

Site	All data (trees over 2 cm)	sd	Small trees (2-10 cm)	Sd	Larger trees (over 10 cm)	sd
SEFAC	161	14.6	135	9.3	90	9.2
Green Valley	182	12.9	164	16.3	90	9.2
Korup	199	18.9	179	17.5	86	12.3
Edoro	152	14.9	141	15.0	67	8.0
Lenda	146	21.0	136	19.3	52	22.0
Gabon	259	n.a.	230	n.a.	107	n.a.

Table 3. *Species richness in 1.0 ha and standard deviation (sd) of the 4 SEFAC plots from the Jengi Project Area, with comparative data from the six Green Valley plots also from the JPA, and from Korup, Ituri (Edoro and Lenda) and from the Monts de Cristal in Gabon (1.0 ha only).*

To produce a more robust count of species, we combined the data from the two 1.0 ha plots in each pair, and then produced comparable datasets from Korup and Ituri (Figure 4). There is a lot of variation between the plot pairs in the Jengi area (SEFAC and Green Valley), which probably represents heterogeneity in the vegetation.

One of the most striking features of the tree diversity was the number of species that we encountered belonging to the genus Drypetes and related genera (family = Putrangivaceae, formerly Euphorbiaceae). Drypetes are mostly small, dioecious trees with animal-dispersed fruits. We found about 16 species from 4.0 ha at SEFAC (Appendix 1) and 19 species in 6.0 ha at Green Valley, compared to 7 species from 50 ha in Korup and 10 species from 40 ha in Ituri.

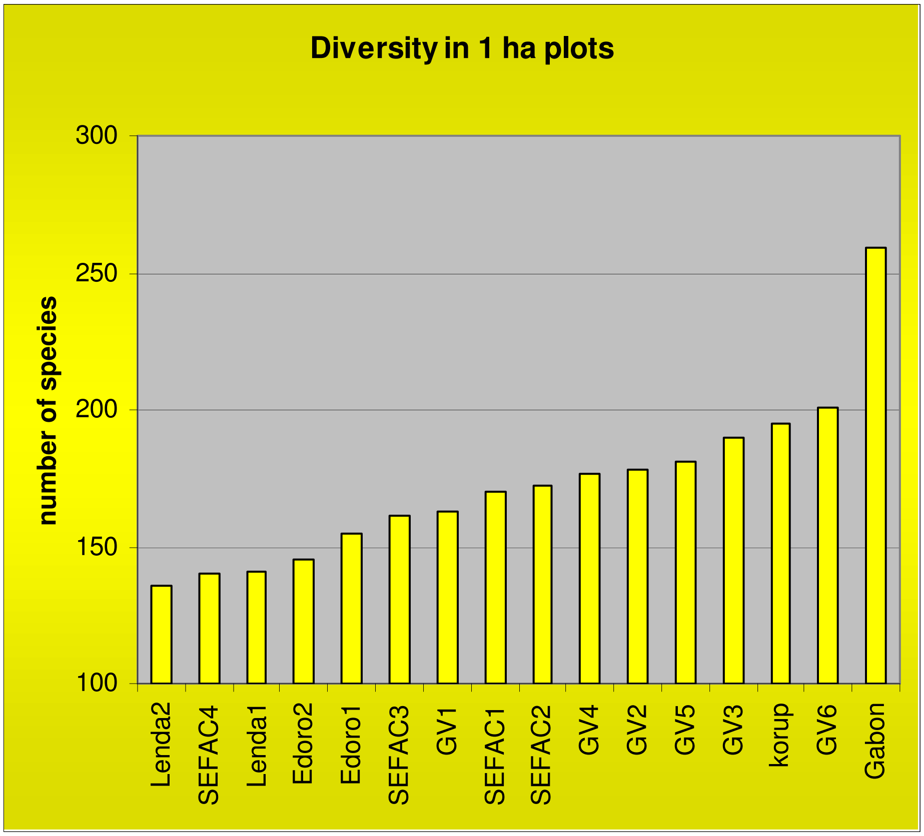
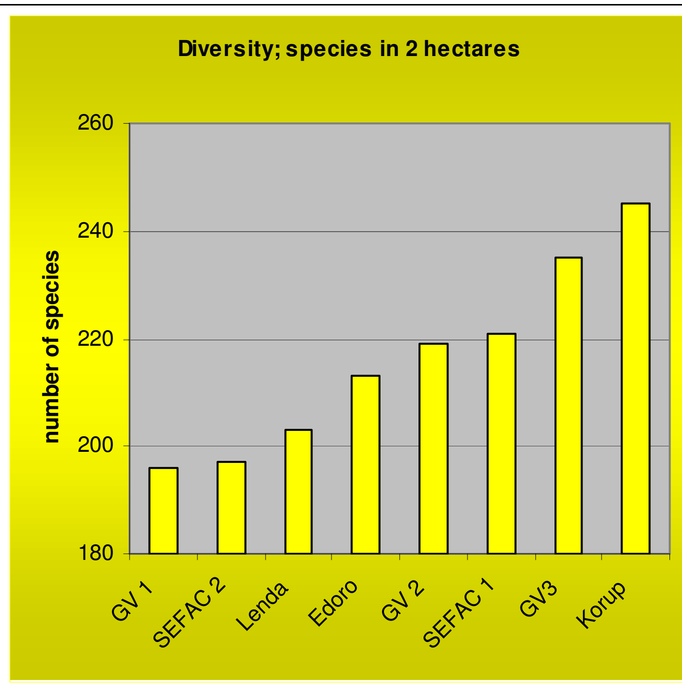


Figure 3: *Species richness per hectare of trees over 2.0 cm diameter for the four SEFAC plots and the six Green Valley plots, with comparative data from Ituri (Lenda and Edoro), Korup, and the Monts de Cristal, Gabon. SEFAC plots are relatively poor in species, and the Monts de Cristal site appears to be the richest.*

Figure 4*: Species richness for 2.0 ha (1.0 ha plots combined in pairs) from Jengi monitoring at SEFAC and Green Valley, with comparative data from Ituri (Edoro and Lenda) and Korup.*



For plant diversity other than trees, we did not have sufficient resources to examine this systematically, despite the great importance of vines and shrubs/tall herbs in the ecosystem and in timber management. Our incidental collections of flowering and fruiting plants yielded a second specimen of the new species of *Kihansia* (Triuridaceae), a genus previously known only from Tanzania. The first specimen was collected during the 2005 work at Green Valley.

From our SEFAC database, we were able to develop species-area curves, using a range of sample sizes from 0.0025 ha to 1.0 ha (Figure 5). Last year, we developed a method to predict larger patterns of diversity from our 1.0 ha dataset, and we applied the same method here to estimate species in 50 ha and 100 ha of forest (Figure 6). Predictions of larger areas than 100 ha will require further verification. The extrapolation is based on a linear model of the three largest sample sizes computed for the species-area curve. Using mean values from the 10 Jengi plots for trees over 2 cm diameter, we predict about 380 species in 50 ha and about 416 species in 100 ha. The species-area relationship is a powerful tool for biodiversity conservation, since it provides a fairly robust estimate of the tree diversity of given areas, estimates that can be tested as the number of 1.0 ha monitoring plots increases.

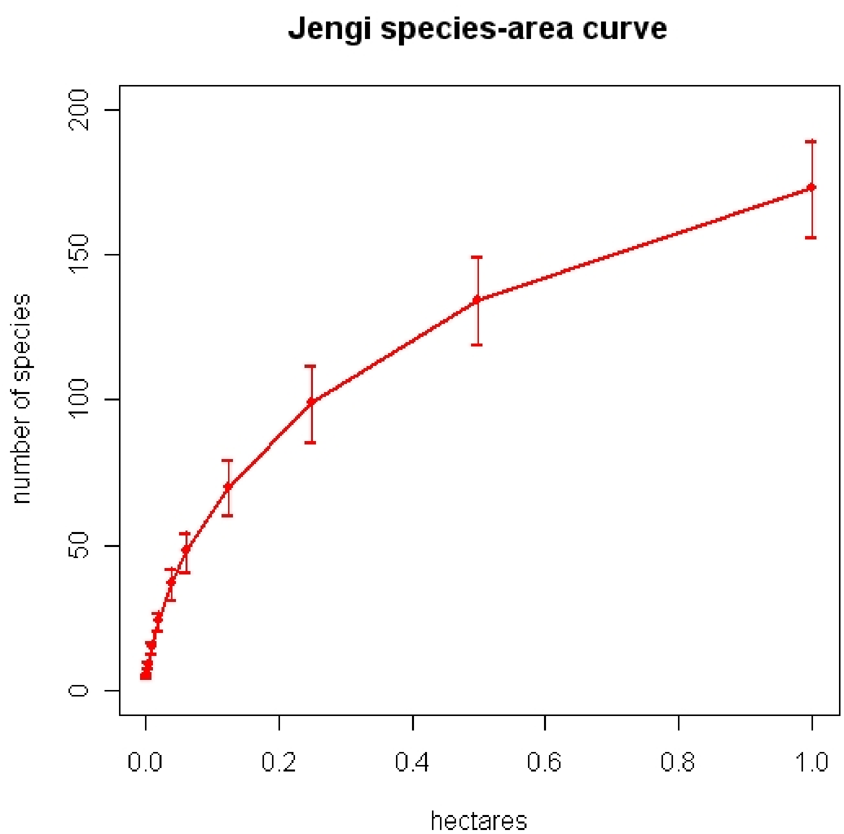


Figure 5. *Species area curve for the Jengi Project Area, mean and standard deviation for ten 1.0 ha plots for trees over 2.0 cm diameter.*

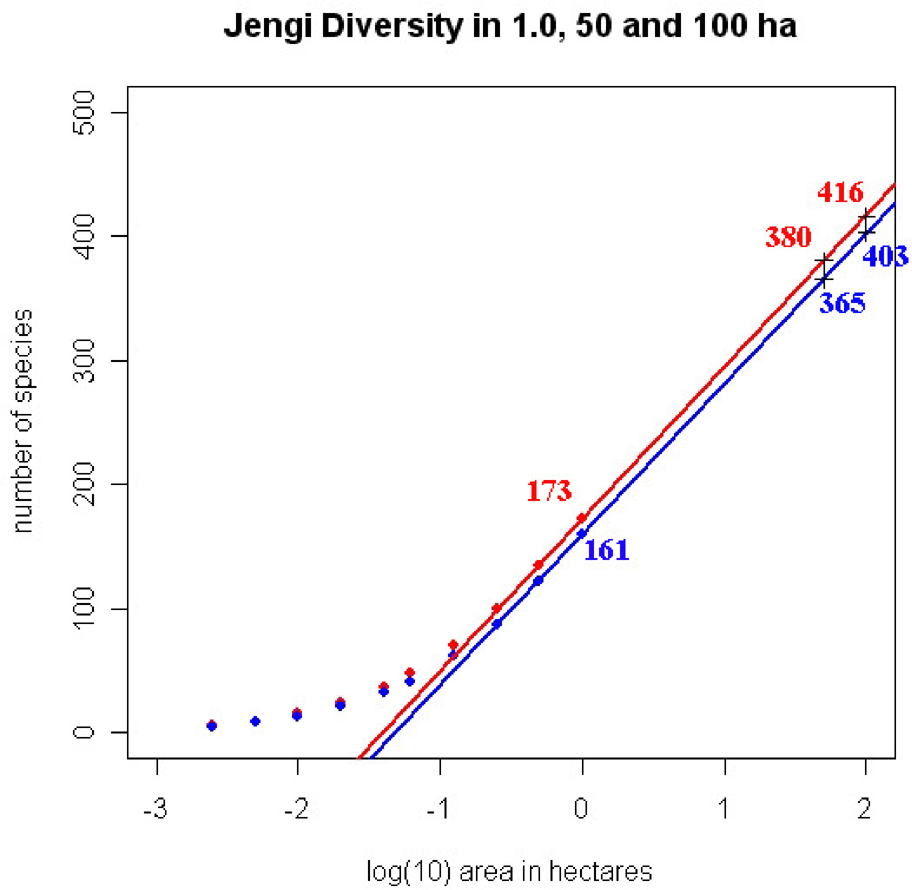


Figure 6. *Species-area and landscape diversity. Extrapolated species-area curve for 4 x 1.0 ha plot data from SEFAC (blue) and all 10 Jengi plots (red) showing the measured number of species in 1.0 ha (161, 173) and the expected number of species in 50 ha (365, 380) and 100 ha (403, 416).*

Species turnover with distance is very important in conservation biology, since it provides an indication of the optimal distance between protected areas, a concept which is directly related to the CARPE Strategic Objective. As a preliminary investigation for the Jengi area, we used a simple metric to measure the turnover of species among the four plots: the number of species in common from pairwise comparisons (Figure 7). Our expectation was that similarity would decrease with distance. A pairs of plots from the same concession, separated by only a few kilometers, should show greater similarity than comparisons between either of them and plots from the other logging concession, about 50 km away and with different management history. The data supported this expectation. The four plots had about 36% of total species in common. Close pairs averaged about 70% species in common, while distant pairs had on average about 54% of the species in common. The fairly high species turnover even between the close pairs of plots (30% of the species not in common) could be due to several causes, including heterogeneity in the vegetation and sub-optimal sample size.

We compared similar datasets with trees over 2.0 cm dbh from the four 1.0 ha corner plots in the 50 ha forest monitoring plot in Korup, where close pairs are separated by 300 m, and more distant plots by about 800 m. Interestingly, the similarity between plots in

Korup separated by 800m was about the same as for SEFAC plots separated by 50 km (56.6% vs 54.5% species in common), suggesting that the tree flora in SEFAC concessions and probably over the whole Jengi project area is more homogeneous than in the wetter forest at Korup, and consequently could be conserved by more widely-spaced protected areas.

PLOT	1	2	3	4
1	100	70.4	58	50
2		100	58.4	51.4
3			100	69.1
4				100

Figure 7. *Species similarity: pairwise comparison between plots, percent of species in common. Results for close pairs in orange, distant pairs in white.*

2. Forest Structure

A total of 11461 trees of diameter 2.0 cm or more belonging to 292 species were record in the four plots. In the unlogged forest of the northern concession (UFA 10-008), a total 221 species were recorded, and 197 species were found in the two plots in the logged-over southern concession (UFA 10-012). In the unlogged northern plots, the understory was monodominant with *Sloetiopsis usambarensis* (Moraceae), while the most abundant understory species in the logged southern plots was *Grossera macrantha* (Euphorbiaceae), but only weakly dominant. .

	Forest plots				
Diam. Class	1	2	3	4	All 4 ha
2-10cm	2972	2961	1717	2224	9874
10-20cm	272	278	217	250	1017
20-30cm	71	84	51	57	263
30-40cm	35	31	26	38	130
40-50cm	15	15	12	17	59
>50cm	33	21	36	28	118
TOTAL	3398	3390	2059	2614	11461
No. species	170	172	161	140	292

Table 4: *Stand structure and diversity of four 1.0 ha plots in the two SEFAC concessions, the northern, unlogged plots in red, the logged, southern plots in blue.*

Stand structure of the four plots is shown in Table 4. The southern plots (blue) have fewer small trees and fewer species than the northern plots (red). The difference in small stem density can be attributed in part to the understory monodominance of *Sloetiopsis* in the northern plots. The southern logged forest (plots 3 and 4) has a lower density of trees in the 2-10 cm diameter class compared to the northern unlogged forest in plots 1 and 2

(Table 4). Tree densities are fairly similar for trees over 30 cm diameter, and the obderved differences are likely due to the fairly small sample size for larger trees. Larger trees in the southern, logged forests belonged mostly to the less commercialized (group 2) and potentially commercialized (group 3) categories of exploitable species, while the northern plots had more stems in group 1 (commercial species).

	basal area m^3/ha	Tree density 2-10cm	tree density 10 – 30 cm	tree density 30 - 60 cm	tree density >60 cm
SEFAC	30.0	2449	335	57	21
Green Valley	35.9	2907	353	70	30
Korup	26.1	3504	408	73	11
Edoro 1	26.2	4109	388	55	21

Table 5. *Comparison of forest structure. Mean basal area (m^2 per ha) for trees over 10 cm diameter, and mean number of trees per hectare for four diameter classes. SEFAC concessions with comparative results from Jengi/Green Valley, Korup and Ituri-Edoro.*

When the mean values for tree density and basal area from SEFAC are compared with other areas (Table 5), we can see that tree densities are relatively low in all but the largest size class, while basal area is in the mid-range. It is interesting to note that *Triplochiton scleroxylon* (ayous) the most abundant large tree at Green Valley, and the most important timber species in terms of volume, is completely absent from our SEFAC census. Another interesting difference between the SEFAC and Green Valley sites is the absence of the pioneer umbrella tree, *Musanga cecropioides*, from the logged plots. This species is ubiquitous in disturbed forests throughout southern Cameroon, its absence in the SEFAC plots is unusual and unexplained.

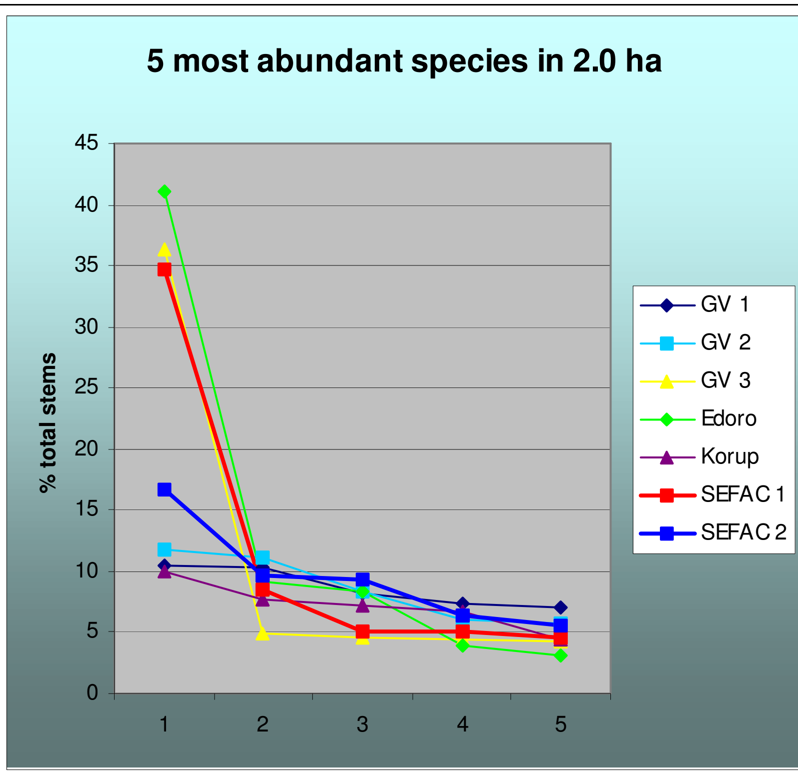


Figure 8. *Understory dominance: abundance of the five commonest understory species for two pairs of plots from SEFAC, compared to Green Valley, Korup and Ituri-Edoro. The red line, SEFAC 1, is the northern pair of plots; the dark blue line, SEFAC 2, is the southern pair of plots. Strong dominance is shown in SEFAC1, GV3, and Edoro.*

Understory dominance at SEFAC, Green Valley and other African sites is shown in Figures 9 (above) and 10 (below). The northern pairs of plots at SEFAC 1 and Green Valley 3 both have understory monodominance by *Sloetiopsis usambarensis* (Moraceae), and resemble the Ituri-Edoro plot, which shows understory near-monodominance by *Scaphopetalum dewevrei* (Malvaceae). The southern SEFAC plots show less understory dominance, but still more than the southern pairs of plots at Green Valley and the CTFS plot at Korup. Strong understory dominance in terre firme tropical forests is unusual, generally tropical forests are characterized by high species-richness and low dominance. Here, it is probably an indicator of the successional status of the forest and likely to be linked to other aspects of forest structure, such as the regeneration of timber trees. Our preliminary hypothesis is that northern part of the Jengi area is in an earlier successional stage than the southern part, and is responding to a past catastrophe, probably natural.

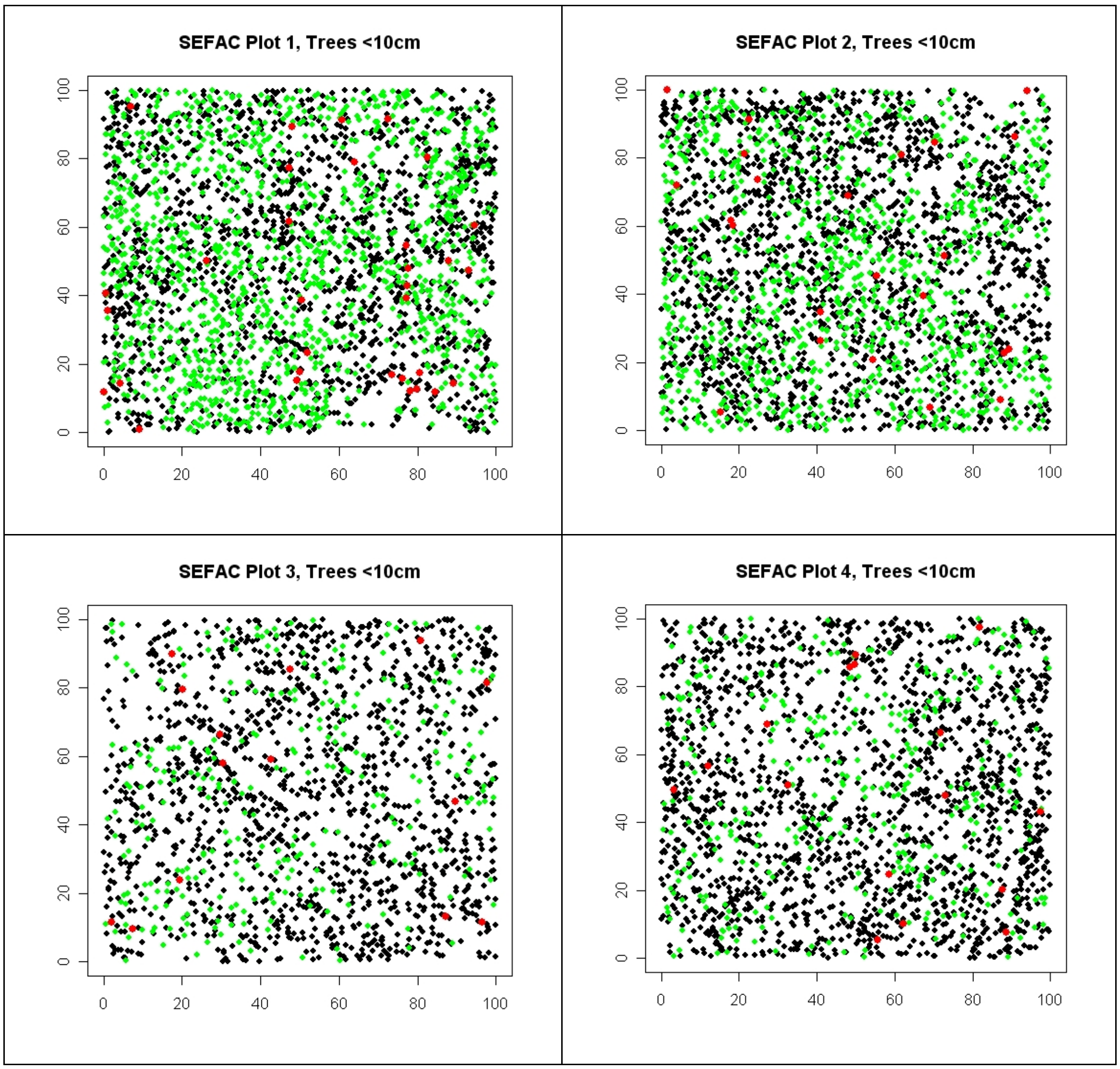


Figure 9. *Four 1-ha plots from SEFAC/Jengi showing the saplings and small trees, under 10 cm diameter. Timber species in red, understory dominant species in green, all other saplings in black. The dense understory dominant in plots 1 and 2 (north, unlogged) is* Sloetiopsis usambarensis*, the much more sparse understory dominant in plots 3 and 4 (south, logged) is* Grossera macrantha*.*

3. Exploited Species

Genus	Species	Trade	<10	10-30	30-50	>50	Total
Afzelia	*Spp*	Doussié	3	3	1	0	7
Pouteria (Aningeria)	*Altissima*	Aningré_A	0	0	0	1	1
Entandrophragma	*cylindricum*	Sapelli	15	3	0	5	23
Entandrophragma	*utile*	Sipo	2	1	0	2	5
Entandrophragma	*angolense*	Tiama	0	1	0	0	1
Entandrophragma	*candollei*	Kosipo	2	0	0	1	3
Erythrophleum	*ivorense*	Tali	1	1	0	4	6
Guarea	*Sp.*	Bosse?	11	2	0	0	13
Guarea	*thompsonii*	Bosse fonce	3	0	1	0	4
Guarea	*cedrata*	Bosse Clair	23	8	1	0	32
Khaya	*ivorensis*	Acajou	2	0	0	1	3
Lophira	*alata*	Azobe	1	2	0	0	3
Lovoa	*trichilioides*	Bibolo	0	1	0	0	1
Mansonia	*altissima*	Bété	0	0	1	0	1
Pericopsis	*elata*	Assamela	7	1	3	1	12
Pterocarpus	*spp*	Padouk	10	0	0	2	12
Terminalia	*superba*	Limba	6	4	7	23	40
Totals			86	27	14	40	167

Table 6. *Stand structure for 14 species of exploitable timber, two groups of species (*Afzelia *and* Pterocarpus*) and one uncertain species (*Guarea *sp.) found in the four 1.0 ha plots in the two SEFAC concessions.*

Stand structure for the exploitable species is shown in Table 6, and their distributions in the four plots are shown in Figure 10. Our results and the mandatory pre-logging inventories conducted by the timber company (data not available) indicate that there are sufficient trees to permit further harvests at all sites. However, the 10 – 30 cm size class appears to be relatively poor in the timber species, so in future, the volume of timber from these species will decline.

The numbers of saplings of the timber species (and of all species of canopy trees) in the understory is very low. It appears that the regeneration is insufficient to replace the canopy, and this is especially true of the important timber species. Growth rates are needed to confirm this observation, but it is unlikely that the saplings would have high enough survival and fast enough growth rates to replace the current canopy trees. Consequently, we would expect the timber volumes to decline in future, and to remain low until the valuable species can be replaced or the market switches to other species currently unexploited. This finding supports our observations from the 6 plots at Green Valley in the Jengi Project Area, established in 2005.

In 2005, we were able to show the distributions of saplings of exploitable species in canopy gaps created by logging, using the common pioneer tree species *Musanga cecropioides* as an indicator (Figure 11), and we demonstrated weak relationship between the saplings and the light gaps, with the conclusion that the light gaps created through logging were not of optimal quality to encourage the regeneration of these species, possibly because of competition from the dense shrub layer that develops in light gaps in this type of semideciduous forest. Given the sapling densities observed in the southern (logged) SEFAC concession, it is likely that the same conclusion can be applied here. However, the indicator species *Musanga* was completely absent from the SEFAC plots, so we were not able to monitor the gaps by this method.

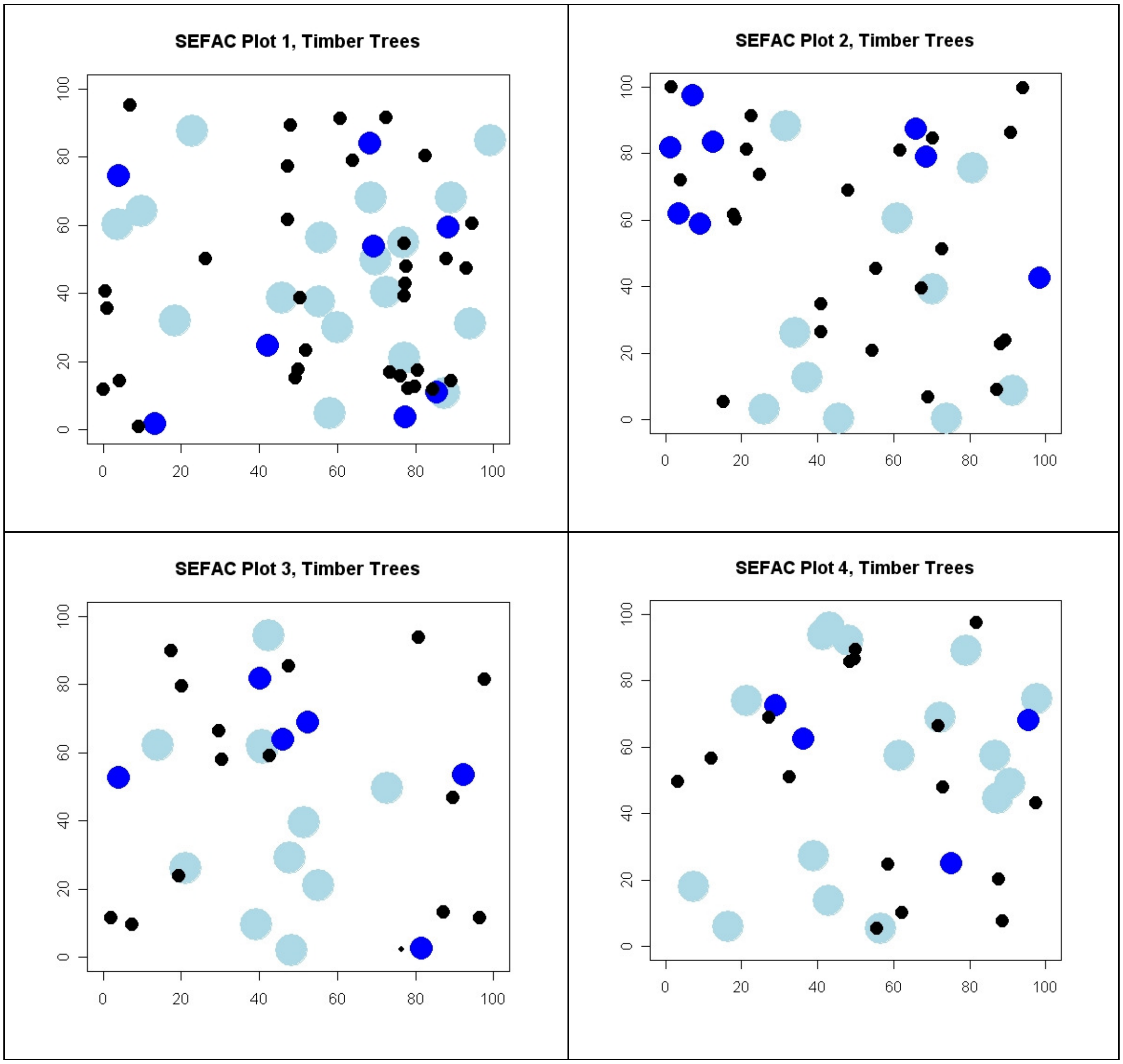


Figure 10. *Distributions of timber trees (18 species) in the four 1.0 ha plots. Over 30 cm diameter: pale blue; 10 – 30 cm diam: blue; 2 – 10 cm diam: black.*

DISCUSSION

1. Standard Methodology for the Congo Basin

Our objective is to address multiple CARPE IR's through our field program, including both a local landscape-level approach through IR 2.1 (sustainable management plans), and a basin-wide approach through 1R 3 (monitoring the state of the basin), as well as training and capacity-building related to IR 2. We are achieving this objective through the basin-wide deployment of a standard field design, the permanent 1.0 ha forest monitoring plot. At present, these plots are being established in two series, differing in the diameter cutoff. The plots established by the Smithsonian MAB program have a minimum diameter of 10 cm. Containing about 500 trees, these plots can be spread rapidly across the landscapes to give wide coverage, and can be complimented by additional datasets collected with other funding.

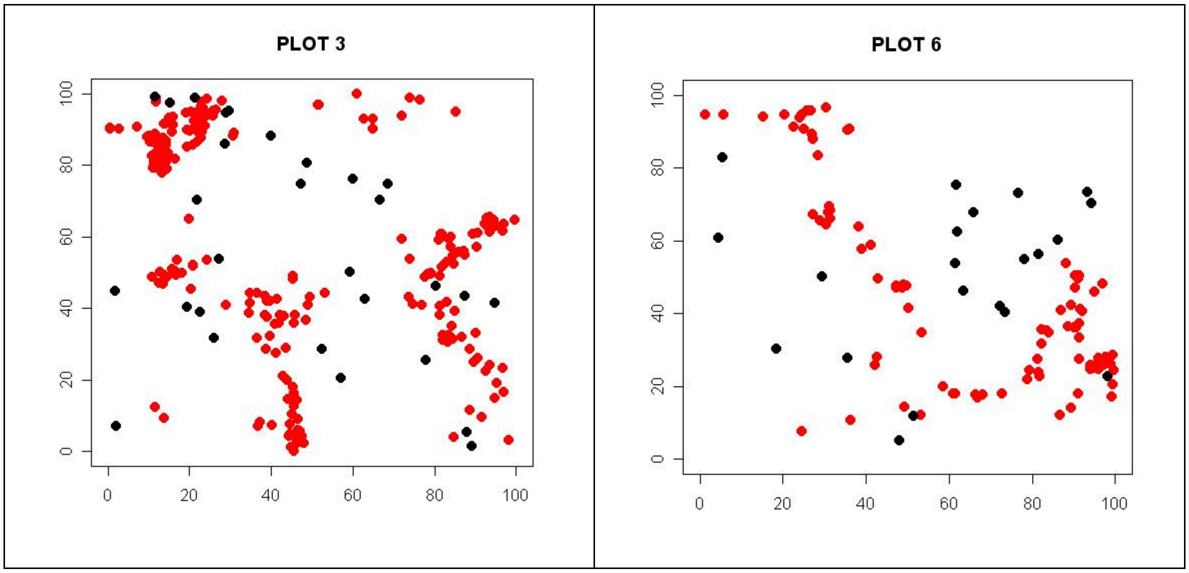


Figure 11. *Two plots from our FY05 Jengi/Green Valley report, showing* Musanga *regeneration (red) in the gaps opened by logging, with the saplings of the economic species (black) not associated with the gaps.*

We used a minimum diameter of 2 cm, with approximately 3,000 trees and saplings per hectare. These plots take longer to establish, but contain important additional information on the forest regeneration and biodiversity. The 1.0 ha datasets can be scaled up to landscape scales or larger by adding more plots and by linking the geo-referenced plot information to satellite images. The plots with 2 cm cutoffs can also be scaled down, since they contain a large amount of information on the neighborhood of individual trees and saplings. They can be used to monitor regeneration after a single treefall for example.

For some analyses of population dynamics, the individual trees can be used as the samples rather than the whole plot, which greatly increases the number of samples in these analyses and the robustness of the results. In future the results from the monitoring plot network can be used to address more specific forest management questions associated with individual forest types or management regimes.

Our conclusion here is that the deployment of a regional network of standard 1.0 ha forest monitoring plots is a highly effective way of monitoring biodiversity, structure and dynamics at both the landscape and the regional scales, and addresses some key forest management issues related to natural change and the effects of logging. We hope to expand the plot network in future, and help to establish monitoring programs in all landscapes in collaboration with our CARPE partners.

2. Biodiversity in the Semideciduous Forest

Our forest monitoring plots each contain about 3000 trees over 2.0 cm diameter, and therefore provide a fairly robust measure of tree diversity, which can be extrapolated to larger scales. Tropical forests are of interest to conservation largely because of the numerous species of plants and animals that they contain, and our work provides one of the best assessments available of the richness of a central African forest. Large samples of forest plants provide robust indicators of the importance of a forest to biodiversity conservation, in contrast to other groups such as megafauna, that, because of unique influences on their distributions including hunting, are poor indicators of anything other than themselves.

The results that we obtained from this study were rather ambivalent concerning the biodiversity importance of the Sangha Tri-National Landscape. Our starting hypothesis based on the literature and our previous exploration was that the landscape was probably relatively poor in biodiversity, and supported secondary forest with a flora comprised mostly of common, widely-distributed species. Following logically from this hypothesis we speculated that the main importance of the area to biodiversity conservation was megafauna, and that this was being addressed through poaching control and the current system of protected areas and corridors.

Our preliminary results support the view that the forests are secondary and changing in species composition over time as the forest becomes more mature, and future recensus after five years will provide more detailed information on change. From the literature, the secondary nature of the forest probably derives either from catastrophic disturbance in the not so distant past (hundreds of years), or else represent a stage in the change from savanna to forest in response to long-term climate change. Although the tree diversity is lower than in the wetter evergreen forest of central Africa, the species are rather patchily dispersed, and many are therefore likely to be absent from the protected area network. When the biodiversity inventory of the area is more complete, we will be able to document any additional conservation measures that are needed.

3. Timber Harvest and Regeneration

As a preliminary finding it appears that although the timber species probably require large light gaps for regeneration, those gaps created in the semideciduous forest through logging are not of the right quality, probably because of too-intense competition for light and soil resources from shrubs, climbers and pioneers. We hope to develop and test hypotheses based on this finding during future monitoring in the area, to develop more sustainable forest management and contribute to CARPE IR 1.2.

The paucity of juvenile timber trees would appear to be a serious problem for future harvests in this landscape. If our observations on the lack of regeneration are generally true then at some point in the not-so-distant future, the forests will rapidly loose value, at least from the current suite of timber species. We will have a better idea of the time scale of this event when we have growth measurements from the 5-year recensus. There is an urgent need to focus forestry research on the problems of tree regeneration if the Jengi Project area is to reap the benefits of well-managed forests in future.

Forest enrichment has been addressed elsewhere by forestry projects such as the French-funded Dimako project to the north of this landscape, and by the Government of Cameroon with assistance from various foreign sources through the Forestry Department and parastatals at various sites in the country. However, at the present time, the capacity of the Cameroon Government to implement enrichment plantings remains low, while the baseline information on the ecological processes in the semideciduous forest is largely missing. As far as we could ascertain, there are currently no official forestry projects focused on tree regeneration in the Jengi area. The partnerships that we are forming through CARPE are a good forum in which to approach the problem of forest regeneration, since they combine technical expertise from CTFS with WWF, the timber industry, the timber certification process, a forest conservation project and the Government of Cameroon.

4. Future Activities

The collaboration between WWF, CTFS and two logging companies, Groupe Decolvenaere and SEFAC proved to be a successful combination for the implementation of CARPE IR 1.2, which requires the creation of sustainable management plans. A total of eleven 1.0 ha permanent monitoring plots have been established so far. We plan to continue this collaboration in future. Future activities include the integration of data from timber cruising into our analysis, establishment of more plots, recensus of existing plots after five years, immediate post-harvest recensus of plots that are logged, and continued development of the plant species list for the area. Recensus of the monitoring plots will yield a lot of information on forest growth, recruitment and mortality, and will provide us with a more accurate picture of the health of the forest and the way that the forest changes over time, and the implications for timber harvest.

Appendix 1. Personnel involved in the establishment of four 1-ha monitoring plots in SEFAC forest concessions in SE Cameroon (UFAs No. 10 008 and 10 012), 21 July – 31 August 2006.

Name	Team	Position
THOMAS, Duncan	CTFS Management	Program oversight
CHUYONG, George	CTFS Management	Survey/Coordination with WWF
USONGO, Leonard	WWF Jengi Project	Coordination with Jengi Project
NZOOH, Zacharie	WWF Jengi Project	Coordination with Jengi Project
OUMAR, Abakar	SEFAC	SEFAC/Forest Management officer
SAINGE Moses	Logistics/ Botany	Lead Botanist, Field Manager
MAMBO, Peter	Botany	Botanist
YAYA, Jean-Marie	Botany	Field Assistant, Tree Climber
MOTOVE, Marcus	Logistics	Driver
EDOUA, Bengona	Logistics	Catering
ANGOUNOU, Joseph	Cadastral Survey	SEFAC Surveyor
ATANGANA, Lionel	Cadastral Survey	SEFAC Surveyor
KOKU Etienne	Cadastral Survey	Field Assistant
VALENTINE Pascal	Cadastral Survey	Field Assistant
BALLA, Dieudonne	Enumeration	Recorder/ Team Leader 1
TINEFEH, Fredrick	Enumeration	Recorder/ Team Leader 2
OKAA, Anatole	Enumeration	x-y coordinates
KET Jean Syvert	Enumeration	x-y coordinates
NAMPLE, Clovis	Enumeration	x-y coordinates
SOULEYMAN, Landry	Enumeration	Diameters
NDENGEU, Thierry	Enumeration	Diameters
MEMPEL, Cedric	Enumeration	Diameters
NKUNDE, Louis	Enumeration	Tree tags
ABDOULAYE, Dzock	Enumeration	Tree tags
HAYIBA, Emmanuel	Enumeration	Back-up

Appendix 2. Metadata: details of the four SEFAC plots plus the eight permanent monitoring plots established in FY04 andFY05.

Country	Location	Logging	forest type	d/m N	d/m E	Size	min dbh
Cameroon	Green Valley, south 1	control	semideciduous	03 15.47	14 28.83	1.0 ha	2.0 cm
Cameroon	Green Valley, south 2	control	semideciduous	03 15.40	14 30.16	1.0 ha	2.0 cm
Cameroon	Green Valley mill 3	5 years	semideciduous	03 22.40	14 33.02	1.0 ha	2.0 cm
Cameroon	Green Valley mill 4	5 years	semideciduous	03 23.01	14 32.60	1.0 ha	2.0 cm
Cameroon	GV SOTREF 5	15 years	semideciduous	03 49.21	14 43.57	1.0 ha	2.0 cm
Cameroon	GV SOTREF 6	15 years	semideciduous	03 49.21	14 37.22	1.0 ha	2.0 cm
Cameroon	Lobeke National Park 1	control	mbau monodominant	02 09.35	15 44.18	1.0 ha	2.0 cm
Cameroon	SEFAC 1/7, north	control	semideciduous	02 56.94	15 56.37	1.0 ha	2.0 cm
Cameroon	SEFAC 2/8, north	control	semideciduous	02 57.83	15 57.08	1.0 ha	2.0 cm
Cameroon	SEFAC 3/9, south	logged	semideciduous	02 30.83	15 56.67	1.0 ha	2.0 cm
Cameroon	SEFAC 4/10, south	logged	semideciduous	02 30.78	15 56.37	1.0 ha	2.0 cm
Gabon	Monts de Cristal N.P. 1,	control	sp-rich evergreen	00 28.00	10 16.68	1.0 ha	1.0 cm

Appendix 3: Species list for the four plots in the SEFAC forest concessions (UFA 10-008 and UFA 10-012).

sp.code	family	genus	species
AFRLE	Huaceae	Afrostyrax	lepidophyllus
AFZ1	Fabaceae	Afzelia	bella
AFZPA	Fabaceae	Afzelia	pachyloba
ALB1	Fabaceae	Albizia	zygia
ALB2	Fabaceae	Albizia	adianthifolia_cf
ALB3	Fabaceae	Albizia	.
ALBH	Fabaceae	Albizia	adianthifolia
ALLAF	Sapindaceae	Allophylus	africanus
ALSBO	Apocynaceae	Alstonia	boonei
AMP1	Fabaceae	Amphimas	.
AMPPT	Fabaceae	Amphimas	pterocarpoides
ANGPY	Fabaceae	Angylocalyx	pynaertii
ANIAL	Sapotaceae	Pouteria	altissima
ANIMA	Acanthaceae	Anisotes	macrophyllus
ANNO	Annonaceae	Hexalobus	grandiflorus
ANNO1	Annonaceae	Monodora	.
ANOMA	Annonaceae	Anonidium	mannii
ANTH	Fabaceae	Pterocarpus	osun
ANTH3	Fabaceae	Anthonotha	cladantha
ANTLA	Phyllanthaceae	Antidesma	laciniatum
ANTMA	Fabaceae	Anthonotha	macrophylla
AORCL	Rubiaceae	Aoranthe	nalaensis
AULCA	Rubiaceae	Aulacocalyx	jasminiflora
BAP1	Fabaceae	Baphia	silvatica
BAP2	Fabaceae	Baphia	.
BARFI	Passifloraceae	Barteria	fistulosa
BEIE	Lauraceae	Beilschmiedia	acuta
BEIE1	Lauraceae	Beilschmiedia	zenkeri_cf
BEIFU	Lauraceae	Beilschmiedia	fulva
BEIY	Lauraceae	Beilschmiedia	mannii
BELCO	Rubiaceae	Belonophora	coreacea
BIGNO	Bignonaceae	Markhamia	tomentosa
BIGNO	Bignonaceae	Markhamia	tomentosa
BIGNO1	Bignonaceae	Markhamia	lutea
BLI2	Sapindaceae	Lychnodiscus	grandifolius
BRIAT	Phyllanthaceae	Bridelia	atroviridis
BRIMI	Phyllanthaceae	Bridelia	micrantha
CAN1	Rubiaceae	Canthium	vulgare_cf
CANPS	Rubiaceae	Canthium	psychotrioides_cf
CARA	Meliaceae	Carapa	.
CARP	Polygalaceae	Carpolobia	.
CASBA	Salicaceae	Casearea	barteri
CASS1	Rhizophoraceae	Cassipourea	zenkeri_cf

CASS2	Rhizophoraceae	Cassipourea	.
CEIPE	Bombacaceae	Ceiba	pentandra
CELAD2	Ulmaceae	Celtis	adolfi_friderici
CELMI	Ulmaceae	Celtis	mildbraedii
CELPH	Ulmaceae	Celtis	philippensis
CELTE	Ulmaceae	Celtis	tessmannii
CELZE	Ulmaceae	Celtis	zenkeri
CHY1	Sapindaceae	Chytranthus	talbotii
CHY2	Sapindaceae	Chytranthus	angustifolius
CHY4	Sapindaceae	Pancovia	laurentii
CHY5	Sapindaceae	Chytranthus	macrobotrys
CHYE	Sapindaceae	Chytranthus	atroviolaceus
CHYM	Sapindaceae	Chytranthus	gilletii
CHYT	Sapindaceae	Chytranthus	carneus
CHYTA	Sapindaceae	Chytranthus	mortehanii
CITAR	Rutaceae	Oriciopsis	glaberrima
CLE1	Annonaceae	Cleistopholus	staudtii_cf
CLEPA	Annonaceae	Cleistopholus	paterns
COF	Rubiaceae	Corynanthe	.
COF2	Rubiaceae	Tricalysia	crepiniana
COF3	Rubiaceae	Coffea	.
COF4	Rubiaceae	Tricalysia	gossweileri
COL2	Malvaceae	Cola	flavo-velutina_aff
COLAL	Malvaceae	Cola	altissima
COLFL	Malvaceae	Cola	flavo_velutina
COLLA	Malvaceae	Cola	lateritia
COLNI	Malvaceae	Cola	ballayi
COPMI	Fabaceae	Copaifera	mildbraedii
CORAU	Boraginaceae	Cordia	myxa_cf
CROT1	Euphorbiaceae	Croton	.
CUV1	Rubiaceae	Cuviera	longiflora
DACED	Burseraceae	Dacryodes	edulis
DAS1	Achariaceae	Dasylepis	seretii
DEIN	Sapindaceae	Ganophyllum	giganteum
DESDE	Malvaceae	Desplastsia	chrysochlamys
DIAPA	Fabaceae	Dialium	pachyphyllum
DICGL	Euphorbiaceae	Dichostemma	glaucescens
DICHM	Dichapetalaceae	Dichapetalum	albus
DICPU	Thymeliaceae	Dicranolepis	pulcherrima
DICR1	Thymeliaceae	Dicranolepis	grandiflora
DIOCA	Ebenaceae	Diospyros	canaliculata
DIOCR	Ebenaceae	Diospyros	crassiflora
DIOIT	Ebenaceae	Diospyros	iturensis
DIOMA	Ebenaceae	Diospyros	mannii
DIOMA2	Ebenaceae	Diospyros	.
DIOS1	Ebenaceae	Diospyros	.
DIOS2	Ebenaceae	Diospyros	abyssinica
DIOS3	Ebenaceae	Diospyros	pseudomespilus_cf
DIOS4	Ebenaceae	Diospyros	.
DIOY	Ebenaceae	Diospyros	bipindensis_cf

DISCA	Euphorbiaceae	Discoglypremna	caloneura
DRY1	Putrangivaceae	Drypetes	klainei_cf
DRY2	Putrangivaceae	Drypetes	leonensis_aff
DRY3	Putrangivaceae	Drypetes	afzelii_aff
DRY4	Putrangivaceae	Drypetes	floribunda
DRY5	Putrangivaceae	Drypetes	.
DRYA	Putrangivaceae	Drypetes	chevalieri_cf
DRYAF	Putrangivaceae	Drypetes	aframensis
DRYGI	Putrangivaceae	Drypetes	callipes
DRYGO	Putrangivaceae	Drypetes	gossweileri
DRYIV	Putrangivaceae	Drypetes	ivorensis
DRYLA	Putrangivaceae	Drypetes	laciniata
DRYLE	Putrangivaceae	Drypetes	leonensis
DRYMO	Putrangivaceae	Drypetes	molunduana
DRYN	Putrangivaceae	Drypetes	parvifolia
DRYPA	Putrangivaceae	Drypetes	paxii
DRYPR	Putrangivaceae	Drypetes	preussii
DUBMA	Malvaceae	Duboscia	macrocarpa
ELADR	Euphorbiaceae	Elaeophorbia	grandifolia
ENTAN	Meliaceae	Entandrophragma	angolense
ENTCA	Meliaceae	Entandrophragma	candollei
ENTCY	Meliaceae	Entandrophragma	cylindricum
ENTUT	Meliaceae	Entandrophragma	utile
ERIOB	Malvaceae	Eriobroma	oblongum
ERYIV	Fabaceae	Erythrophleum	ivorensis
ERYMA	Erythroxylaceae	Erythroxylum	mannii
EUGLO	Rubiaceae	Euclinia	longiflora
EUP2	Salicaceae	Lindackeria	.
FRIE1	Annonaceae	.	.
FUNEL	Apocynaceae	Funtunia	elastica
FUNT	Apocynaceae	Funtunia	latifolia_cf
GAM1	Sapotaceae	Gambeya	subnuda_cf
GAMBE	Sapotaceae	Gambeya	beguei
GAMLA	Sapotaceae	Gambeya	lacourtiana
GAMPE	Sapotaceae	Gambeya	perpulchna
GAR1	Clusiaceae	Garcinia	punctata
GARSM	Clusiaceae	Garcinia	smeathmannii
GLYBR	Malvaceae	Glyphaea	brevis
GROMI	Euphorbiaceae	Grossera	macrantha
GUA1	Meliaceae	Guarea	cedrata_aff
GUATE	Meliaceae	Guarea	tessmannia
GUATH	Meliaceae	Guarea	thompsonii
HEXCR	Annonaceae	Hexalobus	crispiflorus
HOMT	Salicaceae	Homalium	africanum
HUNT	Apocynaceae	Hunteria	ballayi
IRVEX	Irvingiaceae	Irvingia	excelsa
IRVGR	Irvingiaceae	Irvingia	grandifolia
IRVWO	Irvingiaceae	Irvingia	wombolu
ISO2	Annonaceae	Isolona	campanulata
ISOTH	Annonaceae	Isolona	thonneri

KEABR	Euphorbiaceae	Keayodendron	bridelioides
KEKE	Ulmaceae	Holoptelea	grandis
KHAIV	Meliaceae	Khaya	ivorensis
KLAGA	Irvingiaceae	Klainedoxa	gabonensis
LAC1	Sapindaceae	Blighia	.
LACH	Sapindaceae	Chytranthus	setosus
LACPS	Sapindaceae	Laccodiscus	pseudostipularis
LANAF	Anacardiaceae	Lannea	africana
LANWE	Anacardiaceae	Lannea	welwitschii
LEPT1	Malvaceae	Leptonychia	amougoui
LEPTM	Olacaceae	Ongokea	gore
LOPAL	Ochnaceae	Lophira	alata
LOVTR	Meliaceae	Lovoa	trichilioides
LYC1	Meliaceae	Guarea	cedrata
MAC1	Euphorbiaceae	Macaranga	.
MACBA	Euphorbiaceae	Macaranga	barteri
MACMO	Euphorbiaceae	Macaranga	monandra
MACSP	Euphorbiaceae	Macaranga	spinosa
MAEEM	Rhamnaceae	Maesopsis	eminii
MANAL	Malvaceae	Mansonia	altissima
MARDI	Phyllanthaceae	Margareteria	discodea
MASAC	Rubiaceae	Massularia	acuminata
MEILE	Annonaceae	Meiocarpidium	lepidotum
MEL2	Meliaceae	Guarea	.
MICPU	Pandaceae	Microdesmis	puberula
MIL1	Fabaceae	Millettia	laurentii_aff
MILBA	Fabaceae	Millettia	barteri
MILSA	Fabaceae	Millettia	sanagana
MONO2	Annonaceae	Monodora	.
MONO3	Annonaceae	Monodora	myristica
MORLU	Rubiaceae	Morinda	lucida
MYRAR	Moraceae	Myrianthus	arboreus
NAUDI	Rubiaceae	Nauclea	pobeguinii
NESPA	Malvaceae	Nesogordonia	papavirifera
NRIN	Euphorbiaceae	.	.
OCHCA	Ixonanthaceae	Octhocosmus	africanus
OCHN1	Ochnaceae	.	.
OCHNA	Ochnaceae	Ochna	afzelii
OCHT1	Ixonanthaceae	Octhocosmus	.
ONC1	Salicaceae	Oncoba	gilgiana
ONC2	Salicaceae	Lindackeria	.
ONC3	Salicaceae	Buchnerodendron	speciosum
ONC4	Salicaceae	Oncoba	welwitschii
ONCAF	Salicaceae	Oncoba	echinata
ONCMA	Salicaceae	Oncoba	mannii
OUR1	Ochnaceae	Campylospermum	strictum_cf
OXYLA	Rubiaceae	Oxyanthus	laxoflorus
PANLA	Sapindaceae	Pancovia	pedicellaris
PANOL	Pandaceae	Panda	oleosa
PAUMA	Rubiaceae	Pausinystalia	macroceras

PAUR1	Rubiaceae	Pauridiantha	canthiiflora
PAV1	Rubiaceae	Pavetta	owariensis
PAV2	Rubiaceae	Leptactina	enosmia
PENKA	Menispermaceae	Pennianthus	kamerunensis
PEREL	Fabaceae	Pericopsis	elata
PETMA	Combretaceae	Petersianthus	macrophylla
PHYK	Phyllanthaceae	Phyllanthus	polyanthus
PICNI	Apocynaceae	Picralima	nitida
PIER1	Simaroubaceae	Pierrodendron	africana_cf
PIPAF	Fabaceae	Piptadiniastrum	africana
PIPH	Annonaceae	Piptostigma	calophylla_cf
PIPTI	Annonaceae	Piptostigma	fasciculatum_cf
PLAC	Sapindaceae	Placcodiscus	.
PLE1	Apocynaceae	Pleiocarpa	pycnantha
POLSU	Annonaceae	Polyanthia	suaveolens
PORT	Rubiaceae	Pauridiantha	rubens
PREM1	Lamiaceae	Premna	.
PTESO	Fabaceae	Pterocarpus	soyauxii
RAUMA	Apocynaceae	Rauvolfia	macrophylla
RAUVO	Apocynaceae	Rauvolfia	vomitoria
RICHE	Euphorbiaceae	Ricinodendron	heudelotii
RIN1	Violaceae	Rinorea	cerasifolia
RIN3	Violaceae	Rinorea	brachypetala
RIN4	Violaceae	Rinorea	aramis
RINBR	Violaceae	Rinorea	yaundensis
RINDE	Violaceae	Rinorea	dentata
RINIL	Violaceae	Rinorea	ilicifolia
RINOB	Violaceae	Rinorea	oblongifolia
RINSC	Violaceae	Rinorea	sciaphilia
ROTH1	Rubiaceae	Rothmannia	macrocarpa_cf
ROTH2	Rubiaceae	Rothmannia	longiflora
ROTH3	Rubiaceae	Rothmannia	urcelliformis
ROTHH	Rubiaceae	Rothmannia	whitfieldii
ROTL	Rubiaceae	Rothmannia	talbotii
ROTLO	Rubiaceae	Rothmannia	longiflora_aff
RUB1	Rubiaceae	Aidia	micrantha
RUB2	Rubiaceae	.	.
RUB9	Rubiaceae	Pausinystalia	brachythyrsa
RUBA	Rubiaceae	Oxyanthus	speciosus
RUBB	Rubiaceae	Calicosyphonia	spathicalyx
RUBC	Rubiaceae	Colletoecema	dewevrei
RUMF	Rubiaceae	Oxyanthus	formosus
SANTR	Burseraceae	Santiria	trimera
SAP1	Sapindaceae	Aporrhiza	.
SAP2	Sapindaceae	Lecaniodiscus	cupanioides
SAPL	Euphorbiaceae	Sapium	ellipticum
SAPO	Sapotaceae	Tridesmostemon	omphalocarpoides
SAPOJ	Sapotaceae	Ituridendron	bequaertii
SCHMA	Rubiaceae	Schumanniophyton	magnificum
SCOCO	Achariaceae	Scottelia	coriacea

SLOUS	Moraceae	Sloetiopsis	usambarensis
SPACA	Bignonaceae	Spathodea	campanulata
STAKA	Myristicaceae	Staudtia	kamerunensis
STETR	Olacaceae	Sterculia	tragecantha
STRGR	Olacaceae	Stromboscia	grandifolia
STRPU	Olacaceae	Stromboscia	pustulata
STRTE	Olacaceae	Strombosiopsis	tetrandra
STYCO	Loganiaceae	Strychnos	congolana
SYZ1	Myrtaceae	Syzygium	rowlandii
TABBR	Apocynaceae	Tabernaemontana	brachantha
TERSU	Combretaceae	Terminalia	superba
TETTE	Fabaceae	Tetrapleura	tetraptera
THOM	Acanthaceae	Thomandersia	hensii
TILIA1	Malvaceae	Desplastsia	subericarpa
TILIA2	Annonaceae	Monodora	tenuiflora_cf
TREAF	Moraceae	Treculia	africana
TRIAC	Anacardiaceae	Trichoscypha	acuminata
TRIC1	Rubiaceae	Tricalysia	.
TRIC2	Rubiaceae	Tricalysia	lasiodelphys
TRICA	Rubiaceae	Tricalysia	pallens
TRIHE	Meliaceae	Trichilia	heudelotii
TRIPR	Meliaceae	Trichilia	prieureana
TRIRU	Meliaceae	Trichilia	rubescens
TRISC	Malvaceae	Triplochiton	scleroxylon
UNK1	.	.	.
UNK2	.	.	.
UNK5	Fabaceae	Gilbertiodendron	preussii_cf
UNK6	Huaceae	Afrostyrax	.
UNK7	Myrtaceae	.	.
UNLEG	Fabaceae	Pterygopodium	.
UNLEG2	Fabaceae	Pterygopodium	oxyphyllum
UVACO	Annonaceae	Uvariopsis	congensis_cf
UVAPY	Annonaceae	Uvariastrum	pierreanum
UVAR	Annonaceae	Uvariodendron	fuscum_cf
VERP	Asteraceae	Vernonia	conferta
VIT1	Verbenaceae	Vitex	.
VIT2	Verbenaceae	Vitex	.
VITEX	Verbenaceae	Vitex	myrmecophila
VOAAF	Apocynaceae	Voacanga	africana
WAFR	Passifloraceae	Paropsia	grewioides
WCAN	Rubiaceae	Psilanthus	mannii
WHEI	Rubiaceae	Coffea	congensis
WHOM	Salicaceae	.	.
WPSIL	Rubiaceae	Tricalysia	lecomteana
XYLAF	Annonaceae	Xylopia	phloidora
XYLI	Annonaceae	Xylopia	hypolampra
XYLO	Annonaceae	Xylopia	.
ZANLE	Rutaceae	Zanthoxylum	lemairei
ZANTE	Rutaceae	Zanthoxylum	tessmannii
ZZINDET	.	.	.

Appendix 4: Distribution of trees in the 4 1.0 ha plots in SEFAC logging concessions (the northern plots 1&2 are in unlogged UFA 10-008 and southern plots 3&4 are in logged UFA 10-012). The locations of the plots are given in Appendix 1, and the scientific names for the codes are given in Appendix 2.

Sp. code	**PLOTS**				
	1	**2**	**3**	**4**	**All**
AFRLE	23	23	3	0	49
AFZ1	0	0	2	0	7
AFZPA	0	0	2	5	7
ALB1	5	4	0	0	9
ALB2	2	0	2	0	4
ALBH	1	0	0	0	1
ALLAF	0	0	0	1	1
ALSBO	1	0	20	2	23
AMP1E	1	2	0	0	3
AMPPT	2	0	2	0	4
ANGPY	14	19	15	28	76
ANIAL	0	0	0	1	1
ANIMA	0	0	0	1	1
ANNO	0	0	8	1	9
ANNO1	0	0	0	1	1
ANOMA	6	6	3	1	16
ANTH	3	1	0	0	4
ANTH3	0	10	3	0	13
ANTLA	2	3	6	2	13
ANTMA	3	0	12	23	38
AORCL	0	0	3	1	4
AULCA	2	4	0	5	11
BAP1	133	178	1	1	313
BAP2	0	0	6	20	26
BARFI	2	2	1	1	6
BEIE	1	3	4	0	8
BEIE1	0	0	1	0	1
BEIFU	1	1	5	1	8
BEIY	2	0	0	0	2
BELCO	6	4	0	0	10
BIGNO	4	0	23	15	42
BLI2	0	0	8	2	10
BRIAT	2	0	0	0	2
BRIMI	0	1	2	3	6
CAN1	0	0	1	0	1
CANPS	0	0	1	0	1
CARA	1	1	2	4	8
CARP	0	0	0	1	1
CASBA	0	1	0	0	1
CASPA	0	0	2	2	4

CASS1	0	2	1	0	3
CASS2	0	0	1	0	1
CEIPE	0	2	2	0	4
CELAD2	1	0	0	0	1
CELMI	9	2	2	2	15
CELPH	10	11	2	2	25
CELTE	8	2	33	29	72
CELZE	1	1	3	1	6
CHY1	1	3	0	0	4
CHY2	4	2	1	0	7
CHY5	2	0	0	0	2
CHYE	0	1	0	0	1
CHYM	1	0	0	0	1
CHYT	0	1	0	0	1
CHYTA	0	0	15	12	27
CITAR	14	15	0	0	29
CLE1	0	0	1	0	1
CLE2	0	0	1	0	1
CLEPA	4	2	0	2	8
COF	2	4	2	1	9
COF2	1	1	1	0	3
COF3	0	2	0	0	2
COL2	0	0	0	1	1
COLAL	0	0	0	1	1
COLFL	0	0	4	3	7
COLLA	7	5	12	0	24
COLNI	4	3	0	2	9
COPMI	2	2	0	0	4
CROT1	1	1	1	3	6
CUV1	0	1	0	0	1
DACED	0	2	0	0	2
DAS1	0	4	0	0	4
DEIN	0	0	0	1	1
DESDE	8	3	1	1	13
DIAPA	0	0	4	4	8
DICGL	16	34	1	0	51
DICHM	1	0	0	0	1
DICPU	0	1	0	0	1
DICR1	0	9	0	2	11
DIOCA	0	2	7	12	21
DIOCR	18	12	1	0	31
DIOIT	117	92	125	171	505
DIOMA	1	2	6	5	14
DIOMA2	0	0	0	1	1
DIOS1	315	262	222	227	1026
DIOS2	25	5	1	1	32
DIOS3	0	0	3	0	3

DIOS4	0	0	1	0	1
DIOY	6	1	2	0	9
DISCA	2	5	10	3	20
DRY1	35	23	1	0	59
DRY2	10	6	0	0	16
DRY3	77	72	3	45	197
DRY4	4	8	5	4	21
DRY5	0	4	1	2	7
DRYA	0	4	0	0	4
DRYAF	19	29	0	0	48
DRYGI	134	113	0	17	264
DRYGO	1	2	2	8	13
DRYIV	26	31	27	17	101
DRYLA	11	26	1	0	38
DRYLE	62	31	4	10	107
DRYMO	2	2	0	0	4
DRYN	6	27	8	22	63
DRYPA	4	0	0	0	4
DRYPR	4	0	0	0	4
DUBMA	4	5	4	1	14
ELADR	1	0	0	0	1
ENT1	1	0	0	0	1
ENTAN	0	0	0	1	1
ENTCA	2	1	0	0	3
ENTCY	9	7	4	4	24
ENTUT	0	1	3	0	4
ERIOB	0	0	32	10	42
ERYIV	3	1	1	1	6
ERYMA	1	1	1	0	3
EUGLO	0	3	0	0	3
EUP1	0	1	0	0	1
EUP2	0	0	8	5	13
FRIE1	0	0	34	34	68
FUNEL	18	4	39	22	83
FUNT	1	1	0	0	2
GAM1	9	4	1	0	14
GAMLA	3	0	0	0	3
GAR1	1	1	0	0	2
GARSM	0	2	0	0	2
GLYBR	0	0	1	1	2
GROMI	116	97	345	436	994
GUA1	1	1	1	0	3
GUATE	5	0	2	3	10
GUATH	2	1	0	1	4
HEXCR	6	5	2	0	13
HOMT	1	0	0	0	1
HU	0	0	0	1	1

HUNT	0	0	39	62	101
INDET	0	0	0	1	1
IRVEX	0	0	1	0	1
IRVGR	0	1	0	0	1
IRVWO	0	0	2	0	2
ISO2	0	0	0	1	1
ISOTH	0	2	3	17	22
KEABR	4	8	10	14	36
KHAIV	0	0	0	3	3
KLAGA	3	0	1	1	5
LAC1	0	0	2	1	3
LACH	0	0	1	0	1
LACPS	2	1	0	2	5
LANAF	1	2	2	0	5
LANWE	0	0	1	1	2
LEPT1	1	0	0	1	2
LEPT11	0	0	2	0	2
LEPTM	0	2	6	3	11
LOPAL	0	0	1	2	3
LOVTR	0	0	1	0	1
LYC1	11	14	4	4	33
MAC1	0	3	1	0	4
MACBA	2	2	1	13	18
MACMO	6	1	1	2	10
MACSP	16	12	0	0	28
MAEEM	1	1	0	0	2
MANAL	1	0	0	0	1
MARDI	5	1	5	1	12
MASAC	13	6	2	4	25
MEILE	0	0	1	0	1
MEL2	0	0	1	0	1
MICPU	6	4	0	0	10
MIL1	0	1	0	0	1
MILBA	48	43	9	189	289
MILSA	1	1	0	0	2
MONO2	0	1	3	4	8
MONO3	0	0	1	0	1
MORLU	1	0	0	0	1
MYRAR	2	1	0	0	3
NAUDI	0	1	5	0	6
NESPA	7	5	2	2	16
NRIN	0	5	0	0	5
OCHCA	2	9	15	13	39
OCHNA	0	2	0	0	2
OCHT1	4	4	0	0	2
ONC1	2	5	3	7	17
ONC2	4	5	3	7	17

ONC3	0	7	0	47	54
ONCAF	0	0	18	0	18
ONCMA	1	0	0	0	1
OUR1	0	1	0	0	1
OXYLA	1	0	0	0	1
PANLA	0	4	0	0	4
PANOL	1	0	14	18	33
PAUMA	12	23	12	16	63
PAUR1	0	1	0	0	1
PAV1	1	1	0	0	2
PAV2	0	2	2	0	4
PENKA	0	0	6	10	16
PEREL	9	1	0	0	10
PETMA	0	1	1	0	2
PHYK	1	0	2	0	3
PICNI	2	1	7	6	16
PIER1	0	0	1	1	2
PIPAF	0	0	1	1	2
PIPH	0	0	4	5	9
PIPT1	0	1	0	0	1
PLAC	1	0	0	0	1
PLE1	0	0	17	35	52
POLSU	58	73	62	42	235
PORT	0	0	2	1	3
PREM1	0	0	2	0	2
PTESO	1	3	2	2	8
RAUMA	0	0	1	0	1
RAUVO	0	1	0	1	2
RICHE	0	0	1	0	1
RIN	1	0	0	0	1
RIN1	33	298	34	30	395
RIN2	0	2	0	0	2
RIN3	7	33	0	0	40
RIN4	0	8	90	161	259
RINBR	0	0	0	19	19
RINDE	0	0	5	60	65
RINIL	0	2	0	0	2
RINOB	14	26	2	24	66
RINSC	81	91	1	1	174
ROTH1	1	4	0	0	5
ROTH2	1	0	1	2	4
ROTHH	1	1	1	0	3
ROTL	1	0	2	0	3
ROTLO	0	0	1	1	2
RUB1	15	15	1	0	31
RUB2	0	1	1	0	2
RUB9	23	18	25	12	78

RUBA	1	0	0	0	1
RUBB	5	7	0	0	12
RUBC	1	1	0	0	2
SANTR	2	0	0	0	2
SAP2	0	1	0	0	1
SAPL	0	1	0	0	1
SAPO	1	0	0	0	1
SAPOJ	1	0	0	1	2
SCHMA	1	1	2	1	5
SCOCO	9	10	9	2	30
SDRYGI	1	1	0	0	2
SLOUS	1315	1036	0	0	2351
SPACA	0	0	0	1	1
STAKA	6	3	0	0	9
STETR	2	0	3	0	5
STRGR	0	1	0	1	2
STRPU	10	17	85	112	224
STRTE	1	1	0	0	2
STYCO	1	0	1	0	2
SYZ1	0	1	0	0	1
TABBR	0	0	2	0	2
TERSU	9	10	12	9	40
TETTE	1	0	1	1	3
THOM	151	193	228	211	783
TILIA1	0	5	6	1	12
TILIA2	0	2	0	0	2
TREAF	0	0	0	1	1
TRIAC	0	1	0	0	1
TRIC1	1	0	0	0	1
TRIC2	1	0	0	0	1
TRICA	1	1	1	0	3
TRIHE	3	2	1	2	8
TRIPR	1	0	0	0	1
TRIRU	17	15	21	31	84
TRISC	1	0	1	3	5
unk	6	1	0	0	7
UNK2	2	4	3	7	16
UNLEG	7	0	0	0	7
UNLEG2	3	1	0	0	4
UVACO	2	2	0	0	4
UVAPY	2	3	0	1	6
UVAR	0	0	0	5	5
VERP	1	1	5	0	7
VIT1	2	0	0	0	2
VIT2	0	2	0	1	3
VITEX	0	0	2	0	2
VOAAF	14	10	67	23	114

WAFR	1	1	0	0	2
WCAN	0	0	0	3	3
WHE1	0	2	2	2	6
WPSIL	0	0	0	3	3
XYL1	8	4	0	1	13
XYLAF	1	1	1	0	3
XYLO	3	7	2	2	14
ZANLE	0	0	2	1	3
ZANTE	17	2	19	33	71
Totals	3398	3390	2059	2614	11461