CAFOGROM Amazon Forest Growth Model - Data and system updates for 2011

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Executive Summary

This report describes work undertaken in Oxford from August-September 2011, and in Brazil during October 2011 to recalibrate and update the CAFOGROM model. The background to CAFOGROM is described. It was developed in three versions from 1994, 1996 and 1998, with a scientific publication by Alder & Silva (2000). The model uses data from EMBRAPA Tapajós and Jarí experiments measured from 1981 onwards. The new measurements to be incorporated were from 2003 and 2007.

The work of updating the growth functions proved to be more complex than expected, mainly due to major changes in software and data systems since 1998. EMBRAPA has moved to an entirely new, SQL based database MFT, whilst CAFOGROM used an FoxPro-based pre-processor linked to the now obsolete SFT database. This necessitated considerable extra work, and ultimately meant that the objectives of the consultancy could not be fully completed.

However, a number of important phases were progressed. The 1998 version of CAFOGROM was compared with the new measurement data, and found generally accurate within a ±15% deviation of volume from actual measurements on simulations over the period 1981-2007. It was then used to test the SFB management guidelines based on a 35 year felling cycle and restriction of 30 m3/ha removals. It found that on both the better Tapajos km67 sites, and the less productive Tapajos km 114 area, that this prescription was fully sustainable and relatively conservative, provided that the yield or harvested volume was defined in terms of a broad set of species comprising around 50% of stocking above 50 cm dbh, and not allowed to focus on a small number of high-value species.

Analysis work was progressed with respect to creation of pathways from the EMBRAPA MFT database to an intermediate database CIMIR3, for which algorithms were completed to calculate tree increments, order statistics for tree size, Weibull parameters for stochastic tree increment functions, species grouping tools, and plot summary data for basal areas, volumes and biomass for both model validation and development of aggregate functions for lugging damage, competition and recruitment. Excel tools were also developed relative the with stochastic increment analysis and species grouping.

Three significant workshop presentations were delivered (slides are included in the Annex to the report), on 7th and 21st October in Brasilia at the SFB offices, and at EMBRAPA Amazônia-Oriental in Belém on 14th August. Additionally several other meetings were held for more detailed discussions with research staff. A further scientific paper is planned for delivery at the IUFRO Montpellier Conference 15-18 November 2011 which will focus on the new data and growth functions being developed.

As the full updating of CAFOGROM remains to be completed, the consultant proposes that this be progressed over the next 6 months within his existing research programme, with a further visit to Brazil in May 2012 to present results and undertake case studies.

Contents

Acknowledgements

Many people have been involved with the CAFOGROM project over the years, especially relative to the capture and analysis of the data. Original work at EMPBRAPA Amazonia-Oriental involved the group lead by José Natalino M Silva including J. O.P de Carvalho, J do Carmo Lopes, R.P. de Oliveira and Lia Cunha de Oliveira. Natalino also initiated the present mission while a director of SFB in 2010. Joberto V. de Freitas as current Director of Forest Management at the Brazilian Forest Service further facilitated the visit and gave considerable time to the consultant in background briefings etc. In Belem at EMBRAPA Amazônia Oriental, the team at the Projeto Bom Manejo including Ademir Roberto Ruschel and Marcio Hofmann M Soares gave full support. Ademir Ruschel is a key participant in current updating of field measurements and datasets, and explained the use of the MFT database and assisted in providing updated datasets and relevant explanations. Lucas Mazzei and J. Francisco Pereira (in Belem) and Marcus VN d'Oliveira (in Rio Branco, Acre) of EMBRAPA as forest modellers helped to draw out many details discussed in this report and provided many useful suggestions. Lucas also provided much information on ongoing analyses and is facilitating the Montpellier IUFRO meeting and has assisted with the registration process there. Milton Kanashiro also contributed significantly to the workshops and meetings. The Director Claudio J.R de Carvalho and Deputy Director Austrelino S Filho at EMBRAPA Amazonia Oriental facilitated the major workshop on 14th October with their presence and organisational support. Again in Brasilia, Pedro Bruzzi Leon at SFB has supported the administrative interface with the FAO project GCP/BRA/070/EC. The FAO staff team, including Christina Lima in Brasilia, and Andrea Perez at the regional office in Lima, Peru, have helped with travel arrangements and other administrative matters. In Oxford, Adriana Reis de Santana did much to prepare me linguistically for this visit, whilst in the modern world, ever present via Skype, my wife Pat Alder has provided continued support and assistance throughout.

Disclaimer

The analyses and interpretations presented in this report are those of its author acting as an independent consultant. This document is not a publication of SFB, FAO or EMBRAPA, but rather a report to them. As such, its findings and recommendations may not be in accord with any position of these organizations and remain the professional views of the author.

Acronyms and abbreviations

CAFOGROM.................. CPATU Amazon Forest Growth Model
CIMIR.............................. Calculation of Increment Mortality and Recruitment
CPATU............................ Centro de Pesquisa Agropecuaria da Amazonia Oriental (now called EMBRAPA Amazonia Oriental)
dbh.................................. tree diameter at breast height (1.3 m above ground).
DFID................................ Department for International Development of the United Kingdom.
EMBRAPA...................... Empresa Brasileira de Pesquisa Agropecuaria
ESA................................. European Space Agency
FAO................................. Food and Agriculture Organization of the United Nations
FMT................................. Forest Management Toolkit
IUFRO............................. International Union of Forest Research Organizations
MS................................... Microsoft Corporation.
PSP.................................. Permanent sample plot
RIL.................................. Reduced Impact Logging
SFB.................................. Servicio Florestal do Brasil
SFM................................. Sustainable Forest Management
SQL................................. Structured Query Language

In this text where a size range is expressed as 5-10, for example, it always means greater than or equal to 5 and less than 10. A range express as 45+ means greater than or equal to 45.

Introduction

Scope of this report This report is an output from a consultancy commissioned by the Forest Service of Brazil (SFB - *Servicio Florestal do Brasil*) and supported by the Food and Agriculture Organisation of the United Nations (FAO) under project GCP/BRA/070/EC *Manejo Florestal, Apoio à Produção Sustentável e Fortalecimento da Sociedade Civil na Amazônia Brasileira*[1].

The consultant's terms of reference provide for the following outputs:

- A preliminary technical report, based on work done on the database in the UK, to be produced by 1st September 2011.
- Presentation of results from a workshop in Brasilia, by 7th October 2011.
- Revised, finalised version of the model, with projections according to SFB specifications, by 21st October 2011.
- A finalized user manual, by 31st October 2011.
- A scientific Paper to be presented at the IUFRO Montpellier meeting on 17 November 2011.

In the event, the complexity of the dataset and the tasks required exceeded expectations, whilst a number of additional formal meetings were scheduled. For this reason, the first four outputs outlined above have been combined into the present report, which covers:

- Progress on data analysis and updating of the model.
- Comparisons of model performance with latest measurement data.
- Application of the model to evaluate SFB forest management regulations.
- Description of new species grouping and stochastic growth functions.
- Proposals for the further evolution of the CAFOGROM model.
- Slides sets from the various meetings and workshops held, in Annex A.

Background to CAFOGROM CAFOGROM began life in 1994. At that time, at the request of Natalino Silva at EMBRAPA Amazonia Oriental, the consultant was commissioned to update work that had been done using the STANDPRO model of Korsgaard (1982, 1993) by Silva (1989) to examine initial growth trends on the plots at Tapajós and Jarí established from 1981 to 1984 (see Table 1). A new model was devised (CAFOGROM), built on the principle of cohort projection described by Vanclay (1989). This version 1 of CAFOGROM was written in the C language, to maximize speed and efficiency in a task which was then at the limit of the capabilities of desktop computers. Alder (1994) describes this development, whilst the complete CAFOGROM C programme together with some details of the analysis are listed in Alder (1995).

[1] Forest Management, Support to Sustainable Production and Strengthening of Civil Society in the Brazilian Amazon.

With further measurements on the plots, the consultant was asked to update the model in 1996. At this time, based on experience in Costa Rica with the SIRENA model (Alder, 1996a) it was decided to re-write CAFOGROM in the VBA language which comes as part of the standard Excel package. This made the model much more accessible to research workers and developers, and also improved to quality of outputs from the model, which appear as Excel charts and spreadsheets. At this time to, a translation of the user manual into Portuguese was made to further aid accessibility (Alder, 1996b).

A third visit in 1998 focussed updating functions against latest available measurements and on verification of the model against the latest data (Alder, 1998). A publication *Forest Ecology and Management* (Alder & Silva, 2000) gives a detailed and peer-reviewed description of all the functions in the model, the procedure for species grouping, and verification tests against the EMBRAPA experimental plots. The techniques also contributed to the development of the MYRLIN concept for a simple modelling strategy using pan-tropical average growth rates for species groups (Wright & Alder, 2000; Alder *et al*., 2002).

During this time also, a significant amount of work was published by the EMBRAPA team responsible for the plots, including Silva & Uhl (1992), Silva et al (1994, 1995, 1996). This work contributed to the development of the growth functions for CAFOGROM.

The present visit therefore comes some 12 years after the last updates to CAFOGROM were made. In this context, it will be seen that changes in data management and programming software have affected expectations of what has been possible during the duration of the project, with the basic modifications needed especially to data systems being considerably more than were anticipated. The VBA programming language has also gone through several major version upgrades, with the result that there are compatibility issues with the former version, originally programmed for Excel 5 (of 1995 release).

CIMIR : The CAFOGROM data analysis tool

CAFOGROM was designed to be configured or updated automatically from the original data system used by CPATU[1], called SFC. SFC itself was a Clipper application which processed and produced DBF files in dBASE 3 format. An application was written by the consultant, documented in Alder (1996), called CIMIR which generated from the SFC files summary tables of increment, mortality, and recruitment, and could perform species grouping according to a simple method. CIMIR is a FoxPro programme. CAFOGROM itself requires 6 data files for calibration, which are generated directly from the SFC data files by CIMIR. These files are fully documented in Alder (1996) and briefly summarised in the presentation *CAFOGROM data requirements* in Annex A (see page 23).

In planning and agreeing the timeframe for the present assignment, the consultant assumed that the SFC system remained in use, and that therefore the process of updating the CAFOGROM data files would be relatively straightforward. Unfortunately this has proved not to be the case. A new system, based on SQL Server, called MFT is now used as a standard EMBRAPA system for PSP and experimental data. Additionally, FoxPro is now obsolete and no longer supported as a database system. This meant that a completely new approach needed to be taken with regard to the method of data analysis.

Converting MFT data for analysis for CAFOGROM

The MFT system is a complex database with a large number of tables and data fields. The consultant had to investigate the structure of this database in order to understand how the various elements linked together, and then devise a strategy for analysis of the key parameters: Species lists and grouping, increment, mortality, ingrowth (recruitment), logging damage and competition effects. As MFT uses long field names that are not suitable for typing as interactive commands, and also contains complex arrangements for some key variables that are used routinely in analysis, it was decided to extract and re-code the required data.

The first step was the conversion of the SQL Server .DAT file supplied with remeasurement data available to 2007 into a MySQL database. This is the personal preference of the consultant, as he is more familiar with MySQL and has it installed on his system. However, the language and processes for SQL Server and MySQL are both based on the standard ANSI SQL language, and are compatible, so that steps described here can be equally well applied via SQL Server. MySQL has the further advantage of being a very widely used and open source system that is free to download and install (see http://www.mysql.com)

A database containing simplified and consolidated extracts from MFT called CIMIR3 was created. This is a time consuming process, involving many different manipulations depending ion the data field involved. All names were shortened, stripping of the initial table number used in MFT. Some separate tables were consolidated. In

[1] The former name for EMBRAPA Amazônia Oriental.

some cases keys were added to improve the brevity and efficiency of common queries. For example, referencing a single tree in MFT requires reference to about 8 separate identifiers. These were consolidated into a single key called IUA (*identifição unica de arvore*) which considerable identifies the many queries required to calculate increment, mortality etc. In all cases only EMBRAPA data was extracted, and the *Empresa* code (EMBRAPA=3) was therefore dropped from all tables of extracted data. The main details are given in the tables below.

CIMIR3 table	Originating tables in MFT	Content	Description of changes made
areas	d20_area	Top level description of each set of plots. Location and site data, prior and measurement history, title	Table number stripped off. Field names shortened in most cases. Empresa omitted. Latitude and longitude degrees minutes second combined into single field in Google Earth compatible syntax. Extra column RP manually entered for each area with codes used in Alder reports 1994-2000 for cross referencing.
simesp	d01_familia d02_genero d03_especie	Species list, species code number, genus, species, family, ecological, commercial and growth model group	A simplified species list which used only species actually occurring in the data sets for CPATU, combined botanical names into a single file and also included commercial and species group information derived from later analysis.
tudarv	p23_arvore	All tree data, one record per tree per measurement. Diameter, crown, defect, damage scores, species, stem code	Simplified names and codes, stripped out unwanted columns, added a unique tree identfieid key (IUA) and an area weight (NPHA) that depended on plot and subplot size. Eg a tree measured on a ¼ plot would have NPHA = 4, one on a 0.1 ha subplot would have NPHA=10, on e on a 1 ha main plot would be NPHA=1.
medicao	d18_medicao	Measurement dates for each measurement number and each area.	Remove empresa code and irrelevant records, field names simplified
cif	d19_classe_identificacao_fuste	Code for tree identifying dead, damaged, healhy stems and cause (logging, treatment, natural)	Remove empresa code and irrelevant records, field names simplified
dano	d11_dano	Logging damage codes	
iluminacao	d12_iluminacao	Crown illumination codes	
podridao	d14_podridao	Decay codes	

Initially these conversions took some time, about a week, as the consultant had to explore the database, determine what was relevant and what was not (many apparently interesting data fields are either unpopulated or only occasionally used and not usable for consistent analyses across all sets), what the field names meant, as documentation was limited, and how to deal with the issues created by the numerous foreign (ie linked) keys in the database, which prevent any alterations, even to copied tables and fields. Subsequently, when provided with other copies and updated datasets, these conversions could be done in a day using stored queries.

It is not proposed that CIMIR3 should be seen as a necessary intermediate step in developing growth functions for CAFOGROM or similar models. The consultant found it a natural approach because of his familiarity with SQL, and the need to explore the data in various undefined ways. Another way of doing this that would probably be better in the long run would be to code into MFT the summarization processes required for the typical analyses to output results as Excel-type files for further analysis.

Current status of analysis

In addition to the general complexity of exploring and converting a completely new data system, that had not been envisaged originally, the data set has been updated twice in the form provided to the consultant, to include new measurements from 2008 and 2010 on some areas and further corrections. This has necessitated re-iterating the conversion process, though it does become faster with practice.

Additionally, some data is missing from the data set which has blocked a more symmetric analysis. Trees below 20 cm, though present and measured on the Jari plots up to the last measurement in 1996, are missing from the MFT data. Adding this data in from the old Clipper DBF files is quite a difficult task, but it seems that this will be necessary if the Jari data is to be fully used.

Some processes have been completed. A new species grouping has been well progressed, as described on pages 13-14, and stochastic models for tree increment developed (pages 14-15). Other areas, notably mortality, remain to be completed as there are issues to be researched relative to estimating mortality coefficients when the measurement period is highly variable. The **Conclusions** (page 16) suggest a strategy to complete the analysis and develop a fully updated model.

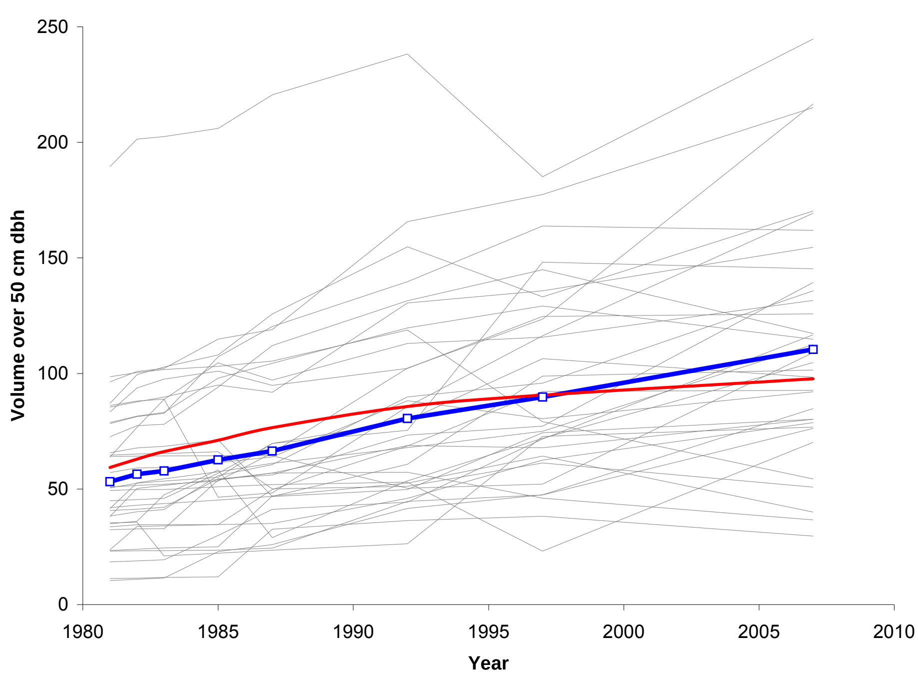
Data sets used for the comparisons The data used in these comparisons are from permanent sample plots (PSPs) established at km67 (2°53'S, 54°55'W) and km 114 (3°18'S, 54°56'W) in Tapajós National Forest. These data are used in detail to re-calibrate the species growth functions. The km67 plots have been measured 8 times over the period 1981-2007 . These plots were initially logged in 1979 and not treated silviculturally. The logging specified the removal of 16 trees per ha from 38 commercial species, amounting to approximately 75 m3/ha. There are 36 plots, each of ¼–ha (50 x 50 m) on which all trees down to 5 cm dbh were measured (Silva, 1989).

The km 114 plots were arranged as an experiment with different silvicultural treatments. However, these plots were damaged by severe forest fire in 1997, and from the original 48 treated and 12 control plots, only 35 treated and 6 control plots survived to be re-measured in 2003. These plots were of the same size and measurement system as at km 67 (¼–ha, trees over 5 cm dbh measured). The treated plots were measured 6 times from 1981-2003 (before treatment 1in 1981, other measurements after treatment, and the controls (not treated) from 1983-2003.

Tapajós km67 plots Figure 1 shows actual growth data from 1981 to 2007 for the Tapajós km 67 PSPs. During this 26 year period, volume increment was 2.2 m3/ha/yr on a residual volume of 53 m3/ha above 50 cm dbh. Of this,

Figure 1 : Actual and simulated volumes for Tapajós km 67 PSPs

Mean of Actual Plot Volumes 50 cm+ Individual Plots Simulated Volume 45 cm+

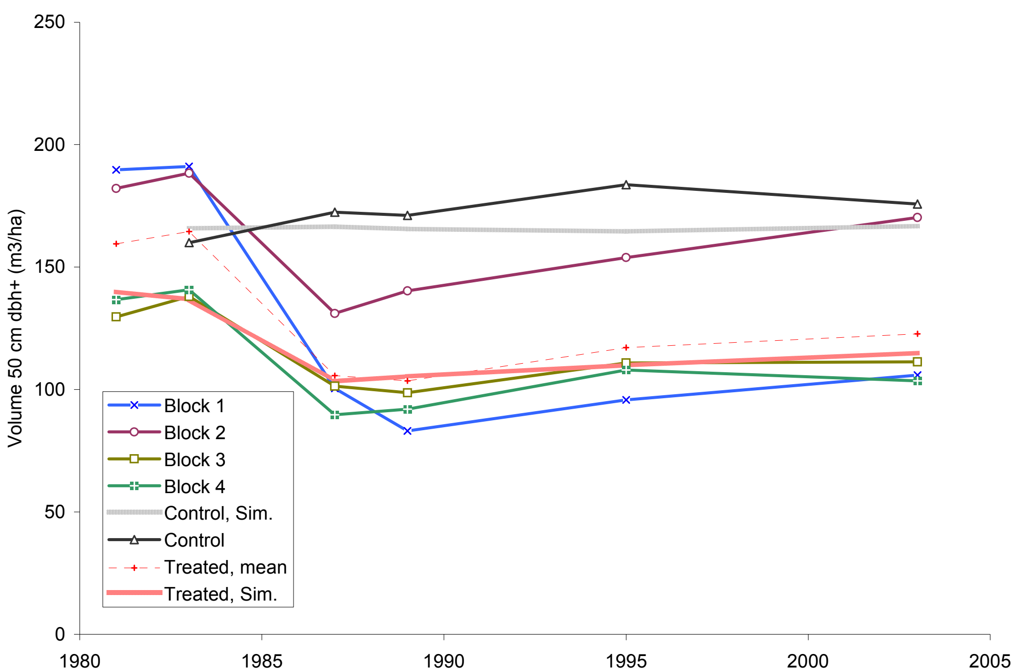


approximately 54% is estimated to be commercial (1.2 m3/ha/yr). The actual plot data, shown as thin grey lines, shows the great variation that occurs from plot to plot, both in initial condition, and in growth. As the plots are relatively small for tropical forest (¼-ha), the presence or absence of a few large trees can lead to great variation.

The red line[1] on the chart shows the result of a simulation using a stand constructed as the average of the size and species distributions of the individual plots. This starts some 10% higher than the blue line[2] which represents the average volumes of the individual plots (as volume and diameter have different sample distributions, their means are not the same). The simulation tracks the average of the plots well, but with a slightly lower slope. Increment for the simulation over the 26-year period is 1.5 m3/ha/yr of all species, or 0.8 m3/ha/yr commercial.

Tapajós km 114 plots Figure 2 shows the mean volume of the experimental blocks at km 114. Each block and the control originally included 12 PSPs. Block 1 was harvested in a way similar to km 67, with a minimum diameter of 45 cm dbh and some 90 m3/ha removed over the whole area, though the effect at the level of a ¼-ha plot was very variable. Blocks 2-4 were subject to a lighter harvesting nominally, with a 55-cm minimum dbh, and were additionally treated with arboricides post harvest to reduce basal areas of non-commercial species by 30%, 50% and 70% respectively. The control block was left without harvesting or treatment, as primary forest.

Figure 2 : Actual and simulated volumes for Tapajós km 114 PSPs
See text for a description of the treatments



[1] Red Line: In monochrome, it can be seen as the line of medium bold thickness, without data markers.
[2] Blue Line: In monochrome, the thickest line, with square data markers.

Figure 2 shows the average volumes for each treatment. These lines are each the means of 12 plots, and the variation is considerable, giving an overall picture similar to Figure 1, with little discernible tendency between treatments. The variation is due to the combination of highly variable initial conditions for each plot, and the variable effect of treatment as it was applied on top of that.

Two simulations are made for comparison. One, shown as the cross-hatched thick red line, simulates the mean composition of blocks 1-4, subject to a simulated felling with a diameter limit of 55 cm dbh and intensity equivalent to the eman of that observed. This can be compared to the thin dotted line which is the actual mean of the four treatment blocks.

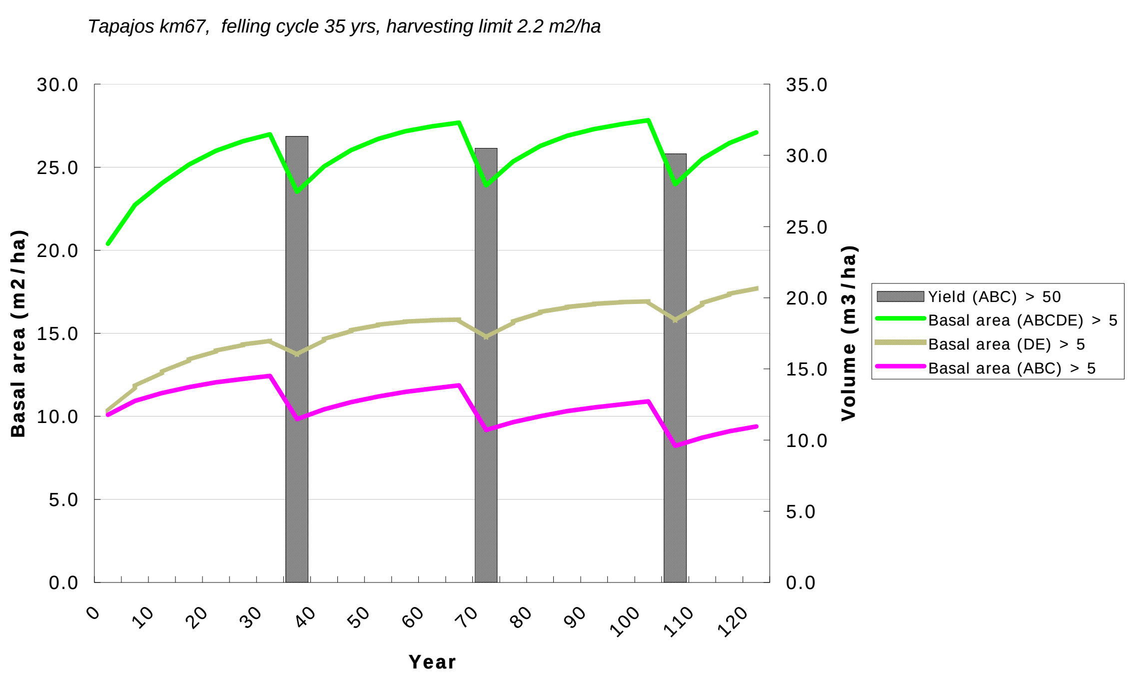
These stands show quite a low increment compared with the km 67 plots. The mean increment of the blocks was 1.07 m3/ha/yr over 16 years from 1987 to 2003, whilst the simulation predicted an increment of 0.72 m3/ha/yr over the same period. The control, untreated block, has a mean growth over its whole measurement period (20 years) of 0.16 m3/ha/yr, with the simulation of the control being in almost exact equilibrium, with net growth of 0.01 m3/ha/yr.

Felling cycle and allowable cut Currently, SFB are proposing that mechanically-harvested mixed tropical forests must be managed on the basis of an allowable cut of 30 m^3/ha over a 35 year felling cycle, or 0.86 m3/ha/year. An alternative regulation is in place for forests under community management which do not use mechanical timber extraction, which allows for a 10 year felling cycle and removal of 10 m^3/ha, or an allowable cut of 1 m3/ha/year.

The simulations discussed here examine the sustainability of the mechanised harvesting regulation for allowable cut and felling cycle (30 m3/ha over a 35 year cycle), with respect to the two baseline forests discussed in the last section, being Tapajos km 67 and Tapajos km 114. These two are compared as they appear to represent sites of comparatively high and low productivity, as measured by net long-term growth.

Harvesting with a broad base of commercial species Figure 3 shows the result of simulated harvesting of km 67 plots using a broad definition of commercial species comprising 91% of the initial post-harvest volume over 50 cm in 1981. With this broadly defined harvestable species base, production of 30 m3/ha every 35 years is sustainable over 3 cycles (which includes implicitly a 4th cycle, being the initial harvest immediately before the start of the simulation).

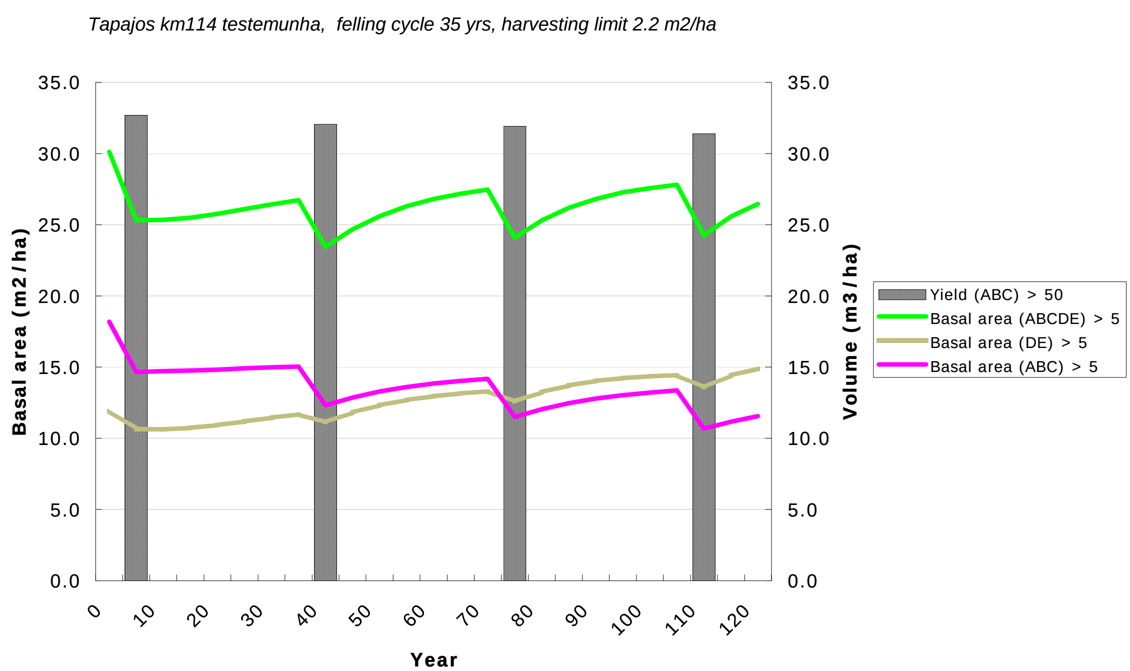
Figure 3 : Simulated harvesting at Tapajos km67 over 3 cycles with a broad base of commercial species
The chart is pasted directly from CAFOGROM. A harvesting limit of 2.2 m2/ha basal area is c. 30 m3/ha volume.



In Figure 3, the first harvest is taken at 33 years after the start of the simulation, as this stand had been exploted 2 years prior to the inventory date, in 1979. This amounts to an initial 35 year cycle, with subsequent cycles being of the same duration.

Figure 4 shows the same results for the management of the Tapajos km 114 control plots, which is previously unlogged forest. It will be recalled from Figure 2 that the growth curve for this plot is flat, indicating an equilibrium situation. Figure 4 shows that with harvesting of 30 m3/ha on a 35 year cycle, this site also gives a sustained yield.

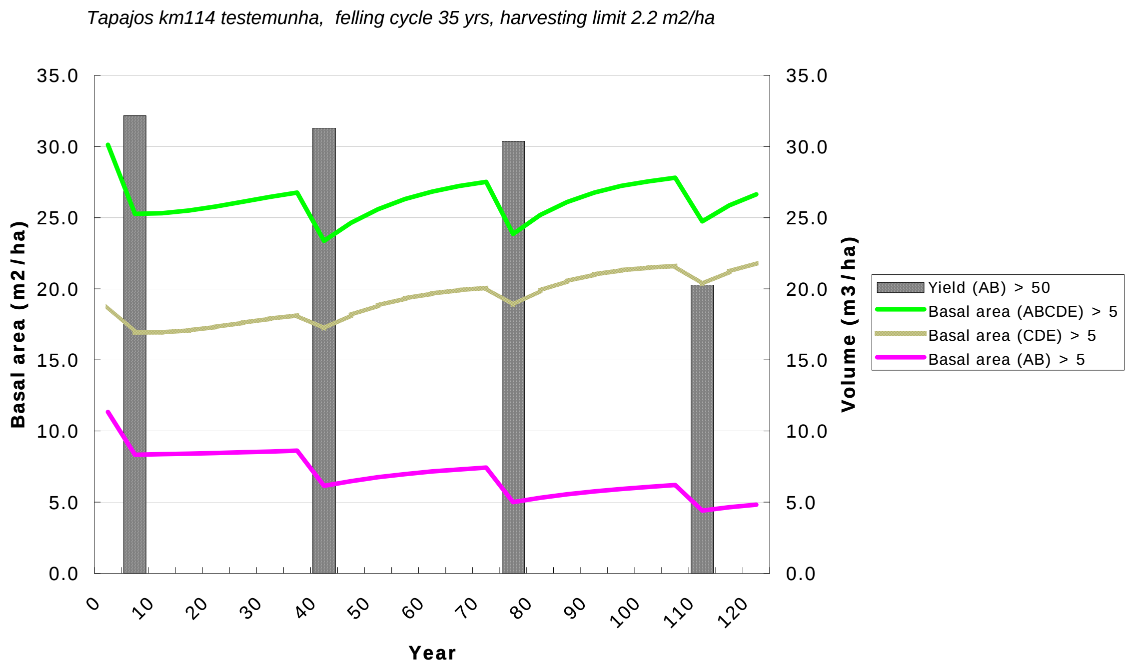
Figure 4 : Simulated harvesting at Tapajos km114 over 4 cycles with a broad base of commercial species
The chart is pasted directly from CAFOGROM. A harvesting limit of 2.2 m2/ha basal area is c. 30 m3/ha volume.



Harvesting with fewer species However, this picture of sustainability depends on using a broad range of species, or perhaps harvesting different species at different cycles. If there is concentration on a narrower range of current, fully commercial species (categories A and B within the CAFOGROM species list), then the volumes of those species above 50 cm dbh no longer fully recovers between 35 year cycles, as shown Figure 5. The species harvested in this case represent about 50% of the initial stock.

It can be seen that, whilst the harvesting can be maintained for 3 felling cycles, at the fourth cycle, yield of these most commercial species will decline. In reality, this is not a bad result, as it is unlikely the market for species will be the same, 80 years hence, as it is now, whilst all the simulations show that, on both sites, stand overall stocking and basal area recover fully between cycles.

Figure 5 : Simulated harvesting at Tapajos km114 over 4 cycles with a limited base of commercial species
The chart is pasted directly from CAFOGROM. A harvesting limit of 2.2 m2/ha basal area is c. 30 m3/ha volume.



Spatial variation and modelling It is obvious that tropical forest varies considerably in species composition, size-class structure and less measureable site factors over quite small distances in the forest. CAFOGROM simulates an average stand, but in future it should be extended to simulate multiple individual plots, or stand tables representing a mosaic of forest compositions, simultaneously to give a more realistic result for the out-turn from a large forest area.

Likewise, because demand for species varies over time, and availability varies spatially, there is a need for a more spatially aware type of modelling of forest management of a number of forest blocks representing the operational felling series of a concession.

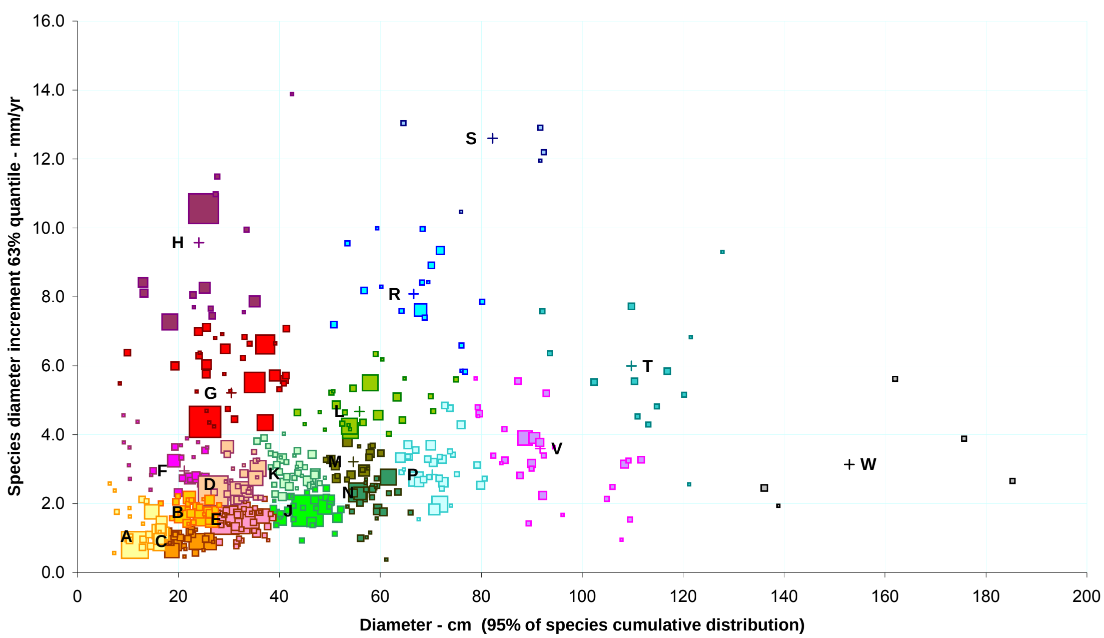
Species Grouping A method of species grouping is fundamental to development of growth models for natural tropical forest. This is because there are so many species in the forest, and few of them are sufficiently represented in the data to allow individual growth functions to be developed. The issue of species grouping has been extensively discussed in the literature, and is reviewed in, for example, Alder & Silva (2000) and Alder *et al* (2002).

Alder & Silva (2000) describe the method adopted for the 1998 version of CAFOGROM. This involves ordination of species in a space of 5 dimensions, including commercial/non-commercial attribute, mean diameter increment, annual mortality rate, proportion of dominant trees, and maximum observed diameter. From this method 56 species groups were produced.

The large number of groups, and the multi-dimensional ordination method results in a classification that is hard to understand or communicate, and is quite sensitive to changes in the data set. It is also, in the present context, difficult to update. In earlier versions of CAFOGROM, and in also in other studies done since, notably Alder *et al* (2002) for the MYRLIN model, a simpler ordination method has been used based on 2 axes: Mean increment, and 95% quantile of the diameter distribution.

This method was run with the revised datasets, with the slight amendment that the Weibull α (alpha) was used instead of the mean diameter increment. This related to the adoption of a stochastic model for diameter increment, as described in the next section.

Figure 6 : Species grouping, based on increment-tree size ordination.



The result was to form 19 species groups. Table 1 below characterises the groups and their most common component species.

Table 1 : Species groups formed by ordination of diameter on increment

Diameter is the 95% quantile of the diameter distribution, as an indicator of typical species mature size. Increment is the 63% quantile of the increment distribution, equivalent to the Weibull α parameter of the increment distribution.

Group	**Major species in group** The percentage given is the proportion of the group comprised of that species. Only species comprising the top 3, or the first 66% of the group are shown.	Diameter (95% quantile) cm	Increment 63% quantile mm/yr	No. species	No. Trees
A	*Rinorea flavescens (41%), Eugenia lambertiana (10%), Sloanea froesii (8%), Theobroma speciosa (7%)*	13.8	1.058	25	3859
B	*Neea sp (26%), Perebea guianensis (19%), Cordia alliodora (11%), Sahagunia racemifera (10%)*	23.6	1.743	27	2612
C	*Duguetia echinophora (30%), Guarea kunthiana (15%), Talisia longifolia (13%)*	20.8	0.903	24	2929
D	*Protium apiculatum (44%), Lauraceae (14%), Guatteria poeppigiana (10%)*	30.4	2.555	28	4484
E	*Rinorea guianensis (34%), Eschweilera odora (14%), Eschweilera blanchetiana (12%)*	31.8	1.536	41	4791
F	*Tachigali sp (27%), Miconia sp (17%), Virola cuspidata (15%), Anaxagorea dolichocarpa (7%)*	21.1	2.950	26	958
G	*Inga sp (41%), Jacaranda copaia (15%), Bixa arborea (14%)*	30.5	5.212	34	5233
H	*Cecropia sciadophylla (62%), Cecropia obtusa (13%), Cecropia leucocoma (7%)*	24.1	9.569	15	3084
J	*Sapotaceae (58%), Unidentified (10%), Eschweilera amara (7%)*	45.8	1.790	31	3547
K	*Maquira sclerophylla (10%), Protium sagotianum (9%), Iryanthera sagotiana (7%), Enterolobium maximum (7%), Helicostylis pedunculata (7%), Dendrobangia boliviana (7%), Astronium gracile (6%), Castilla ulei (5%), Micropholis venulosa (4%), Sterculia excelsa var. pilosa (4%)*	43.2	2.873	37	1523
L	*Carapa guianensis (24%), Virola michellii (24%), Sclerolobium chrysophyllum (23%)*	55.9	4.672	26	1810
M	*Eschweilera juruensis (21%), Apeiba albiflora (17%), Mouriri collocarpa (9%), Hevea sp (9%), Dialium guianense (9%)*	54.7	3.211	17	815
N	*Geissospermum sericeum (36%), Pouteria sp (21%), Pouteria bilocularis (12%)*	57.8	2.315	27	1924
P	*Couratari oblongifolia (19%), Minquartia guianensis (17%), Iryanthera juruensis (7%), Qualea albiflora (6%), Trattinnickia rhoifolia (5%), Chimarrhis turbinata (5%), Micropholis guyanensis (4%)*	70.3	2.839	32	2347
R	*Tachigali myrmecophylla (41%), Sclerolobium tinctorium (17%), Apeiba burchellii (10%)*	66.6	8.080	17	567
S	*Schizolobium amazonicum (33%), Parkia ulei (31%), Parkia decussata (25%)*	82.2	12.595	5	64
T	*Aspidosperma sp (21%), Bertholletia excelsa (16%), Pseudopiptadenia psilostachya (16%), Swartzia polyphylla (14%)*	109.8	5.992	13	258
V	*Manilkara huberi (26%), Goupia glabra (15%), Manilkara bidentata (8%), Syzygiopsis oppositifolia (8%), Dipteryx odorata (6%)*	91.7	3.594	28	1203
W	*Caryocar villosum (49%), Dinizia excelsa (18%), Hymenolobium petraeum (14%)*	152.9	3.134	5	57

As discussed in Alder *et al* (2002), this type of ordination has a robust and easily interpreted relation to ecology and wood characteristics. For example group H on Figure 6 will be seen as small and fast growing trees. These also tend to be relatively short-lived, high mortality species with typical extreme pioneer habit that flourish after disturbances such as heavier logging or road construction. As can be seen from Table 1, all are Cecropia species. Wood density will be low. In group S, for example, you have large, fast growing species, typically gap opportunists such as *Schizolo-*

bium amazonicum and some *Parkia* species. These will also have low-density timber of low durability, and therefore not much liked by the timber industry. On the other hand in groups V, T and W will be found the progressively larger trees of slow growth, with denser, more durable timber that often include the preferred timber trees. Groups M and above in the alphabetical sequence can all normally grow above the commercial limit of 50 cm, and subject to characteristics of tree form or conservation constraints (such as for *Bertholletia excelsa*, are potentially commercial).

The question of species grouping method and its implications was much discussed in various meetings during the time in Brazil. It is clear that the 1998 version of CAFOGROM lacks the flexibility needed in terms of reporting outputs by commercial groups. In the updated 2011 CAFOGROM an alternate strategy will be used, in which input data describing the stands to be simulated is retained at the species level. This will allow the allocation of species to commercial categories to be changed within model scenarios. From the discussions, this was clearly an important issue, as the definition of what is commercial varies greatly according to the location and objectives of each forest management situation.

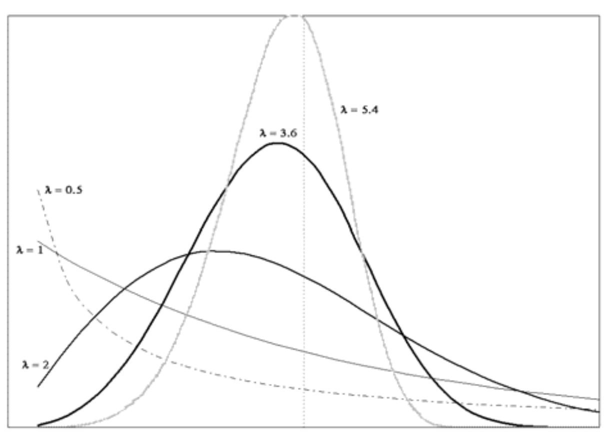
Stochastic growth functions Earlier versions of CAFOGROM used deterministic functions that predicted the increment of a cohort based on its mean size, canopy position and damage status, as described in Alder & Silva (2000). In reality, the correlation of such functions with increment is low, typically with R^2 less than 50%, which means that over 50% of the variation in increment is not predicted by the model.

On the other hand, the author has long noted that the probability distribution of increment can be modelled with the Weibull distribution (Bailey & Dell, 1973; Alder, 1995, p 126-134). The two parameter cumulative form of the Weibull distribution can be expressed as:

$$P = 1 - \exp(-(x/\beta)^{\lambda}) \qquad \{eqn. 1\}$$

Where the x is the variable, in the case tree increment, P is the probability that any increment will be less than or equal to x, β is the Weibull scale parameter, which corresponds to the 63% quantile of the distribution, and λ is the shape parameter. Figure 7 shows some of the shapes the distribution can take. When λ is less than 1, a J-shaped hyper-exponential distribution is seen; with λ = 1, then the Weibull is the same as an exponential distribution. For values of λ above 1 up to 3.6, a unimodal, left-skewed distribution is seen. Above 3.6, the distribution becomes more spike shaped and slightly right-skewed. In the author's experience, increment data tends to show values of λ from 1 to 2, unless the data is

Figure 7 : Shapes of the Weibull distribution



limited to a few values.

Bailey & Dell (1973) describe methods for fitting the Weibull parameters. A very quick approximation that works well has been given by Nelson (1982), also described in Alder (1995, p. 129). This can be done in a single SQL statement. Given a variate x (such as increment), then using $y = ln(x)$, $\lambda = 1.283 / \sigma_y$ and $\beta = \exp(\mu_y + 0.5772/\lambda)$.

The SQL statement below, for example, creates the output table illustrated in Figure 8 in a single step from a table of tree increments (INCARV).

```
CREATE TABLE WEIBSTATS SELECT A.ESP, A.NARV, ROUND(1.283/SDLINC,3) AS LAMDA, ROUND(EXP(AVLINC
    +0.5772/(1.283/SDLINC)),3) AS BETA, 0 AS D95 FROM (SELECT ESP, COUNT(IPA) AS NARV, AVG(LN(IPA)) AS AV-
    LINC, STD(LN(IPA)) AS SDLINC  FROM INCARV WHERE CIF=1 AND IFNULL(IPA,0) >0 AND NPHA IS NOT NULL AND
    MUPM<>1 GROUP BY 1) AS A WHERE SDLINC>0 ORDER BY 2 DESC;
```

We have noted that the scale parameter β is the 63rd percentile of the cumulative distribution function (eqn. 1). In figure 7, all the curves have the same value of β, shown as the vertical dotted line. In the species grouping method (see Figure 6 and Table 1), this is used as the index of species increment, rather than mean increment.

Employing a stochastic function for growth involves a fundamentally different approach. Each original cohort will give rise to many sub-cohorts over each iteration of the model. A collection function will regroup these child cohorts according to their size and other parameters. The result is a much more realistic representation of the uncertainty and variability in a real world projection.

Figure 8 : Table of species increment Weibull parameters produced directly by a single SQL command.

Note that esp is species code, narv is number of sample trees, lamda is λ in text, beta is β in text, and d95 is 95% quantile of cumulative diameter distribution. This latter is calculated separately by a stored SQL procedure note shown here. The listing is a small extract and does not show all species.

esp	narv	lamda	beta	d95
15	211	1.591	5.713	391
16	8	1.836	7.583	642
29	28	1.308	2.150	503
44	55	1.482	5.545	1104
59	13	1.825	1.862	473
60	40	1.380	2.067	222
63	5	1.000	1.757	362
87	120	1.269	6.483	293
203	14	2.204	1.530	1095
214	32	1.404	1.766	593
227	4	1.185	3.343	230
235	8	0.879	3.495	350
241	27	1.912	3.424	297
243	5	3.580	3.772	92
245	19	1.242	4.746	298
250	28	1.346	2.451	1361
256	14	1.585	2.502	318

The paper to be presented at the Montpellier IUFRO meeting will examine this subject in more detail. This remains a work in progress and for that reason it is not explored further in this report.

Work completed within the consultancy Although substantial progress has been made on re-calibrating CAFOGROM, this work has not been completed within the time frame available, and the studies presented here have therefore applied the 1998 version of the model to review and evaluate the extended datasets now available.

As noted in the introduction, major changes to the data system, the fact that the dataset was updated during the course of the consultancy and had to be re-converted twice, and issues caused by some missing data on the Jari plots have all contributed to an over-run in the time requirement relative to that originally agreed.

Additionally, it is apparent that CAFOGROM needs updating in is structure and design in a number of respects, as discussed below.

IUFRO Montpellier Paper As part of this project, a paper will be presented at the IUFRO Conference at Montpellier from 15-18 November. This paper will comprise the following material:

- A review section, regarding the past development of CAFOGROM. This will also include material given in this report (pages 9-11) regarding the examination of SFB forest management regulations.
- Consideration of improvements in process for cafogrom, including the species grouping method and stochastic functions. It will explore the implications of stochastic functions of increment, with examples of projections of diameter distribution compared with data from the new measurements. This will comprise the main scientific focus of the paper.
- In conclusion, it will reiterate points from the section below regarding other aspects of CAFOGROM and how they may be improved.

Further CAFOGROM development It has not been possibly to fully update the 1998 version of CAFOGROM within the timeframe of this project, both because the dataset and its analysis were more complex and fluid than originally envisaged, and also because CAFOGROM itself needs updating in a number of important respects. The following strategy is proposed to bring this work to a conclusion:

- The consultant will work on the completion of this project *pro bono* within the context of his other research over the next 6-8 months.
- This will focus on rewriting the CAFOGROM model to achieve a number of improvements.
- The model will be simplified with respect to the calibration process. At the moment, it is too complex and too closely linked to very specific (and now obsolete) data formats.
- The growth functions will be modified from a deterministic to stochastic form.

- The competition functions will be related to environmental constraints from pan-tropical functions that will allow the model to show site and climatic sensitivity.
- CAFOGROM will be re-written to use Python and Qt rather than Excel. Python/Qt are fully open-source and platform independent (the software will run on Mac and Linux computers as well as MS Windows). This will bring it into alignment with other modelling work the consultant is doing (see the *Forest Management Toolkit* (FMT) at www.eofmt.com).
- The model will also be extended in its planning dimension to a more realistic situation with respect to forest inventories and forest enterprise planning. This implies modelling from a baseline of individual sample plots or stand type/compartment summaries, and relating projections to a GIS shape file that delineates forest boundaries. This will allow for a much more realistic representation of the high spatial variation in species composition and stand structure that is normal in natural tropical forest.

As noted, this continuing work will not require any specific funding or support from SFB or FAO as it will be undertaken within the context of other ongoing work with the FMT. However, it might be desirable next year (2012) to schedule another visit of perhaps 2-3 weeks for presentations, workshops and training demonstrations relative to the updated system. Timing would be quite flexible, but May 2012 might be very suitable.

Conclusion This report has described work undertaken to update and re-calibrate the 1998 version of CAFOGROM using new measurements acquired from 2003 onwards. Although there has been good progress in organizing the database and developing a framework of SQL queries, there have been some significant challenges, and the work has far exceeded the original scope envisaged. A completely new data system is now in use by SFB and EMBRAPA, so that existing pre-processing software (CIMIR) was not usable. Additionally, the datasets were not stable during the analysis, but updated twice, requiring repetition of some time consuming phases.

However, a momentum has been established and a pathway defined. Three significant workshops were held during the course of the 3-week visit to Brazil which have allowed priorities and issues to be defined, as well as exposing a number of technical concerns.

A further scientific conference is being held at Montpellier under IUFRO auspices from 15-18 November 2011. At this a co-authored paper will be delivered which especially addresses new growth functions being developed for CAFOGROM, and compares them with information from the recent re-measurement data.

Finally it is proposed that the further development of CAFOGROM is continued by the author within his own research framework over the next six months (without cost to SFB/FAO), with a new visit of 3-4 weeks to Brazil planned for May 2012 to give presentations and training workshops on the new model version and perhaps to work through a number of specific planning scenarios.

Alder, D (1994) The preliminary development of the CAFOGROM forest growth model. Report of a consultancy carried out from 10th October to 9th December 1994 for CPATU, EMBRAPA, Belem, Brazil, as part of the ODA Silviculture Research Project.

Alder, D (1995) Growth modelling for mixed tropical forests. Department of Plant Sciences, University of Oxford. *Tropical Forestry Paper* 30, 231 pp.

Alder, D (1996a) SIRENA: A simulation model for tropical forest management in Northern Costa Rica - User's Guide and Technical Notes. CODEFORSA/ODA Integrated Natural Forest Management Project, Costa Rica. Technical Report, 33 pp.[http://www.bio-met.co.uk/pdf/sirena1.pdf]

Alder, D (1996b)CAFOGROM.XLS: A simulation model for natural tropical forest management : User's guide and technical reference manual. ODA/CPATU Silviculture Research Project, Belem, Brazil. Consultancy Report, 24 pp. (PDFs available in English [http://www.bio-met.co.uk/pdf/cafo1en.pdf] or Portuguese [http://www.bio-met.co.uk/pdf/cafo1pt.pdf], c. 948 kb)

Alder, D (1998) Evaluation and implications of the CAFOGROM forest growth model. DFID/CPATU Silviculture Research Project, Belem, Brazil. Consultancy Report, 24 pp. [http://www.bio-met.co.uk/pdf/cafogrom2.pdf]

Alder, D; Oavika, F; Sanchez, M; Silva, , JNM; Van der Hout, P; Wright, HL. (2002) A comparison of species growth rates from four moist tropical forest regions using increment-size ordination. *International Forestry Review* 4(3)196-205 [http://www.bio-met.co.uk/pdf/ifr2002.pdf]

Alder, D; Silva, JNM (2000) An empirical cohort model for the management of Terra Firme forests in the Brazilian Amazon. *Forest Ecology & Management*, 130:141-157.[http://www.bio-met.co.uk/pdf/fem2000.pdf]

Alder, D; van Kuijk, M (2009) A baseline assessment of forest carbon in Guyana.. Consultancy report for Guyana Forestry Commission. http://www.bio-met.co.uk/pdf/GuyanaBaselineAssessment.pdf

Bailey, RL; Dell, TR (1973) Quantifying diameter distributions with the Weibull function. *Forest Science* 19(2)97-104.

Chave, J; Andalo, C; Brown, S; Cairns, MA; Chambers, JQ; Eamus, D; Folster, H; Fromard, F; Higuchi, N; Kira, T; Lescure, JP; Nelson, BW; Ogawa, H; Puig, H; Riera, B; Yamakura, T (2005) Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia* 145:87-99

Korsgaard, S (1982) A manual for the computer progamming and processing of silvicultural research data. FAO/FO:MAL/76/008 Field Document No.6

Korsgaard, S (1993) A user's guide to the computer programmes used in processing and tabulating forest research data from the CPATU permanent sample plots. CPATU/EMBRAPA/IICA Technical Paper No. 1, c. 100 pp.

Nelson, W (1982) *Applied Life Data Analysis*. John Wiley & Sons, New York. 634 pp.

Oliveira, Lia C de (1997) Dinâmica de crescimento e regeneração natural de uma floresta secundária no estado do Pará.. In: Guariguata, M.R.; Finegan, B. [Ed.] (1997) *Ecology and management of tropical secondary forest: science, people and policy*. Proceedings of a conference held at CATIE, Costa Rica, November 10-12, 1997, pp. 70-88

Phillips, Oliver L.; Baker, Timothy R.; Arroyo, Luzmila; Higuchi, Niro; Killeen, Timothy; Laurance, William F.; Lewis, Simon L.; Lloyd, Jon; Malhi, Yadvinder; Monteagudo, Abel; Neill, David A.; Vargas, Percy Nuñez; Silva, J. Natalino N.; Martinez, Rodolfo (2005) Late twentieth-century patterns and trends in Amazon tree turnover. In: *Tropical Forests and Global Atmospheric Change*, p 107-127, [Ed: Malhi, Y; Phillips, O] OUP, 2005, pp 267.

Pretzsch, Hans; Biber, Peter (2005) A Re-Evaluation of Reineke's Rule and Stand Density Index. *Forest Science* 51(4)304-320.

Silva, J.N.M.; Carvalho, J.O.P. de; Lopes, J. do C.A.; Oliveira, R.P. de; Oliveira, L.C. de. (1994) Growth and yield studies in the Tapajós region, central Brazilian Amazon.. Proceedings, *IUFRO International Symposium Growth and Yield of Tropical Forests*. Fuchu, Tokyo (Japón). 26 Set-1 Oct 1994, pp 19-29.

Silva, JNM (1989) The behaviour of the tropical rainforest of the Brazilian Amazon after logging. D.Phil. thesis, Oxford University. 302 pp.

Silva, JNM; De Carvalho, JOP; Lopes, J. de CA; De Oliveira, RP; De Oliveira, LC (1996) Growth and yield studies in the Tapajos region, Central Brazilian Amazon. *Commonwealth Forestry Review* 75(4)325-329.

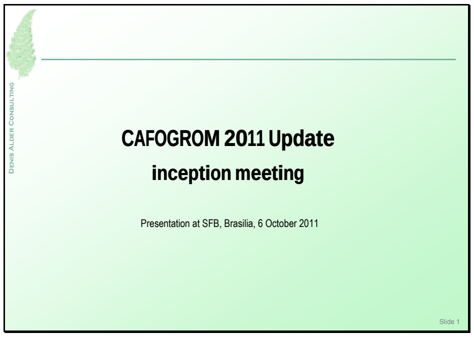
Silva, JNM; de Carvalho, JOP; Lopes, JCA; Almeida BF; Costa DHM; de Oliveira, LC; Vanclay, JK; Skovsgaard, JP (1995) Growth and yield of a tropical rainforest in the Brazilian Amazon 13 years after logging. *Forest Ecology and Management*, 71:267-274.

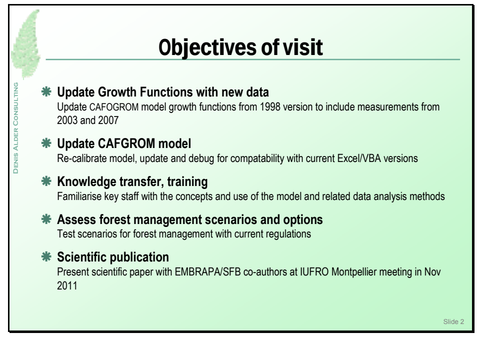
Silva, JNM; Uhl, C (1992) Forest management for timber production: A sustainable use of the Brazilian Amazon. *An. Acad. Bras. Ci.* 64(Supl. 1):89-94.

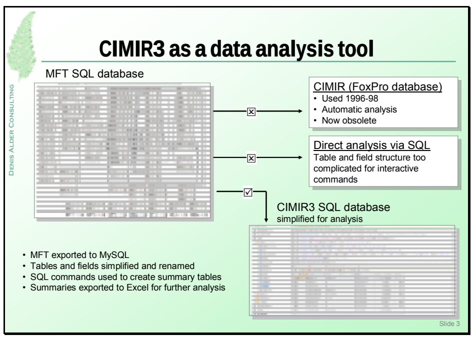
Vanclay, JK (1989) A growth model for North Queensland rainforests. *Forest Ecology and Management* 27:245-271.

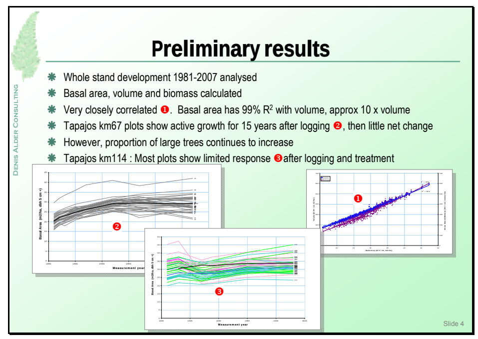
Wright, HL; Alder, D [Ed.] (2000) Humid and semi-humid tropical forest yield regulation with minimal data. Workshop proceedings, CATIE, Costa Rica, 5-9 July 1999. *Oxford Forestry Institute Occasional Papers* 52. 95 pp.

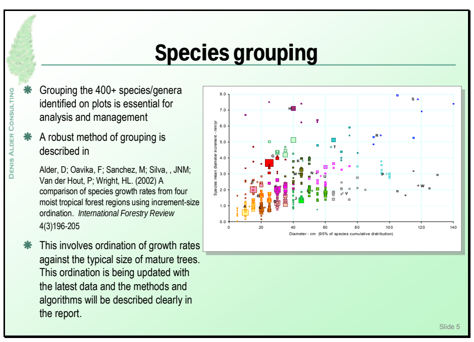
Presentation at SFB, Brasilia, 6th October 2011

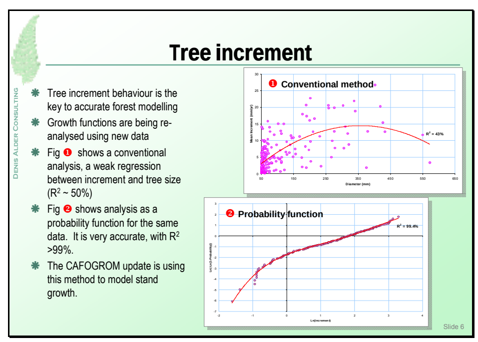


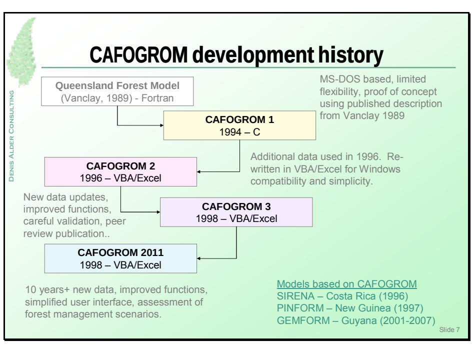


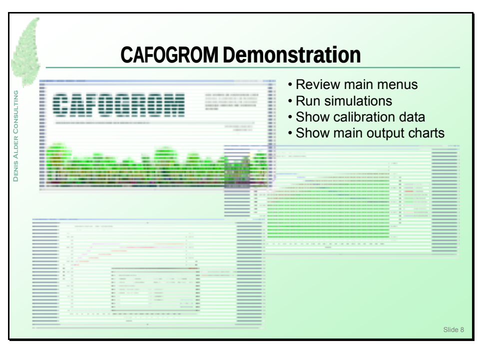


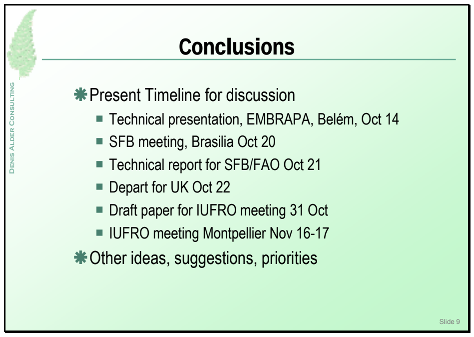




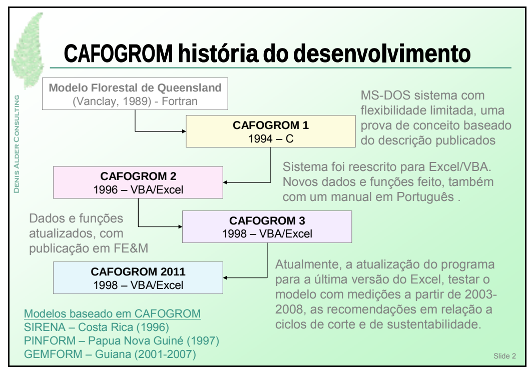


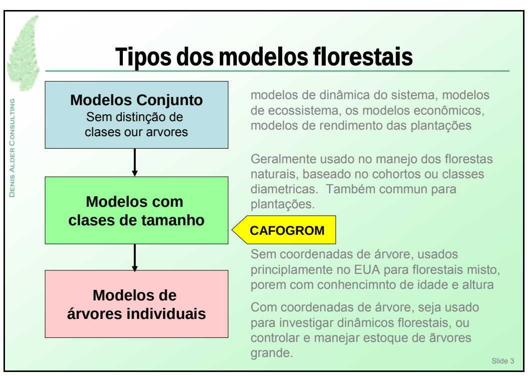


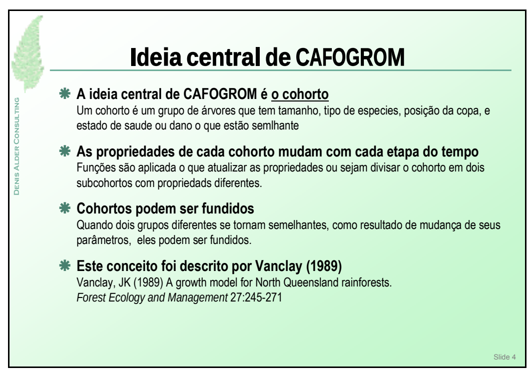


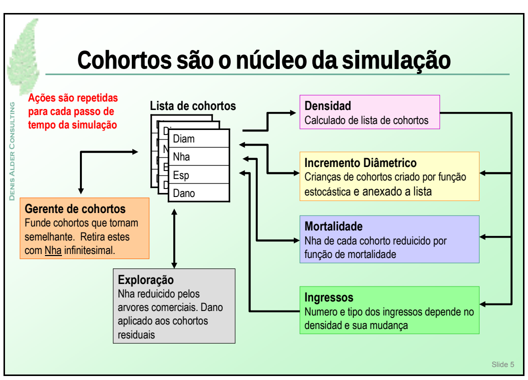


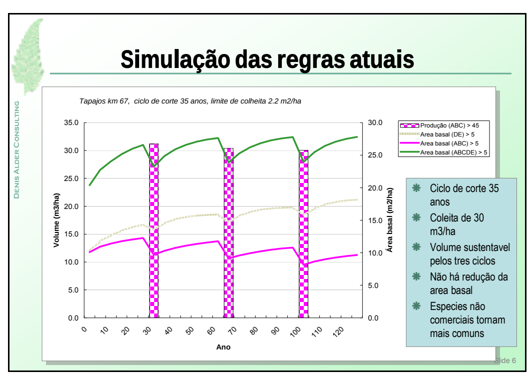
Presentation for EMBRAPA workshop, Belém, 14th October 2011



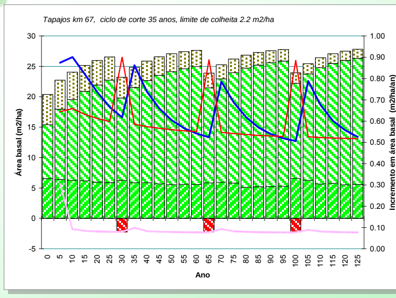








Aspectos de dinâmicos florestais em CAFOGROM



CAFOGROM use funções de:

- Crescimento diametrico
- Mortalidade
- Competição
- Dano de exploração
- Efeito de perturbação sobre a regeneração

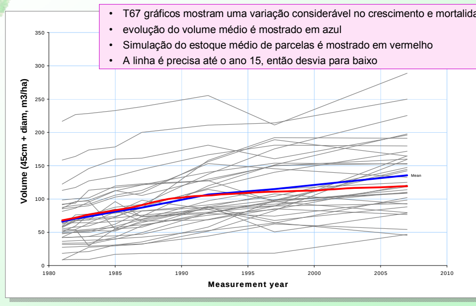
Slide 7

Demonstração do CAFOGROM

Slide 8

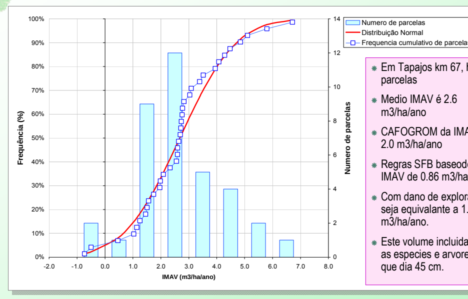
CAFOGROM e dados reais 1981-2007

- T67 gráficos mostram uma variação considerável no crescimento e mortalidade
- evolução do volume médio é mostrado em azul
- Simulação do estoque médio de parcelas é mostrado em vermelho
- A linha é precisa até o ano 15, então desvia para baixo



Slide 9

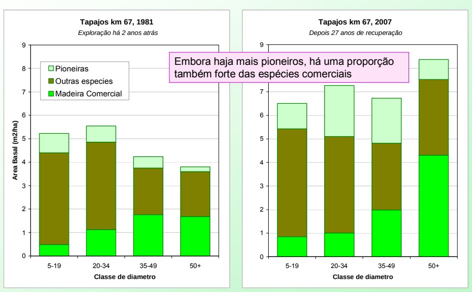
IMAV distribuição por parcelas



- Em Tapajos km 67, há 36 parcelas
- Medio IMAV é 2.6 m3/ha/ano
- CAFOGROM da IMAV de 2.0 m3/ha/ano
- Regras SFB baseodo no IMAV de 0.86 m3/ha/ano
- Com dano de exploração, seja equivalante a 1.8 m3/ha/ano.
- Este volume incluida todas as especies e arvores mais que dia 45 cm.

Slide 10

Crescimento real por especies e tamanho



Embora haja mais pioneiros, há uma proporção também forte das espécies comerciais

Slide 11

Mudanças para versão nova de CAFOGROM

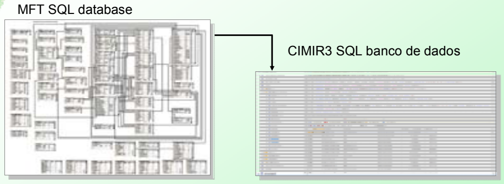
- Simplificação do sistema de agrupamento de espécies
- Uso de uma função estocástica para representar incremento
- Funções mais simples e mais transparente para os danos de exploração e Ingressos
- Documentação de análise de dados baseado em SQL, em vez de algoritmos DBASE
- O resultado deve ser uma versão que pode ser mais facilmente adaptáveis e desenvolvido dentro EMBRAPA / SFB

Slide 12

CIMIR3 : ferramenta de análise de dados

MFT SQL database

CIMIR3 SQL banco de dados

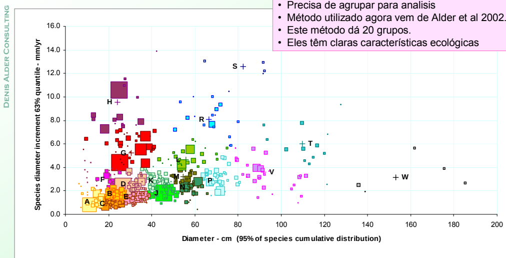


- Cafogrom original usado uma ferramenta de análise de dados chamado CIMIR
- Este base usou FoxPro, o que está agora obsoleto
- Análise de novos dados provenientes da EMBRAPA Amasoft MFT banco de dados
- Usa uma ferramenta de MySQL chamada CIMIR3
- Isto permite que a análise estatística com comandos interativos SQL

Slide 13

Agrupamento de espécies

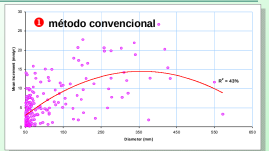
- Florestais naturais têm centenas de especies
- Precisa de agrupar para analisis
- Método utilizado agora vem de Alder et al 2002.
- Este método dá 20 grupos.
- Eles têm claras características ecológicas

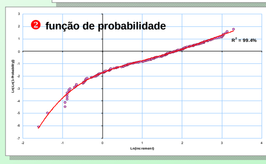


Slide 14

função estocástica de incremento

- Fig ❶ mostra uma análise convencional, uma regressão fraca entre incremento e tamanho da árvore (R2 ~ 50%)
- Fig ❷ análise mostra como uma função de probabilidade para os mesmos dados. Ele é muito preciso, com R2> 99%.
- Novo método deve refletir melhor os incrementos mais elevados alcançados por grandes árvores do dossel.





Slide 15

Conclusões

- A nova versão do Cafogrom será mais simples para atualizar.
- O desafio é para EMBRAPA-se a empreender esta actualização.
- Para uma aplicação mais ampla geografico, parcelas a partir de diferentes tipos de floresta são necessários.
- Modelos do tipo Cafogrom são rápidos o suficiente para ser aplicado diretamente aos dados de parcelas inventárias.
- Este é o objetivo ideal para uso no contexto do manejo florestal sustentável.

Slide 16

Meeting 18th October, EMBRAPA, Belém

CAFOGROM Data Requirements

Informal presentation at EMBRAPA, Belem, 18-Oct-2011

Slide 1

Summary of Data Files

- All files are read by CAFOGROM as CSV files without column headings
- INCMED - Diameter increment summaries by size classes
- MORTAL - Mortality rates for damaged, impeded and dominant trees
- INGRESSO – Recruitment by species group, as % of total for disturbed/undisturbed forest
- DANDEX - Logging damage data
- SOMAB - Basal area for each plot and year of measurement, by various categories
- SUMGRUP – Species group characteristics and main species
- .CIV files – Summarised inventory data

Slide 2

INCMED – Diameter Increment

- All data input/function fitting routines are in module modlprog
- Routine where data read is FillInc
- Each row in the CSV file INCMED.CIM has following data. Critical items are bold.
  model, Ndc, nbq, dap, Dinc, Nt, ssd
- Model is the model code, in text, enclosed in quotes
- Ndc is diameter class number (sequential 1 to max, can be omitted if a diameter class is not populated. CAFOGROM typically expects unequal diameter classes. Eg function $Log_2(D/10)$ +2 where D is in cm will give class values 1,2,3,4 for classes 5-9 , 10-19, 20-39, 40-79 cm etc. However, classes of equal intervals are equally valid. Classes with no data should not be in the list.
- Nbq is 0 for dominant/canopy trees (copa 1-2), 1 for impeded trees (3, 4, not recorded)
- Dap is class mean diameter in cm.
- Dinc is class mean increment, in cm.
- Nt is number of trees in the class
- Ssd is sums of squares of deviations of class
- Currently regressions are fitted unweighted, but Nt and ssd have been used experimentallyfor weighting.

Slide 3

MORTAL – Mortality summaries

- Read in routine MortData in module ModlProg
- Each lines comprises Grup, Nt(1), Amr(1), Nt(2), Amr(2), Nt(3), Amr(3)
- Grup is the model code, quoted (≡ Model for INCMED)
- Nt(1) is number of canopy trees with damage in dataset (this is a raw data count, not corrected for area, plot size, etc. These numbers are to indicate reliability of data).
- Amr(1) is the Annual Mortality Rate as a fraction eg 0.051 is 5.1% annual mortality.
- Nt(2), Amr(2) is the same for impeded trees (crown classes 3,4, unrecorded)
- Nt(3), Amr(3) is the same for undamaged, healthy, canopy trees (classes 1 and 2).

Slide 4

INGRESSO - Recruitment

- File INGRESSO.CIM is read by IngList in module ModlProg
- Data values on each line are Grup, rBA(1), rBA(2), rBA(3), rBA(4), Din
- Grup is the model or species group, quoted as before
- rBA(1) is basal area of recruits after disturbance on locality A (eg Tapajos)
- rBA(2) is the basal area of recruits without disturbance on same locality
- rBA(3) and rBA(4) are the disturbed/undisturbed recruitment BA on a second locality (eg Jari)
- The locality names are set by the program code lines:

```
[b2] = "Tapajos"      'Locality names for 2 sets of recruitment data
[d2] = "Jari"
```

- These names can be changed if required. In the heading of each .CIV file one or other of these names should occur as part of the title to slect the correct data set.

SOMAB – Basal area summaries

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- This file is used to fit competition and recruitment functions.
- It is read by routine ABdata in module ModlProg
- Each line should have the following items
  - Plot identification (quoted, text value)
  - Year of measurement
  - Measurement interval
  - Standing BA of canopy trees
  - BA of damaged trees
  - BA of malformed trees
  - BA of understorey trees
  - BA of recruits
  - Total standing BA
  - Basal area increment
  - Mortality basal area
  - Harvest basal area
  - Treated basal area

DANDEX – Logging Damage

Denis Alder Consulting

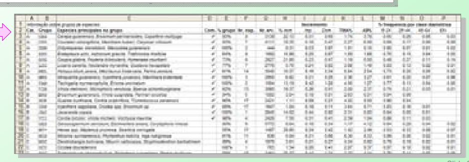
- Read by routine DamgData in module ModlProg
- Each data row has: Plotid, hBA, Ncut, Dbh, hBAc, mBAc, dBAc, sBAc
- PlotID si plot ID in quotes.
- hBA is basal area harvested
- Ncut is the N/ha harvested
- Dbh is the diameter class lower limit in cm.
- hBAc is the harvested BA in this diameter class
- mBAc is the mortality BA (BA of trees that have died) in this diameter class
- dBAc is the BA of trees damaged in this diameter class
- sBAc is the pre-harvest BA in this diameter class.
- Note there are several rows for each plot, and PloID, hBA and Ncut will be the same for each row for the same plot.

SUMGRP – Species Group Summary

Denis Alder Consulting

- This contains information about species groups for reference. A classification based on diameter distribution etc assigns groups to ecological classes.
- Read by GetGrupInfo in module ModlProg
- Columns as per corresponding spreadsheet (Grupos de especies menu)

```
"CAG","Carapa guianensis, Brosimum parinarioides, Copaifera multijuga",1.00,0.83,8,3138,22.13,0.308,0.600,1.736,3.78,0.65,0.26,0.06,0.03
"CUO","Couratari oblongifolia, Manilkara huberi, Caryocar villosum",1.00,0.93,7,4111,18.35,0.184,0.466,2.267,6.00,0.69,0.17,0.06,0.08
"DDM","Didymopanax morototoni, Macoubea guianensis",1.00,1.00,2,444,9.31,0.530,0.968,1.807,0.15,0.90,0.07,0.01,0.02
"DUE","Duguetia echinophora, Duroia sprucei, Conceveiba guianensis",0.00,1.00,3,3813,1.03,0.088,0.229,4.107,0.61,0.97,0.03,0.00,0.00
```



.CIV Forest basis files

Denis Alder Consulting

- A forest inventory summary for the forest to be simulated in cohort form
- The first line is a title. This should include a name that metches one of the regeneration lists (see INGRESSO)
- Second and subsequent lines are cohort data, as follows:
  - Grup Species group code, in quotes
  - Nha Number of trees per ha in a group, a deimal number, may be quite small
  - Dbh The mean diameter of the cohort, a real number
  - Fd The damage status of the cohort: (0) if undamaged, (1) if damaged or decayed

Conclusions

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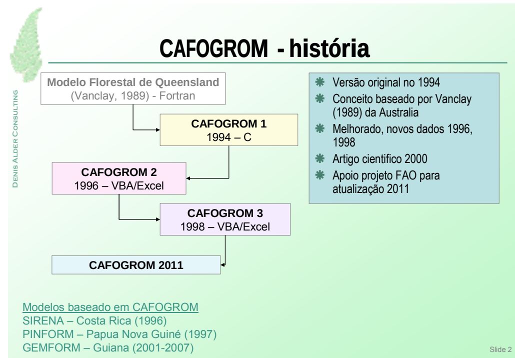
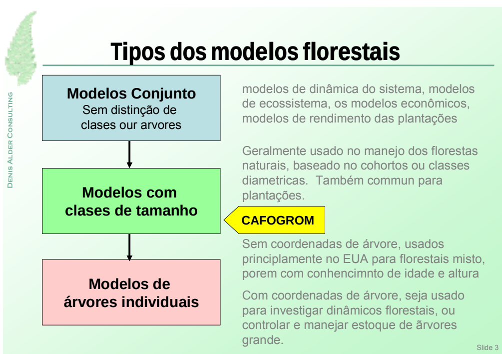
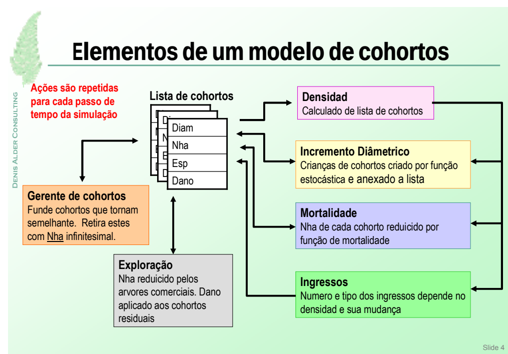
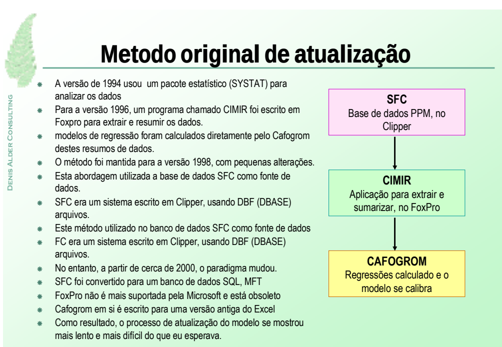
- These file structures are complex, and difficult to set up manually
- Originally, the CIMIR database linked directly to the SFC database and egenrated these files automatically
- The goal should be to have a similar facility the operates on the MFT database.
- Alternatively, CAFOGROM can be simplified so that, like the first version, all functions are anlysed externally and input as equations.
- Which way is better?

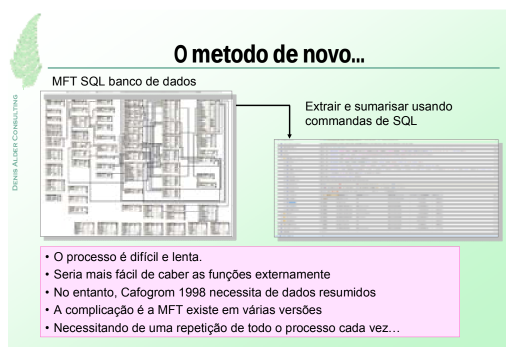
Presentation for SFB, Brasilia, 21st October 2011

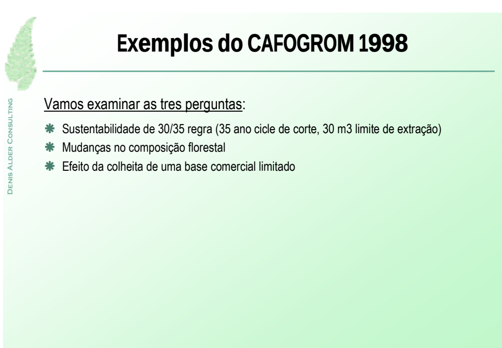


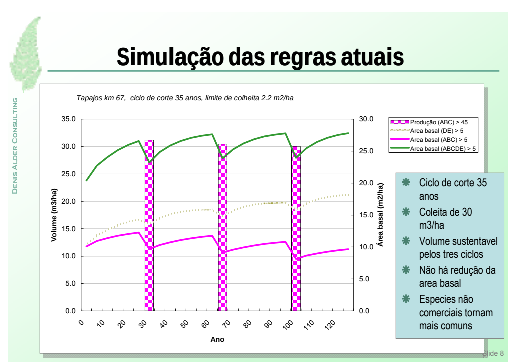




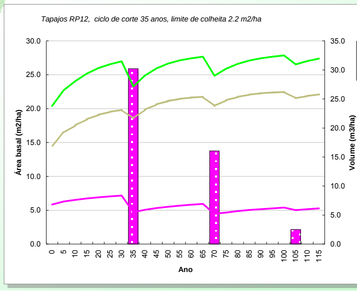






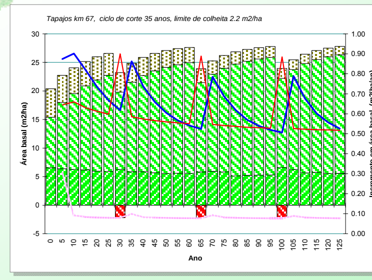


Simulação com poucas especies comerciais



- Com base estreita de especies comerciais, produção não é sustentavel
- O nivel de 30 m3 cortar deve aplicada pelo menos de 50% de volume a pé.

Aspectos de dinâmicos florestais em CAFOGROM



CAFOGROM use funções de:

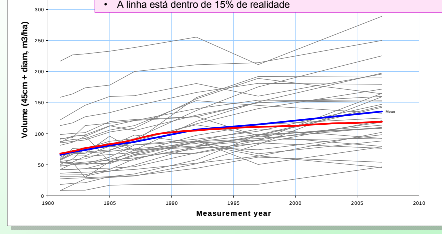
- Crescimento diametrico
- Mortalidade
- Competição
- Dano de exploração
- Efeito de perturbação sobre a regeneração

Embora que simulações não sejam realidade...

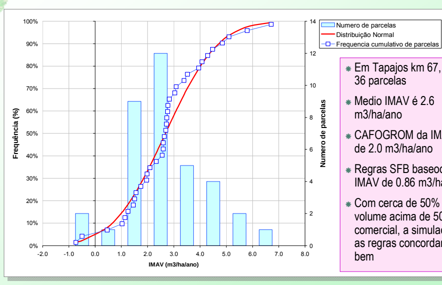
Vamos ver alguns dados reais para comparação

CAFOGROM e dados reais 1981-2007

- T67 parcelas mostram uma variação consideravel no crescimento e mortalidade
- Evolução do volume médio é mostrado em azul
- Simulação do estoque médio de parcelas é mostrado em vermelho
- A linha está dentro de 15% de realidade

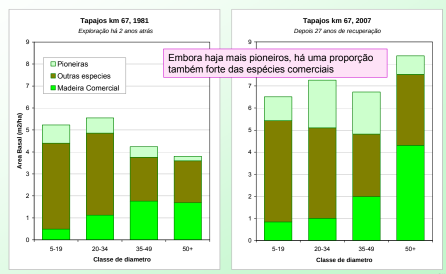


IMAV distribuição por parcelas



- Em Tapajos km 67, há 36 parcelas
- Medio IMAV é 2.6 m3/ha/ano
- CAFOGROM da IMAV de 2.0 m3/ha/ano
- Regras SFB baseodo no IMAV de 0.86 m3/ha/ano
- Com cerca de 50% do volume acima de 50 ser comercial, a simulação e as regras concordam bem

Mudanças na estrutura florestal



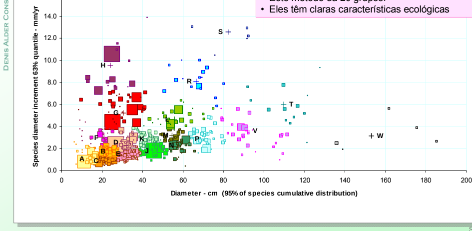
Embora haja mais pioneiros, há uma proporção também forte das espécies comerciais

Indo adiante com CAFOGROM

- Nova sistema de agrupamento de espécies, baseado de MYRLIN
- Uso de uma função estocástica para representar incremento
- Indice de competição mais transparente baseado no razão de copa
- Funções mais simples e mais transparente para os danos de exploração e Ingressos
- O resultado deve ser uma versão que pode ser mais facilmente adaptáveis e desenvolvido dentro EMBRAPA / SFB

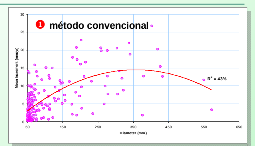
Agrupamento de espécies

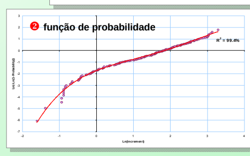
- Florestais naturais têm centenas de especies
- Precisa de agrupar para analisis
- Método utilizado agora vem de Alder et al 2002.
- Este método dá 20 grupos.
- Eles têm claras características ecológicas



função estocástica de incremento

- Fig ❶ mostra uma análise convencional, uma regressão fraca entre incremento e tamanho da árvore (R2 ~ 50%)
- Fig ❷ análise mostra como uma função de probabilidade para os mesmos dados. Ele é muito preciso, com R2> 99%.
- Novo método deve refletir melhor os incrementos mais elevados alcançados por grandes árvores do dossel.





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Slide 17

Conclusões

- A nova versão do Cafogrom sera mais simples para atualizar e usar and sera pronto por Novembre 2011.
- Um artigo científico sera presentado à reunião de IUFRO 17-19 Novembre 2011
- Varióis pesquisadores no EMBRAPA trabalham com modelos florestais agora. Isso vai fazer mais facil para melhorar e atualizar CAFOGROM no futuro.
- Quero agradecer todos que têm feito este visita posivel, em especial Joberto Veloso de Freitas, o diretor SFB, e tambem no Belém, Jose Natalino de Silva, Lucas Mazzei, Ademir Ruschel, J Carmo de Lopes e outros.

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