Development of growth models for applications in Guyana

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A technical report prepared for the Guyana Forestry Commission Support Project with the assistance of the UK Department for International Development, October 2000.

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Revised: 15-Sep-2000

Executive Summary

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Acknowledgments

The work described in this report is based on data proved by the Tropenbos Foudnation and Barama Company Limited. The author is indebted to these organisations for their cooperation. He would particularly like to thank Dejan Lewis of BCL/ECTF, and Peter van der Hout of Tropenbos for assisting with the interpretation of the data files. He is also indebted to Roderick Zagt of Tropenbos for advice and discussions regarding growth and yield issues in Guyana.

Within the GFC, this visit has been facilitated by many staff members. I would like to thank especially Godfrey Marshall, Deputy Commissioner for Forest Resource Management, Neil Bird, the DFID Forest Management advisor, Gavin Nichol, DFID Forest Inventory advisor for their many discussion and comments.

This consultancy was organised through Natural Resources International Limited, whom I would like to thank for efficiently handling the administrative arrangements.

Disclaimer

This report is solely the responsibility of its author, as are any errors or omissions that it may contain. It does not necessarily reflect the views of DFID, NR International Ltd, or the Guyana Forestry Commission and is not an authorised document of any of those organisations.

Abbreviations

BCL	Barama Company Limited
Dbh	Diameter at breast height (1.3 m).
DFID	United Kingdom Department for International Development
Excel	*Microsoft Excel*. A registered trademark of Microsoft Corporation.
GEMFORM	Guyana Empirical Model for Forest Management
GFC	Guyana Forestry Commission
ITTO	International Tropical Timber Organization
PINFORM	PNG/ITTO Natural Forest Model
PNG	Papua New Guinea
PSP	Permanent sample plot.
SSD	Silvicultural Survey Data workbook in Excel
SSM	Silvicultural Survey Macros workbook in Excel
VBA	*Visual Basic for Applications*, a registered trademark of Microsoft Corporation.

Introduction

Terms of reference

The consultant was invited to work with the DFID/GFC Support Project to develop, specifically, a growth model for the natural forests in Guyana, based on earlier work in other countries (Alder, 1997a, 1976, Alder & Silva, 2000). The Terms of Reference for this visit can be summarised as involving the following objectives:

- Analysis of permanent sample plot data (PSPs) available in Guyana to develop growth and mortality functions for stand modelling.

- Development of a practical model for use as a decision support system.

- Provision of software relative to the processing of silvicultural survey data.

- Review of survey and sampling procedures, with recommendations for improvements as necessary.

These TORs have been accomplished, although with some change of emphasis. More time was spent on the software for processing silvicultural survey data than was originally envisaged by the consultant; this is currently the primary activity for forest management efforts, and was a clear priority. Consequently, the type of stand model designed was more limited than, for example, the SIRENA model developed for Costa Rica, and was designed solely for the projection of growth from the silvicultural surveys.

Prior work

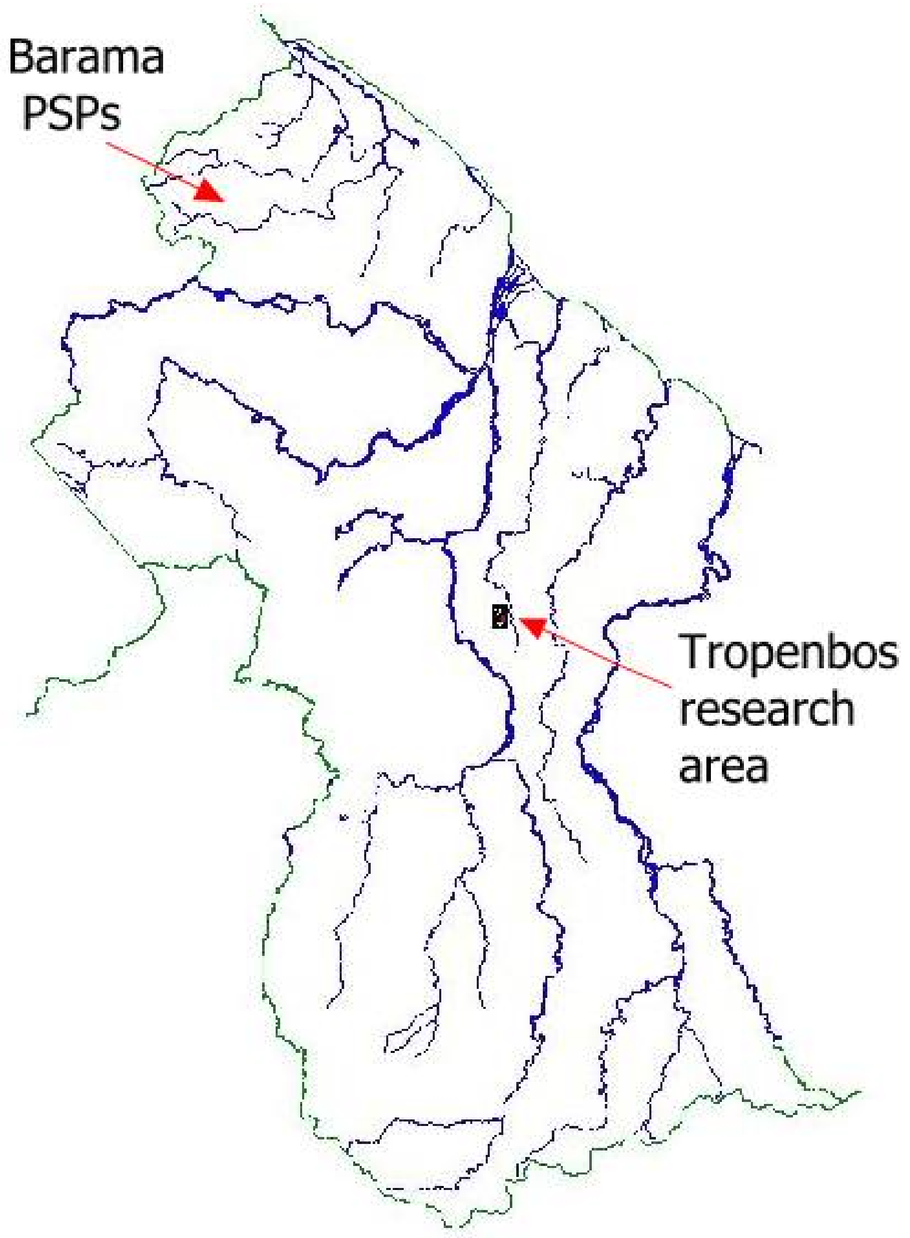
Guyana has a long history of botanical and ecological study, vegetation analysis, inventory and tree volume work. Fanshawe (1952) wrote a study of the vegetation types and forest structure some 40 years ago. The British colonial administration produced extensive base maps, forest type maps, and archived collections of aerial photographs some of which are still available. FAO in the late 1960's undertook an inventory which produced stand tables, vegetation maps, and volume tables, whilst CIDA in the early 1990's complete additional inventory, mapping and volume sampling work. The FAO and CIDA studies are reviewed in Wright (1999).

The Tropenbos Foundation of the Netherlands has been active in Guyanese forest research since the late 1980's, and has undertaken extensive botanical and vegetation studies. Various useful monographs and books have been published on botanical and ecological aspects including Polak (1992), ter Steege (1990), ter Steege *et al* (2000). Growth modelling studies have been undertaken by Zagt (1997), whilst logging impacts and silviculture have been researched by van der Hout (1999).

The Barama Company Limited, Guyana's largest timber company, has undertaken extensive PSP work since 1993, and has employed the Edinburgh Centre for Tropical Forestry (ECTF) as its consultants for this purpose. Some unpublished reports from this work are available, including growth modelling studies by Zagt (ECTF, 1999).

The UK Department for International Development (DFID) has been supporting the rehabilitation and strengthening of the Guyana Forestry Commission (GFC) since 1995. Among other activities, this has included the unearthing and archival in a modern digital format of as much of the historical data as possible from the CIDA and FAO inventories, two or three PSPs established by the GFC, the undertaking of pilot inventories, and stock surveys, and the development of an effective GIS centre within the GFC.

Figure 1 Map of Guyana, showing approximate location of Barama and Tropenbos PSPs



Analysis of data

Introduction

Permanent sample plot data provide the *sine qua non* of growth and yield studies in the tropics. In the present case, extensive data of good quality was provided to the author by Tropenbos and BCL. In addition tree volume and inventory data from the 1993 CIDA studies were available to gather supplementary information.

The analysis of such data sets is not something which can be completed within a few short weeks. For both the above organisations, research is ongoing and many reports have already been produced, as noted in the foregoing section. My objectives were pragmatic and set by the TORs: To determine average mortality and increment rates for commercial species to facilitate growth projection with the silvicultural surveys.

Description of PSPs

As noted above, PSP data were made available by BCL and Tropenbos through the GFC. The Barama plots were of a one-hectare design, established under ECTF supervision according to the recommendations in Alder & Synnott (1992). They were 100 x 100 m square, subdivided into 25 quadrats of 20 x 20 m. All trees down to 20 cm minimum diameter were measured. In a sub-sample of the central 5 quadrats, trees down to 5–cm dbh were measure.

The Tropenbos plots are located at Pibiri, within the concessions of Demerara Timber Limited (DTL), and comprise 15 plots of 1.96 ha each (140 x 140 m), established as a randomised block experiment with 5 treatments in 3 replicates. Van der Hout (1999) gives a complete description of the treatments, organisation and location of the plots. The main plot is divided into 20 x 20 m quadrats on which all trees down to 20-cm dbh are measured. On 100 of these quadrats, there are 10 x 10 m sub-quadrats on which all trees greater than 5-cm dbh are measured.

There are further subplots for measuring smaller saplings and seedlings, but these data were not used for the present exercise.

Table 1 : Numbers of PSPs and annual re-measurements

No. of plots	Measured at least ... times	Sample area (ha)
Barama Company Limited		
78	1	78.0
62	2	62.0
58	3	58.0
52	4	52.0
41	5	41.0
36	6	36.0
12	7	12.0
Tropenbos Foundation (Pibiri Experiment)		
15	4	29.4

Table 1 shows the numbers of plots and their periods of measurements for both dispositions. Measurements were made at approximately annual intervals for both groups of plots. The number of plots is shown cumulatively in the table according to the number of years of measurement. Thus, for BCL, 78 plots were established initially, of which 62 were re-measured once, 58 re-measured twice, etc. Only the PSPs with at least one re-measurement provided useful increment or mortality data.

Data transformations

Each of the data files provided to the consultant by BCL and Tropenbos contained different data formats, measurement standards and coded notes, species codes and species lists. To permit a unified and rapid analysis with Excel and Visual Basic macros, these were converted into a common database using a standardised format. This was done as a series of *ad hoc* manipulations using interactive FoxPro commands, SQL queries, and small programs in order to standardise species codes, convert coded notes to logical flags, summarise quadrat statistics as a competition index, and rectify some problems in recording dead and recruit trees. Only trees 20-cm and above were included in this process because of the limited time available. Two text data files resulted, one with tree data called PSPRF.DAT, and another with quadrat summaries, QUADS.DAT.

Table 2 : Data structure of standardised tree and quadrat files compiled from the Barama and Tropenbos PSPs

Field	*Description*
PSPRF.DAT – Tree measurement information	
Quadno	Quadrat serial number – links to Quads file
Ddate	Date of tree measurement expressed as a decimal
TreeId	Tree number
GenSpp	Species code given as first five letters of genus plus first three of species.
Diam	Reference diameter (Dbh or Dab) in mm.
Flags	Coded notes expressed as an integer number. The numbers below can be added to give a single value depending on the qualitative information applicable to the tree (*e.g.* 40 = climbers+defect).
	1 *Ingrowth tree*
	2 *Unspecified coded note (probably data error in original file)*
	4 *Unreliable measurement (buttressed, strangled, fluted trees etc.)*
	8 *Climbers present*
	16 *Bad form noted*
	32 *Defect due to natural causes (fungi, rot etc.)*
	64 *Logging damage noted*
	128 *Tree logged or killed by silvicultural treatment*
	256 *Dead tree, or disappeared and presumed dead*
QUADS.DAT – Quadrat information	
Quadno	Quadrat serial number – links to PSPRF file
Quadid	Original plot identifier and quadrat number as text
Ntq	Number of trees on the quadrat (trees 20cm +)
Qba	Quadrat basal area (trees 20cm +) in m2/ha

As in other studies I have undertaken, the different species lists and codes were unified by using a code, which is called GENSPP in the various Excel macros. This comprises the first five letters of the genus, a space, and the first three letters of the species, and can be generated fairly automatically once original species codes can be linked with botanical names. There remain misspellings, synonyms, and the like, and the final clean analyses are based on a list in which the various alternative codes are listed for each taxon recognised in the output tables.

PSPs and forest types

In order to characterise the forest types represented by the various plots, an association analysis was carried out using the method of reciprocal averaging (Hall & Swaine, 1976). This method sorts the plots into order, according to the similarity of their species composition, and also sorts species into order, according to their tendency to be associated or disassociated. The results are shown in Figure 2. Plot codes are shown down the left, and species codes along the top. The figures in each cell are the numbers per hectare of trees above 20 cm dbh for that species and plot. Higher frequency values are highlighted in deeper shades of mauve, magenta and red.

It can be seen that there is a complete discontinuity of forest type between the Tropenbos plots, coded PIB-01 to PIB-15, and the Barama plots. Within each group, the same species are consistently common, although there are some subsidiary patterns indicating sub-associations. The characteristic species are summarised in the table below.

This sharp discontinuity of forest types is unusual in my experience. In Ghana, Brazil, Costa Rica, and Papua New Guinea, gradations and a gradualistic change of species composition were more usual within the general lowland moist tropical forest type. It has been noted since the early writings on the subject by Fanshawe (1952), that in Guyana it is possible within a few metres to walk from one species association to a completely distinct one. This present special problems for the forest growth modelling strategy in relation to concession management, as will be discussed later.

Table 3 Characteristic species on the Barama and Tropenbos PSPs

Code	Common name	Scientific name
Barama PSPs		
CATOS COM	Swamp Baromalli	*Catostemma commune*
ESCHW	Kakaralli	*Eschweilera spp.*
PROTI DEC	Kurokai	*Protium decandrum*
LICAN LAX	Kauta	*Licania laxiflora*
PENTA MAC	Trysil	*Pentaclethra macroloba*
ALEXA	Haiariballi	*Alexa spp.*
INGA RUB	Waiki	*Inga rubiginosa*
Tropenbos PSPs		
CHLOR ROD	Greenheart	*Chlorocardium rodiei*
CATOS FRA	Sand Baromalli	*Catostemma fragrans*
LECYT CON	Wirimiri	*Lecythis confertiflora*
SWART LEI	Wamara	*Swartzia leiocalycina*
EPERU FAL	Soft Wallaba	*Eperua falcata*
MORA GON	Morabukea	*Mora gongrijpii*
CARAP GUI	Crabwood	*Carapa guianensis*

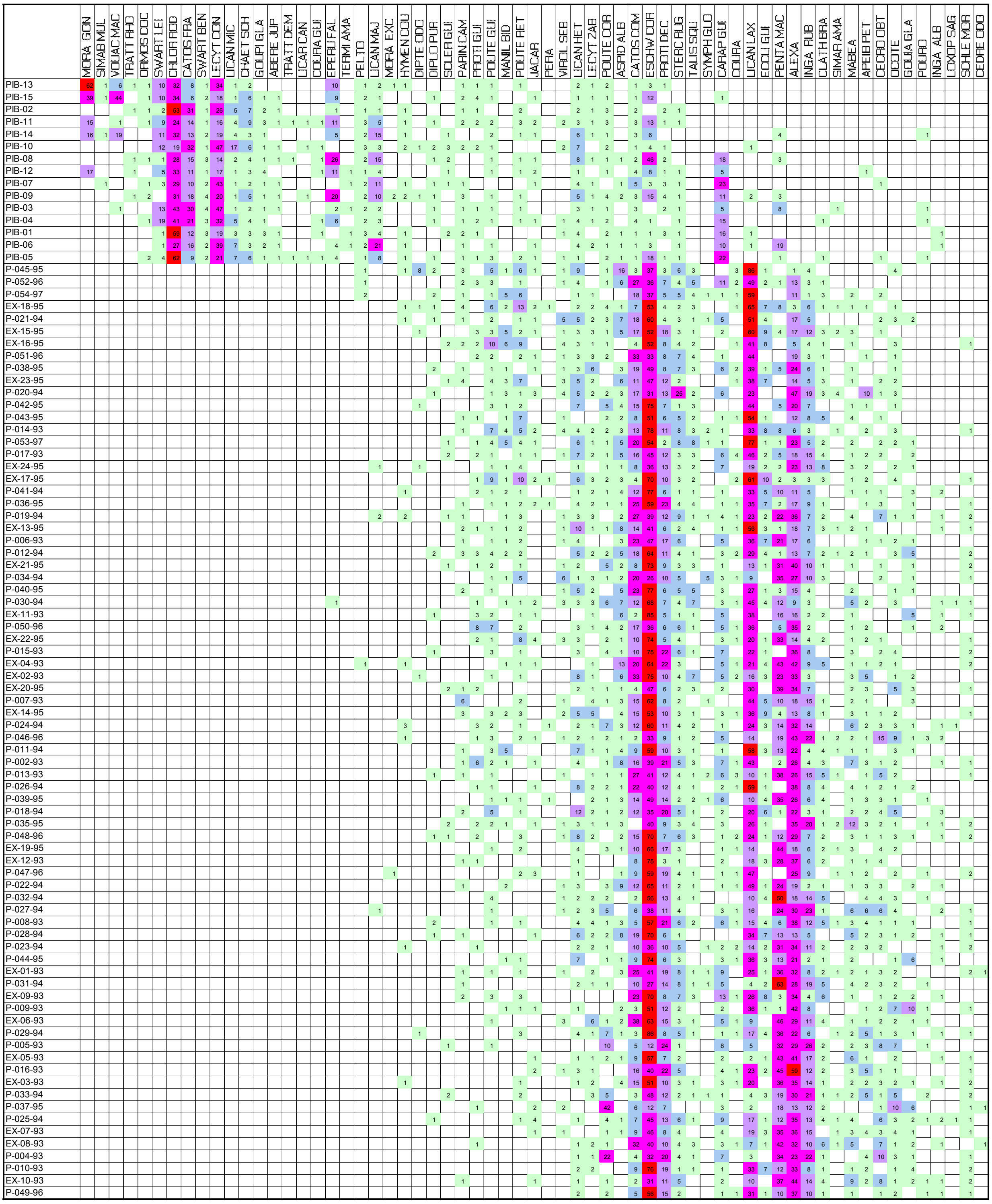
Diameter increment

Individual tree diameter increments were calculated between each re-measurement for analysis purposes. As can usually be expected, there were numerous doubtful measurements, associated with codes for buttressing, changed points of measurement, stem damage, and so on. The data was therefore filtered before summarisation to exclude all negative increments and all increments of more than 5 cm per year, in addition to those specifically noted as unreliable by an appropriate coded note. Only trees over 20 cm dbh were included in this study. Time did not permit the rectification of species codes and other measurement parameters for the small tree sub-samples recorded by both BCL and Tropenbos.

Several facets of increment were examined. It is usually found that diameter increment varies significantly with diameter with a maximum in mid-size ranges, and lower growth rates for smaller or larger trees. To study this, a program was written that grouped increments by species and 10 cm classes, with both mean increment and increment standard error calculated for each class. Generally it seemed that there was no strong relationships with size class for the majority of common species. This is illustrated for four common species in Figure 3 below. The error bars shown are the standard errors of the class mean increments. Those for Greenheart are hardly visible due to the large numbers of trees in the data, resulting in a very small standard error for the mean.

Figure 2 Association analysis of PSPs and species by reciprocal averaging

Rows are plots, columns are species. Numbers show tree frequency/ha above 20 cm dbh, with colours identifying abundance classes.



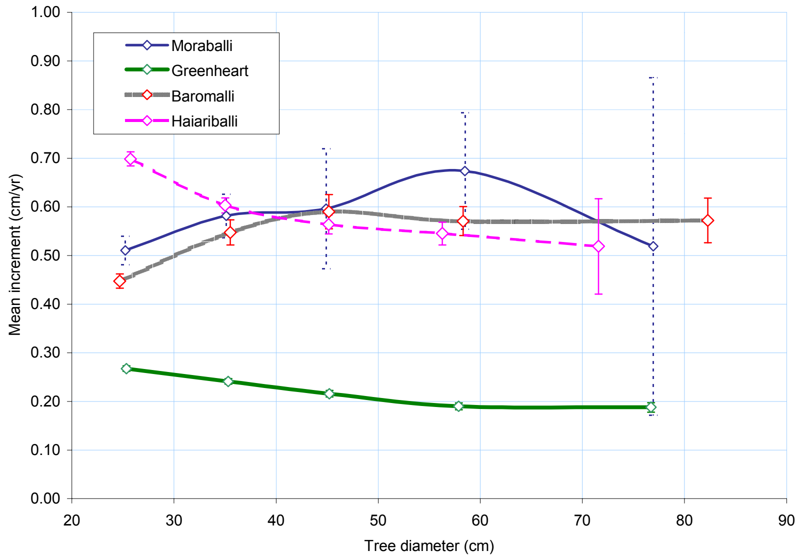


Figure 3 Trend of diameter increment with tree diameter for four common species

It was concluded that although there are weak effects of diameter class on increment above 20 cm, they are not strong enough for common species to require the use of increment-size regressions in stand projections, and a simple mean increment would probably suffice.

Another aspect examined was the autocorrelation between successive increment measurements. This is an indicator of a persistent dominance effect: faster growing trees remain faster growing, and vice versa. It was found that autocorrelations were mostly significant but weak. Important and common commercial species such as Baromalli and Greenheart had R^2 between successive measurements of less than 10%.

The importance of local competitive effects on increment were studied by correlating it with quadrat basal area. This was negligible, with no species having an R^2 above 30%, and most below 10%. However, for all common trees, the sign of this relation was negative, as would be expected, indicating that higher local basal areas were associated with lower growth.

It should be appreciated that the effects of dominance, competition, and age on diameter increment are evidently real. However, in the natural tropical forest it is very difficult to disentangle their covariance, and all trees are growing, during the most critical phases of their life, under intense competitive pressure. This period generally occurs before the tree attains 20 cm dbh, and hence when reviewing data above this size limit, the results are likely to be ambiguous, as found here. In addition, the short term nature of the plots (2-6 years) increases the variance of the diameter increment estimates, and tends to obscure relationships which might be clearer with longer-term measurements.

In conclusion, it was decided the simple mean increment was sufficiently descriptive of tree growth above 20 cm dbh, and little purpose would be served, even had time permitted, by adopting a more complex functional form.

Mortality

Mortality was calculated for each species as the number of trees which die as a percentage of the total number of tree observations. As many of the plots have been disturbed through logging and silvicultural treatment, average mortality can be expected to be high. However , by separating out the mortality rates for all trees scored at any time in their measurement history as having any degree of damage or defect, other than simple poor form, it is possible to have useful figures for baseline mortality on sound trees (non-defective, undamaged), together with rates that may be applied to defective trees.

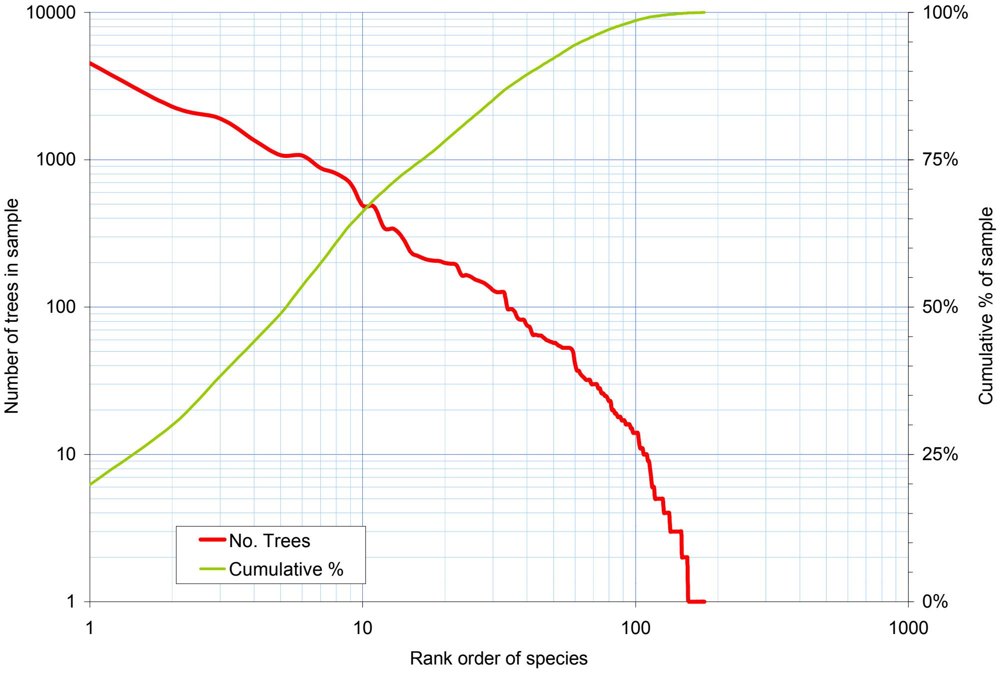
For mortality, apart from distinguishing defective and sound trees, no analysis was made relative to size class or competitive status. These are undoubtedly real effects, but are difficult to detect at the individual species level except for a handful of very common species.

The results of the mortality and increment summaries for all the species on the PSPs are shown in Appendix A. Those which are currently considered commercial by the GFC are marked in the list, but all species are shown for reference purposes, even if they comprise only a single individual.

Species grouping

On the PSPs there are 178 taxa recognised, comprising individual species or narrow groups of two or three species within genera, as listed in Appendix A. As typically occurs in moist tropical forest, many of these species are uncommon, and few are sampled sufficiently well for direct estimation of mortality rates. Of the 178 species, 20 are represented by only a single individual, and 66 by fewer than ten. Only 35 species are represented by more than 100 individuals, which probably represents a minimum sample for reliable mortality estimation. The total sample size is 22,189 trees, of which over half comprise six genera: *Eschweilera, Licania, Al-*

Figure 4 Species sampling characteristics



exa, Pentaclethra, Catostemma and *Chlorocardium* (listed in descending order of frequency). Some 66 species comprise 95% of all trees, and these each include 35 or more individuals. Figure 4 shows these characteristics.

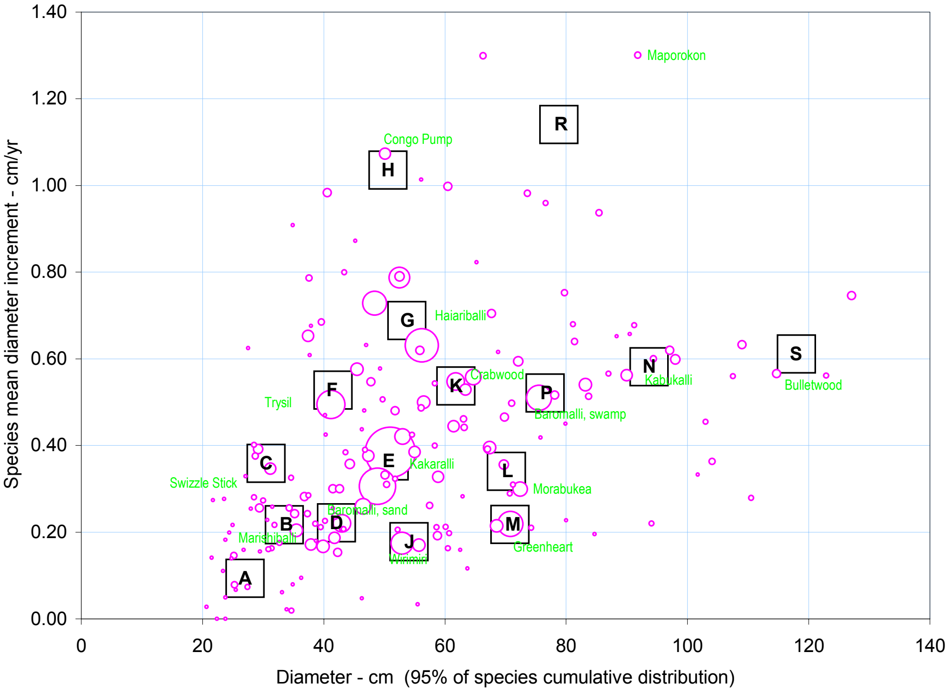
A complete growth model requires that all species be represented, in order to evaluate competitive and successional processes in forest dynamics. This requires some strategy for grouping species in order to provide parameters for the rarer species. In addition, even simple stand projection of commercial species is practically impossible if species are not grouped, as many commercial species of importance are weakly represented in the data. For example, Purpleheart (*Peltogyne*) is represented by only 55 trees, and Locust (*Hymenaea*) by 17.

The method of grouping that I have adopted is described in Alder *et al* (2000), with a comparison of applications in Costa Rica, Brazil and Papua New Guinea. It involves a simple ordination of species mean increment against typical mature size. The latter is estimated as the 95% point on the cumulative diameter distribution, and is shown as Dmax in Appendix A. The ordination data is that shown in Appendix A. Sixteen groups were defined, indicated by the letters A-S (without the use of I or O). These were located initially by a manual process on the graph shown on Figure 5 (using the mouse to drag the group centroid to a suitable starting point). The grouping algorithm then assigns species which are nearest to the centroid to that group, and recalculates the centroid to a new value which represents the group mean, weighted by tree numbers in each species. This process iterates until it stabilises.

There are a number of alternative grouping methods that could be applied. Alder & Silva (2000) describes a k-means ordination in 5 dimensions representing increment, mortality, commercial/non commercial status, and quantiles of the size distribution. Vanclay (1991) describes grouping of diameter increment regressions based on an F-test. The semi-manual process described above offers more control, and is robust with

Figure 5 Growth model groups

The grey squares show the group centroids. Circles are species, whose area is proportional to sample size. Green labels indicate typical common species for each group.



weak data. Purely statistical methods only give reasonably balanced groups when many groups are permitted (the Alder & Silva cited above study had 56 groups). If there are few groups, most species tend to be lumped into a central group, and small atypical outlying groups tend to be formed based on one or two species. In addition, methods based on significance tests work poorly with sparsely represented species.

Figure 5 and Table 4 show the results of this approach, whilst Appendix A gives the growth model assigned to each species. In the figure, the group centroids are shown as squares, with their corresponding letter, and the species by circles. Circle area is proportional to the number of sample trees. The names of the most common species of each group are shown in green near their representative point.

The groups can be interpreted, from a forest management and silvicultural viewpoint, in a way similar to that discussed in Alder *et al.* (2000). The groups J, E, K, P, N and S form a series of moderate to large trees which are neither extreme light demanders or shade bearers, and whose mature size has an approximate relationship to the mean species growth rate. As in other areas studied (*op. cit.*) the majority of the forest stock falls into these categories.

The groups C, F, G, H and R are more light demanding and faster growing species. The C group tends to include small pioneers, some of which may be able to perists after canopy closure with attaining any large size. The F and G group are moderate pioneers, and the H group the typical extreme pioneers of road sides and large log landings – *Cecropia* (Congo Pump) and the like. The R group is weakly represented here, but consists of trees that are both large and fast growing, and may become canopy emergents. They are probably gap opportunist light demanders, rather than colonists of more open areas. In most other zones studied, the slow-growing, large trees, probably shade tolerant are not a well-represented group. However in Guyana, Greenheart falls typically into this area, and characterises the M group.

Table 4 overleaf gives the mean parameters of each species group, and also shows the three most common species in each group. For the individual species, the number of trees, mean increment, and cumulative contribution of the species to the group are shown.

Some commercial species of moderate importance, for example Locust (*Hymenaea*) do not appear in this listing as they are too weakly represented. Appendix A gives statistics for all species included on the PSPs, together with their group attribution and commercial status according to current usage.

Species identifications are sometimes given showing two names. For example Kauta (*Licania guianensis & laxiflora*) in group E and Buruburuli (*Licania heteromorpha & divaricata*) in group D. This indicates that these are distinct and recognised species, but there is a divergence of scientific nomenclature between the Barama and Tropenbos PSPs under the same local name. Where no species name is given, then identifications from the various lists and possible local names are not clear.

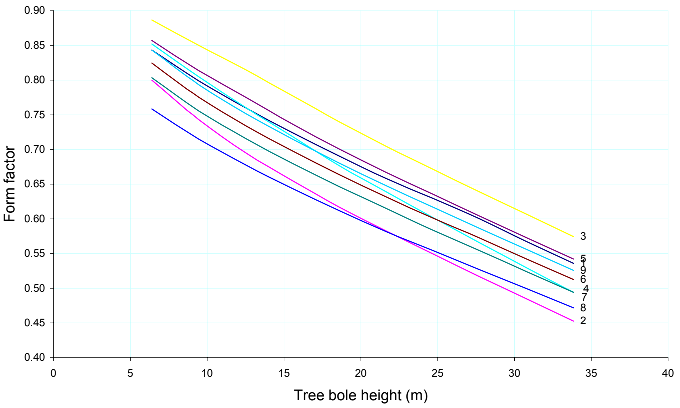
Table 4 Most common species, increment and mortality for species groups

Mg	Parameters of typical species in group					Trees	Dinc.	Annual mortality		Dmax
	Common name	*Botanical name*	*Nt*	*Cum%*	*Dinc*	*N*	*cm/yr*	*Sound*	*Defective*	*P.95*
A	Waiaballi	*Tapura guianensis*	26	22%	0.146	118	0.134	1.48%	11.29%	32.9
	Hiwaradan	*Chaunochiton kappleri*	25	43%	0.078					
	Lu	*Oenocarpus bacaba*	10	52%	0.019					
B	Marishiballi	*Licania canescens & micrantha*	205	28%	0.204	726	0.252	1.80%	5.91%	37.9
	Arara, smooth skin	*Guatteria*	75	39%	0.255					
	Aiomorakushi	*Pouteria cladantha*	35	43%	0.256					
C	Swizzle Stick	*Mabea*	165	58%	0.347	285	0.359	3.39%	5.94%	29.6
	Awasokule	*Tovomita*	82	87%	0.391					
	Haiawa	*Protium guianense*	24	95%	0.375					
D	Baromalli, sand	*Catostemma fragrans*	480	34%	0.220	1408	0.222	1.75%	8.60%	43.9
	Buruburuli	*Licania heteromorpha & divaricata*	340	58%	0.259					
	Kautaballi	*Licania alba & majuscula*	207	73%	0.167					
E	Kakaralli	*Eschweilera spp.*	4527	61%	0.384	7431	0.360	0.87%	3.02%	50.3
	Kauta	*Licania guianensis & laxiflora*	2299	92%	0.306					
	Kokoritiballi	*Pouteria reticulata*	165	94%	0.445					
F	Trysil	*Pentaclethra odorata & macroloba*	1352	75%	0.495	1798	0.518	2.04%	3.95%	42.3
	Kereti Silverballi	*Ocotea puberula*	197	86%	0.576					
	Aromata	*Clathotropis*	153	95%	0.653					
G	Haiariballi	*Alexa*	1906	52%	0.631	3660	0.686	2.25%	5.18%	54.3
	Kurokai	*Protium decandrum*	880	76%	0.728					
	Waiki	*Inga rubiginosa*	691	95%	0.787					
H	Congo Pump	*Cecropia angulata & obtusa*	160	42%	1.073	383	0.983	3.22%	3.65%	55.0
	Corkwood	*Pterocarpus officinalis*	65	59%	0.998					
	Hicha	*Byrsonima spicata*	54	73%	0.983					
J	Wirimiri	*Lecythis confertiflora*	807	64%	0.174	1258	0.198	1.57%	7.13%	54.2
	Wamara	*Swartzia leiocalycina*	194	80%	0.170					
	Itikiboroballi	*Swartzia benthamiana*	53	84%	0.192					
K	Crabwood	*Carapa guianensis*	490	33%	0.548	1464	0.524	1.87%	4.86%	63.5
	Maho	*Sterculia pruriens & rugosa*	343	57%	0.558					
	Moraballi	*Pouteria minutiflora & coriacea*	235	73%	0.499					
L	Morabukea	*Mora gongrijpii*	295	46%	0.299	643	0.340	0.72%	5.62%	69.7
	Bartaballi	*Ecclinusa guianensis*	199	77%	0.395					
	Yaruru	*Aspidosperma exselsum*	82	90%	0.356					
M	Greenheart	*Chlorocardium rodiei*	1070	81%	0.218	1314	0.218	0.82%	2.65%	71.1
	Soft Wallaba	*Eperua falcata*	211	97%	0.215					
	Manyokinaballi	*Geissospermum sericeum*	18	99%	0.210					
N	Kabukalli	*Goupia glabra*	125	33%	0.562	377	0.561	1.97%	2.57%	93.4
	Burada	*Parinari campestris*	84	55%	0.598					
	Soapwood	*Pithecelobium jupunba*	53	69%	0.620					
P	Swamp Baromalli	*Catostemma commune*	1072	64%	0.510	1685	0.527	0.91%	3.37%	78.1
	Shibadan	*Aspidosperma cruentum & album*	221	77%	0.540					
	Suradan	*Hyeronima laxiflora*	93	82%	0.594					
R	Maporokon	*Inga alba*	34	25%	1.301	136	1.145	3.36%	1.54%	79.5
	Kaditiri	*Sclerolobium guianense*	32	49%	1.299					
	Simarupa	*Simarouba amara*	26	68%	0.937					
S	Bulletwood	*Manilkara bidentata*	64	32%	0.566	202	0.623	2.97%	4.32%	109.8
	Purpleheart	*Peltogyne*	55	59%	0.632					
	Parakusan	*Swartzia jenmanii*	52	85%	0.746					

Volume equations for growth model groups

Under the FAO FIDS project prior to 1971, a series of volume tables were developed based on tabulation of form factors against bole height. Nine different *taper series* were tabulated, and applied to nine species groups. Figure 6 shows the appearance of these taper series as functions of form factor on height. These were embodied only in tabular format, to calculate stem volume in ft^3 from tree dbh in inches and bole height in feet. As they required both diameter and height measurement, they are not suitable for modelling work as they stand, as only diameter information is available, not height.

Figure 6 FAO 1971 volume taper series



The CIDA project in the early 1990's felled and measured a substantial sample of trees for volume and decay studies. This data was still available in digital format, both as an undocumented data file, and as a readable text file. In order to examine possible volume equations for use in a stand model, I wrote a Visual Basic routine to re-calculate the tree volumes from this raw data.

It was found in processing this text data that there were several oddities which an investigator needs to be aware of. The software being used by CIDA apparently did not permit dbh's over 99 cm, so there are sometimes discrepancies between butt logs of say 108 cm, and a dbh of for example, 11 cm. Where this error was encountered, the butt log diameter was substituted in the file for the erroneous dbh. There were also some discrepancies between some calculated section volumes and the log diameter and length data. This could be corrected by re-calculating section volume.

Table 5 Mean form height for species groups

FH gross *indicates form height for overbark volume including defect.* FH net *is form height underbark net of defect.* Nt *is the number of volume trees sampled.*

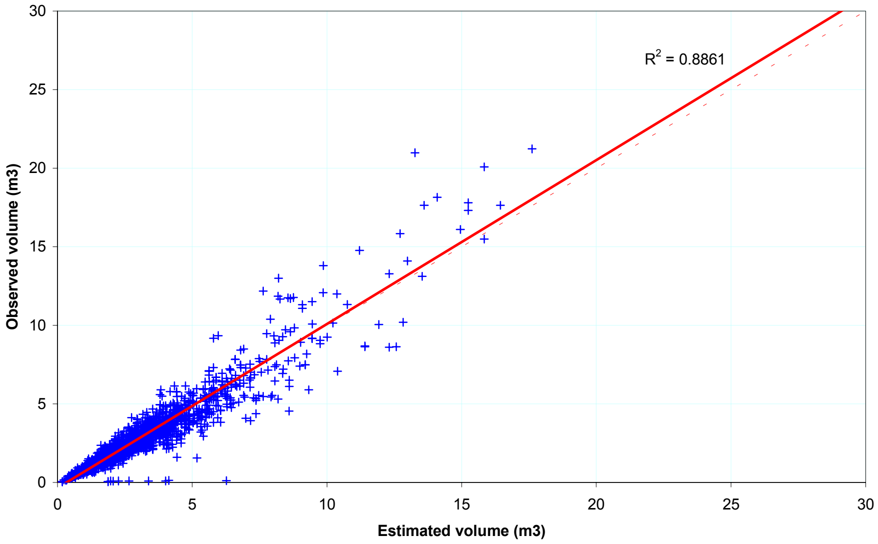
Group	Nt	FH gross	FH net
A	46	13.0	11.2
B	110	13.9	12.5
C	23	11.6	10.6
D	69	14.3	12.6
E	472	13.5	12.1
F	70	13.5	11.9
G	132	13.9	12.6
H	13	11.8	10.6
J	179	14.9	13.6
K	106	14.6	13.0
L	83	14.7	13.6
M	295	14.2	13.0
N	87	13.8	12.5
P	167	16.7	13.8
R	46	14.5	13.2
S	37	17.9	16.4
All	**1935**	**14.3**	**12.8**

In the end, the CIDA felled volume data included 1936 sample trees from 136 species. Baromalli was represented by 99 trees, and Greenheart by 219. The volume data was summarised using the growth model groups discussed in the preceding section. For each group, the average form height, or ratio of tree volume to basal area, was calculated for both gross and net volume. The results are as shown in Table 6.

The statistical quality of this method of volume estimation can be tested by plotting observed volumes for each tree against estimated volumes derived from the mean form height for the appropriate growth model group. The R^2 of such a regression is equivalent to the R^2 of a normal regression between two variables, and represents the percentage of variation in the observations that are accounted for by the model. The deviation of the regression of observed values on estimated values from an intercept of zero and slope of one indicates the bias or lack of fit of the model. This is discussed at greater length in Alder (1998).

Figure 7 shows this quality test. There is very little bias, with the *observed/ estimated* regression deviating only slightly from the ideal indicated by the dotted line. The R^2 equivalent of the model is 89%. Using average form height (12.8 m for net volume) alone gives an R^2 of 88%, but tends to underestimate net volume, as it is not responsive to diameter: form height covariance effects implicit in the fuller model.

Figure 7 Correlation of measured and estimated net volumes for predictions from form heights by growth model groups



Background

The silvicultural survey is a post-harvest survey devised by the project in order to evaluate the effects of current forest management practices, and perhaps to act as a basis for a monitoring system in future (Bird, 2000a). An important component of the present consultancy was the development of software to process the silvicultural survey data, and to provide stand projections from it. This section describes the facilities and use of this software.

General description

The silvicultural survey software is in the form of two kinds of Excel file. The first is a package of macros, or Visual Basic procedures, called *Silvicultural Survey Macros* (SSM). The SSM file contains all the processing procedures used. The second type of file is the user's data file (SSD). This has a fixed structure, comprising the sheets described in the table below. The SSD is originally set up from a file called Silvicultural Survey Data Template, or simply by deleting the data from an existing data file and saving it under a new name.

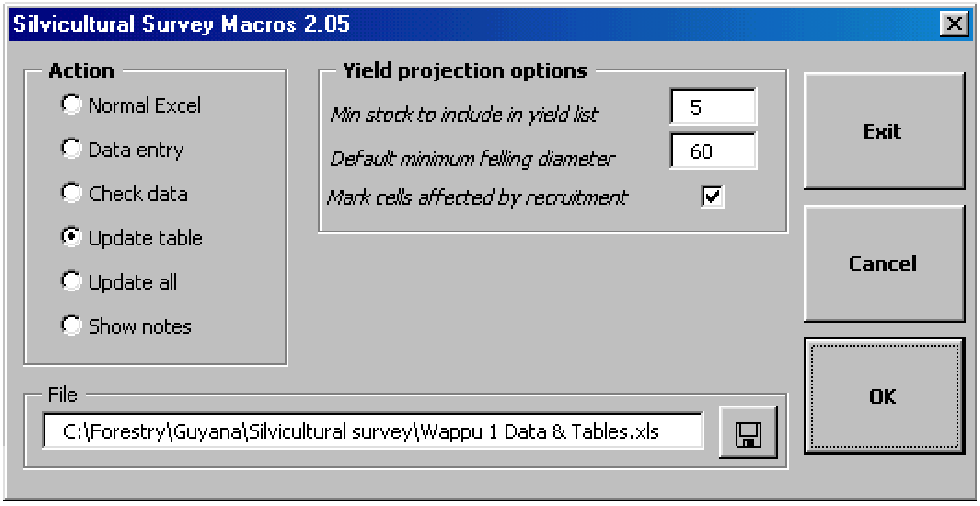
The SSD contains some few macros related only to the speeding up of data entry. For practical reasons related to the way Visual Basic and Excel operate, these could not be separated from the data file and placed in the SSM. However, all the more important and variable programming code is contained within the SSM. This is designed to facilitate maintenance and upgrading. It is only necessary to replace the early SSM file with a newer version, without needing to alter the data files in any way, when an upgrade is introduced.

Sheet name	Description of contents
Notes	Two columns, containing a coded note in the first, and descriptive text in the second. These are used to describe the reason why a tree may have been left at stump after felling.
Data	This contains the survey data and is described more fully in the text. Attached to the sheet are macros which facilitate data entry.
SpList	This gives the species list, including columns for commercial status, common and botanical name, growth model, and minimum diameter for felling.
Growth	This contains a table with the growth model letters and applicable increment and mortality rates, based on the values shown on page 15.
Table1	A table generated automatically by the SSM showing tree stumps by species and diameter classes.
Table2	A table generated automatically by the SSM showing stump counts classified by species and trees left or taken. Notes are attached summarising reasons for trees left.
Table3	A table generated automatically by the SSM showing tree numbers classified by species and damage classes.
RegYield	A worksheet that is used for optimising felling prescriptions for future cycles for sustainable yield. The worksheet is updated by the SSM using diameter limits, felling cycles, and harvesting levels entered by the user.
Table4	A table generated automatically by the SSM showing future stand tables (species by size classes), for two felling cyles, which are based on cutting prescriptions in the RegYield sheet. This table shows only species previously felled.
Table5	As for Table 4, but showing commercial species not previously felled.
Table6	A table generated automatically by the SSM showing a stand table of all trees and all species.
Fig1	A figure generated by the SSM which shows the spatial distribution by 1 ha units of felled stumps, with a user-definable key.
Fig2	A figure generated by the SSM which shows the spatial distribution by 1 ha units of residual trees, with a user-definable key.

The layout of the various tables and figures corresponds exactly to those given in the first silvicultural survey report (Bird, 2000b), with the exception of the RegYield sheet, which was introduced to allow the various possible felling options and controls to be manipulated more easily. The SSM simply automates the generation of these tables, and thereby saves a great deal of time.

Running the silvicultural survey macros

The SSM is run by first opening the file *Silvicultural Survey Macros*. This attaches a small button ◇ to the Excel tool bar which always invokes the SSM dialog box when pressed. The dialog box is also invoked by the F10 key. The dialog box appears as below:



Silvicultural Survey Macros 2.05

Action

○ Normal Excel
○ Data entry
○ Check data
● Update table
○ Update all
○ Show notes

Yield projection options

Min stock to include in yield list: 5
Default minimum felling diameter: 60
Mark cells affected by recruitment: ☑

File: C:\Forestry\Guyana\Silvicultural survey\Wappu 1 Data & Tables.xls

Clicking the OK button executes the option selected in the Action panel. All operations are performed on the indicated file, which is opened in Excel if this has not already been done. The adjacent 💾 button brings up the standard Windows Open File dialog to allow the directory tree to be navigated and a file name selected via the mouse.

The Cancel button closes the dialog box without action. The Exit button closes and saves the data and SSM file. The ◇ will remain visible on the menu bar until Excel is closed, and if clicked, will re-invoke the SSM dialog and re-open the data file.

The Action options include:

- *Normal Excel*: This is essentially a do-nothing option. The data file will be opened, if it is not already, but no other changes or options will be invoked.

- *Data entry:* This activates the Data sheet, and places the system in data entry mode, as described below.

- *Check data*: The data checking macro is run. Any data that appears inconsistent or outside permitted limits is highlighted in yellow, and a note appended to the cell giving details of the query.

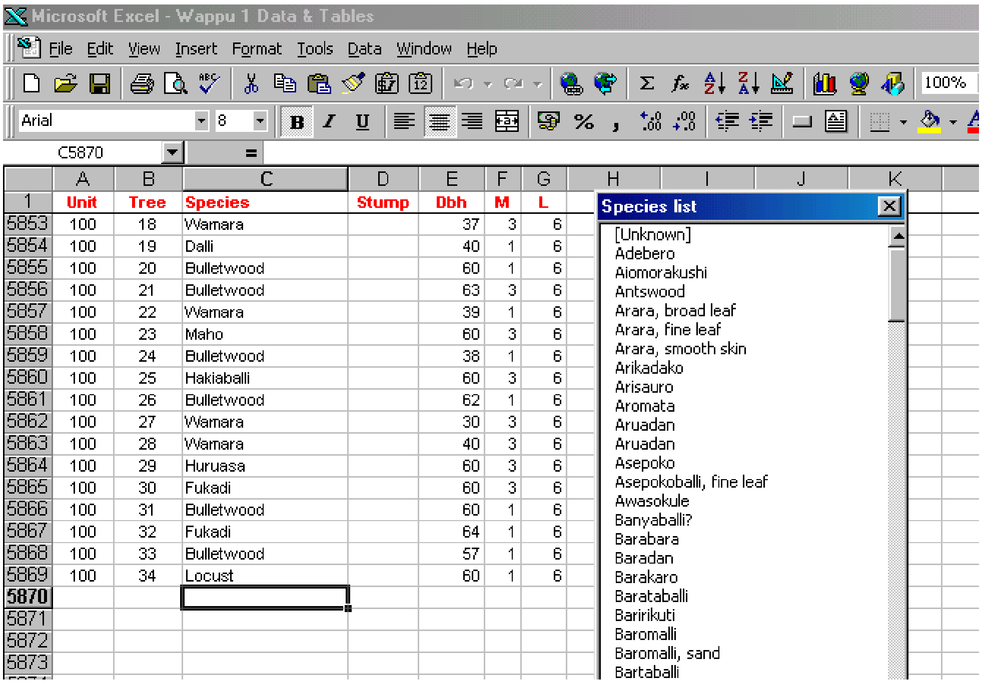
- *Update table:* The currently active sheet, if it is one of Table1-Table6, Fig1-Fig2 or RegYield, will be updated for the current data and options settings. For the Growth, Data, SpList or Notes sheets, no action is taken except for the appearance of a message "T*here is no update function for this sheet*". The F8 key pressed at any time has the same effect as this option, updating the current table.

- *Update all:* This updates all the tables and figures for the current data and settings in a single operation.

- *Show notes*: Documentation notes on the various worksheets are displayed.

Data entry mode

Data entry mode can be invoked either by selecting *Data entry* from the dialog screen, as discussed above, or by clicking on the top row of the Data sheet. This will change from blue to red, or vice versa. In data entry mode, several things are active, as shown in the diagram below:



1	Unit	Tree	Species	Stump	Dbh	M	L
5853	100	18	Wamara		37	3	6
5854	100	19	Dalli		40	1	6
5855	100	20	Bulletwood		60	1	6
5856	100	21	Bulletwood		63	3	6
5857	100	22	Wamara		39	1	6
5858	100	23	Maho		60	3	6
5859	100	24	Bulletwood		38	1	6
5860	100	25	Hakiaballi		60	3	6
5861	100	26	Bulletwood		62	1	6
5862	100	27	Wamara		30	3	6
5863	100	28	Wamara		40	3	6
5864	100	29	Huruasa		60	3	6
5865	100	30	Fukadi		60	3	6
5866	100	31	Bulletwood		60	1	6
5867	100	32	Fukadi		64	1	6
5868	100	33	Bulletwood		57	1	6
5869	100	34	Locust		60	1	6
5870							
5871							
5872							
5873							

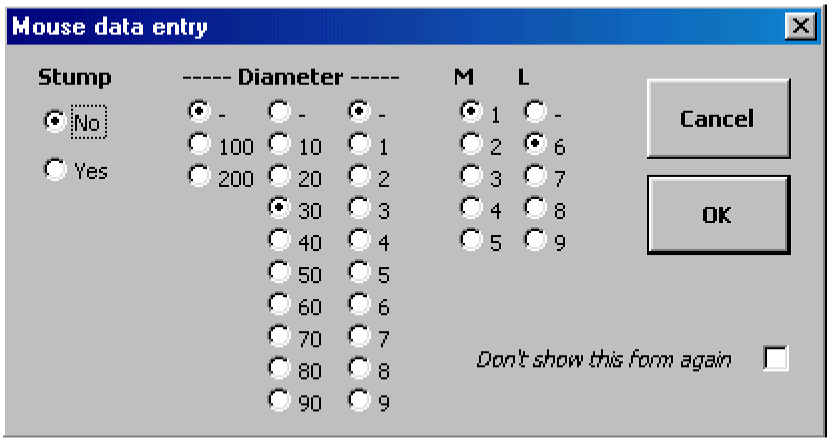
[Unknown]
Adebero
Aiomorakushi
Antswood
Arara, broad leaf
Arara, fine leaf
Arara, smooth skin
Arikadako
Arisauro
Aromata
Aruadan
Aruadan
Asepoko
Asepokoballi, fine leaf
Awasokule
Banyaballi?
Barabara
Baradan
Barakaro
Baratabalii
Baririkuti
Baromalli
Baromalli, sand
Bartaballi

Special actions when selecting a cell in data entry mode	
Top row	Changes from red to blue, turning off data entry mode. Selecting another cell in the top row will turn it red again, switching on data entry.
Column A	Copies down from the cell above
Column B	Copies down and increments the cell above
Column C	Invokes the species list (see figure above). Double clicking on a species will close the list, placing the selected name in column C, and moving the cursor to column E. A species can also be picked by starting to type its name, and then pressing Enter when the right choice in the list has been highlighted. Eg. Typing *so* will bring up Soft Wallaba.
Column D	Toggles between blank and a tick (indicating a stump).
Column E	Brings up the mouse data entry screen, as shown below, unless this is switched off.

Data entry can be made only using the mouse, without touching the keyboard. To allow this another screen called *Mouse data entry* will appear when a cell in column E is highlighted, which appears as shown below. On this screen, selecting the various option buttons and clicking OK will fill in columns D-H and reposition the cursor on column C, with the species list active, and the same species as last entered highlighted. Columns A and B are filled automatically.

Diameters are constructed by adding the various option buttons, with the blank being used where no value is needed.

Some operators may dislike this facility. It can be turned off by checking the *Don't show this form again* box.



With keyboard data entry, the right arrow key in column G will normally cause the cursor to move down a line, fill in columns A and B automatically, and activate the species list with the last entered name highlighted. Pressing enter will then skip over column D (stumps) into column E. The left arrow key in column E will toggle the Stump cell. When the stump cell is checked, but not otherwise, the right arrow will move from columns G to H to allow a coded note to be entered.

This sounds complex in explanation, but in practice is simple and fast, with a minimum of keystrokes, and follows the logic of the data.

If a new species is encountered during data entry, then data entry mode must be turned off and the species list sheet *SpList* selected. The new species common name should be entered, preferably with the additional information required – botanical name, commercial status, and growth model. For the latter, a default value of E should be used if no other information is available. The list should then be sorted on the common name using the Excel AZ↓ key.

The SSM data model

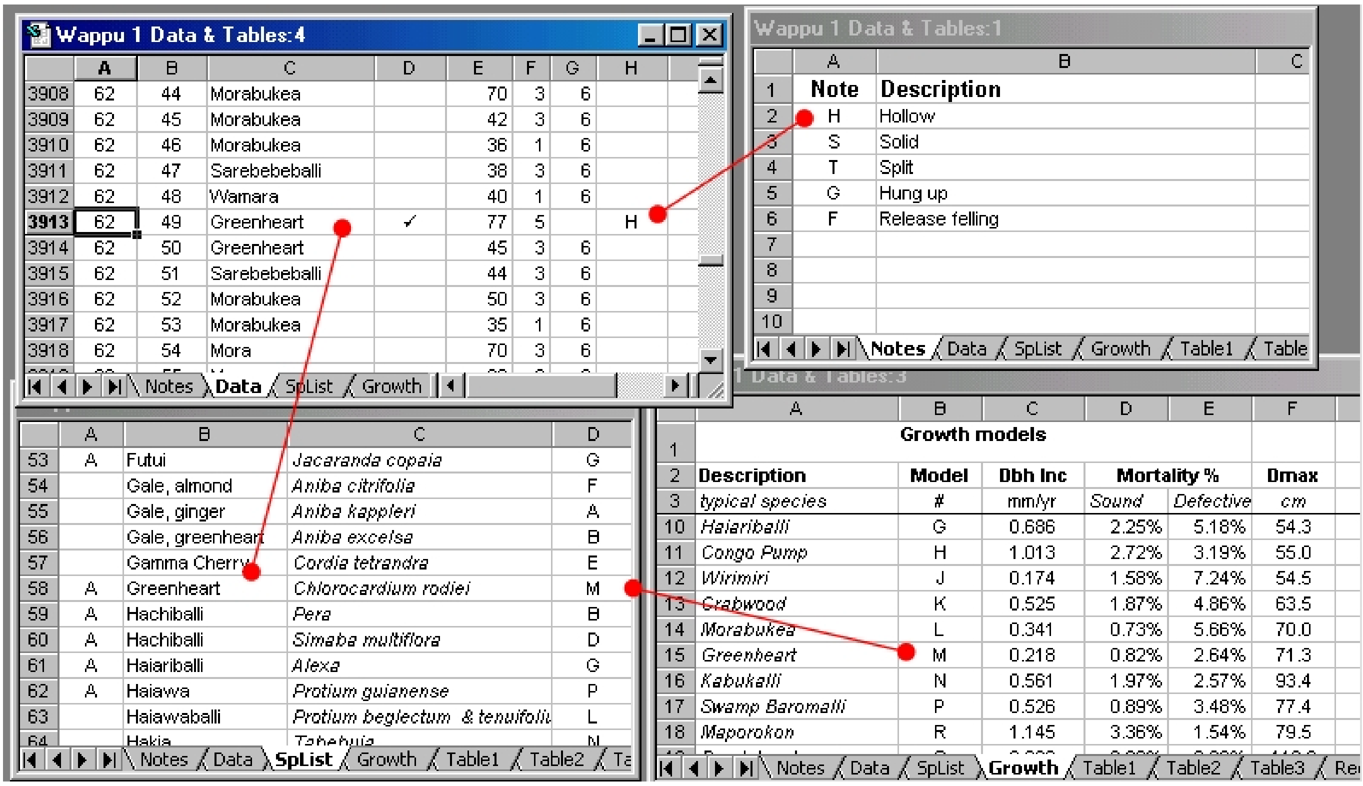
The programs in the SSM file work on relationships that exists among the fields of the sheets *Data, SpList, Growth* and *Notes*, as illustrated in Figure 8. Column C of the *Data* sheet must contain a species name that corresponds exactly with an entry in the list *SpList*. The species list entry must include a growth model code of a single letter, A-Z, in column D that corresponds to the entries in the *Growth* sheet. The parameters in the latter table, it may be noted, are taken from Table 4. However, user's could add their own models, using the unused letters I,O,Q, U-Z. Only the increment rate (column C), and mortality rate for sound trees (column D) are actually used by the SSM.

In column H of the data sheet there may be an optional code if the record is for a stump. This will be linked to the entries in the *Notes* sheet when producing output table 2, which summarises trees left at stump.

The *Data check* routine verifies these relational linkages, as well as other logical requirements in the data, and flags the relevant cell in yellow with a comment if a problem is found.

The table update routines have been designed to be as fault tolerant as possible, and generally will assume a species to be unknown if it cannot be linked between the *Data* and *SpList* sheets. The growth model used will likewise default to E if the linkage between a *SpList* entry and the *Growth* sheet cannot be made. Note codes are simply ignored if they do not match entries in the *Notes* sheet. Some of the more obvious

Figure 8 The relational data model within the Silvicultural Survey Macros



Wappu 1 Data & Tables:4

	A	B	C	D	E	F	G	H
3908	62	44	Morabukea		70	3	6	
3909	62	45	Morabukea		42	3	6	
3910	62	46	Morabukea		36	1	6	
3911	62	47	Sarebebeballi		38	3	6	
3912	62	48	Wamara		40	1	6	
3913	62	49	Greenheart	✓	77	5		H
3914	62	50	Greenheart		45	3	6	
3915	62	51	Sarebebeballi		44	3	6	
3916	62	52	Morabukea		50	3	6	
3917	62	53	Morabukea		35	1	6	
3918	62	54	Mora		70	3	6	

Wappu 1 Data & Tables:1

	A	B	C
1	**Note**	**Description**	
2	H	Hollow	
3	S	Solid	
4	T	Split	
5	G	Hung up	
6	F	Release felling	
7			
8			
9			
10			

	A	B	C	D
53	A	Futui	*Jacaranda copaia*	G
54		Gale, almond	*Aniba citrifolia*	F
55		Gale, ginger	*Aniba kappleri*	A
56		Gale, greenheart	*Aniba excelsa*	B
57		Gamma Cherry	*Cordia tetrandra*	E
58	A	Greenheart	*Chlorocardium rodiei*	M
59	A	Hachiballi	*Pera*	B
60	A	Hachiballi	*Simaba multiflora*	D
61	A	Haiariballi	*Alexa*	G
62	A	Haiawa	*Protium guianense*	P
63		Haiawaballi	*Protium beglectum & tenuifoliu*	L

1 Data & Tables:3

	A	B	C	D	E	F
1	**Growth models**					
2	**Description**	**Model**	**Dbh Inc**	**Mortality %**		**Dmax**
3	*typical species*	#	mm/yr	*Sound*	*Defective*	*cm*
10	*Haiariballi*	G	0.686	2.25%	5.18%	54.3
11	*Congo Pump*	H	1.013	2.72%	3.19%	55.0
12	*Wirimiri*	J	0.174	1.58%	7.24%	54.5
13	*Crabwood*	K	0.525	1.87%	4.86%	63.5
14	*Morabukea*	L	0.341	0.73%	5.66%	70.0
15	*Greenheart*	M	0.218	0.82%	2.64%	71.3
16	*Kabukalli*	N	0.561	1.97%	2.57%	93.4
17	*Swamp Baromalli*	P	0.526	0.89%	3.48%	77.4
18	*Maporokon*	R	1.145	3.36%	1.54%	79.5

and subtle reasons for mismatching entries are corrected by the programs – case differences, leading or trailing spaces in fields.

To start entering data for a new survey, it is recommended that the previous survey is saved under a new name, and then the entries in the *Data* sheet, except for the top row, are selected and deleted. It should not be necessary to modify the related sheets except for occasional new species names. The output tables should not be modified except via the Update action.

Species can be changed from commercial to non-commercial simply by altering the entry in column A of *SpList*. Only an A code is recognised, designating commercial species. Any other entry will be treated as a non-commercial species.

Stand projection and yield regulation

Three data sheets display projected yields over two felling cycles, using the diameter increment and mortality models in the *Growth* sheet.   These are *Table4*, *Table5* and *RegYield*. The latter is the key sheet that allows various options to be tested, such as the felling cycle, the diameter limits for various species, and the number of stems to be harvested at each cycle. Once the first and second cycle yields have been adjusted through these settings, then updating the *Table4* or *Table5* sheets will make use of the *RegYield* settings. These tables provide more detailed diameter-class information about the projected stands.

All the stand projections show and project only trees of commercial species which are defect free and scored as having good form, which are referred to as potential crop trees.   *Table3* shows the sound and defective components of total stocking by species, whilst *Table6* shows total stocking by diameter classes.

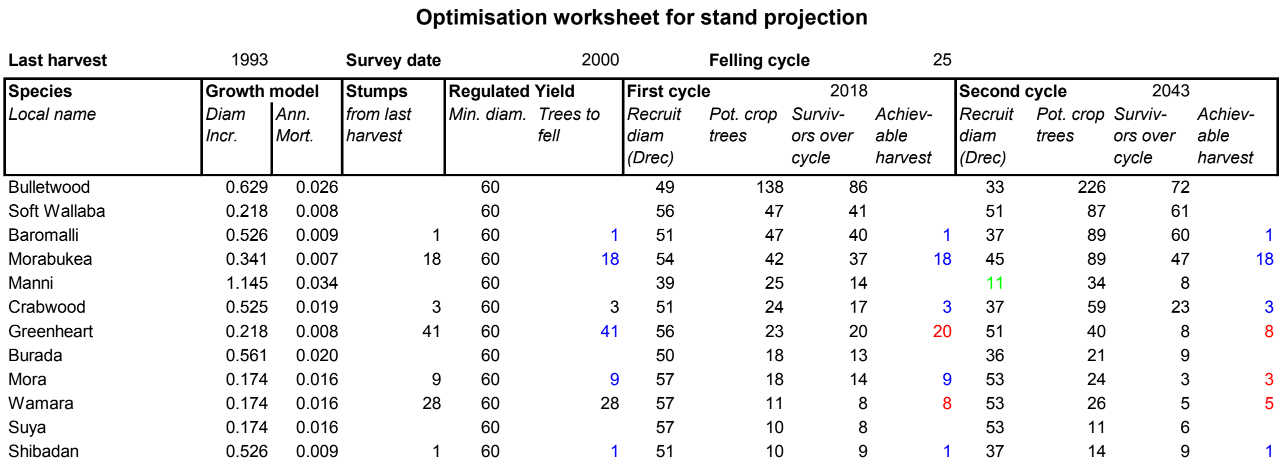
The SSM dialog form (see page 19) has three options that relate to stand projection:

- *Min. stock to include in yield list*. The *RegYield* panel will only shows species whose stock of potential crop trees is above the designated level. If set to zero, all commercial specie swill be shown. All stockings are relative to the total area of the survey which is normally a 1 km^2 block.

- *Default min. felling diameter*. The *RegYield* panel or the *SpList* both allow diameter limits to be set for species. However, where none is given, the default given in this box is used.

- *Mark cells affected by recruitment*. The stand projection method does not include recruitment, and therefore over long projection periods, cells to the left of Tables 4 and 5 become progressively underestimated. The affected cells are marked in grey if this option is checked.

Figure 9 Appearance of the RegYield table from the Silvicultural Survey Macros



Optimisation worksheet for stand projection

Last harvest 1993 **Survey date** 2000 **Felling cycle** 25

Species	**Growth model**		**Stumps**	**Regulated Yield**		**First cycle**		2018		**Second cycle**		2043	
Local name	*Diam Incr.*	*Ann. Mort.*	*from last harvest*	*Min. diam.*	*Trees to fell*	*Recruit diam (Drec)*	*Pot. crop trees*	*Surviv-ors over cycle*	*Achiev-able harvest*	*Recruit diam (Drec)*	*Pot. crop trees*	*Surviv-ors over cycle*	*Achiev-able harvest*
Bulletwood	0.629	0.026		60		49	138	86		33	226	72	
Soft Wallaba	0.218	0.008		60		56	47	41		51	87	61	
Baromalli	0.526	0.009	1	60	1	51	47	40	1	37	89	60	1
Morabukea	0.341	0.007	18	60	18	54	42	37	18	45	89	47	18
Manni	1.145	0.034		60		39	25	14		11	34	8	
Crabwood	0.525	0.019	3	60	3	51	24	17	3	37	59	23	3
Greenheart	0.218	0.008	41	60	41	56	23	20	20	51	40	8	8
Burada	0.561	0.020		60		50	18	13		36	21	9	
Mora	0.174	0.016	9	60	9	57	18	14	9	53	24	3	3
Wamara	0.174	0.016	28	60	28	57	11	8	8	53	26	5	5
Suya	0.174	0.016		60		57	10	8		53	11	6	
Shibadan	0.526	0.009	1	60	1	51	10	9	1	37	14	9	1

Figure 9 shows the appearance of the RegYield sheet. The user can amend the dates for the last harvest, the survey date and the felling cycle above the table, and also figures in the columns headed *Min. diam* and *Trees to fell*. The F8 key invokes the macros which update the projection.

The original harvest is shown in the column headed *Stumps from last harvest*. The program determines, from the minimum diameter limit, what size class can be potentially included over one or two felling cycles. These are shown in the columns headed *Recruit diam* for each cycle.

For example, the above table shows that Baromalli over 51 cm dbh could grow to the specified diameter of 60 cm over 18 years (the residue of the first 25 year cycle from the survey data) . For the second cycle, trees over 37 cm dbh could be included. This is based on the mean growth rate for model P of 0.526 cm yr^{-1}.

If the estimated recruit diameter is less than the survey diameter of 30 cm, then it is shown in green. This indicates that subsequent calculations of probable crop tree numbers will be underestimates, as a necessary part of the population has not been sampled, and there is no recruitment estimation in the projection process.

The defect-free trees of good form above the recruit diameter for each cycle are shown in the column headed *Pot. Crop trees*. These tree numbers relate to the total survey area, normally a square kilometer. The column headed *Survivors over cycle* gives the number of potential crop trees estimated to survive over the period from the survey date to the end of the cycle (in this case, 18 years for the first cycle, 43 years for the second). For the second cycle, the number of survivors is also reduced by the trees felled at the first cycle.

The *Achievable harvest* column shows figures in either blue or red. The blue figures are given where the number of surviving crop trees is greater than the designated yield given in the *Trees to fell* column. The red figures are given where the requested yield cannot be attained because insufficient trees remain, or where they are exactly equal.

The objective of this sheet is to enable felling numbers and diameter limits to be adjusted to ensure a sustainable harvest over two cycles. It provides a means of exploring, through the silvicultural survey, issues of felling cycle, diameter limit, and yield limits above the specified diameter limit.

When a given regime has been specified in this sheet, then updating sheets *Table4* and *Table5* automatically incorporates the specified limits and felling objectives. There are some differences in method. Tables 4 and 5 incorporate a more complicated projection model based on integer arithmetic, which can lead to small differences in the results between the tables.

The limitations of the method need to be appreciated and respected. It does not incorporate either recruitment or felling damage effects, and therefore is unsuitable for projections with either very long or very short felling cycles. The accuracy of this type of projection, emphasising tree numbers over a relatively high diameter limit for individual species, and based on average increment and mortality rates, needs to be validated against long-term plot measurements. However, it can be said that if sustainability cannot be demonstrated on this type of worksheet, then it is unlikely to be achieved in practise.

Stand projection as a growth model

The stand projection system built in to the Silvicultural Survey Macros is a basic growth model, and was designed to fulfil the immediate requirements of the project. It is quite simple, in that there are no density dependent or site dependent effects, no allowance for logging damage, and no recruitment. Some work has been done relative these latter issues, but due to the emphasis placed on the Silvicultural Survey, this remains work in progress.

The stand projection system can be applied to any type of incomplete stand data, including stock surveys. The steps applied to projecting a future diameter distribution are very simple. These involve:

- List the survey data in a spreadsheet with the local name, the equivalent growth model code, looked up from a species list, and the original diameter.
- Over the time intervals required, look up the increment from the growth model table, and add it to the original diameter, multiplied by the years elapsed.
- Summarise the projected diameters by the required size classes (eg 10 cm classes), and then adjust them for the expected survival over the required interval.

A worksheet called StandProj.xls has been prepared to exemplify these steps, using only worksheet functions. That is, it does not contain any Visual Basic macros. It includes the standard species group parameters from Table 4, and a species list. The only advanced Excel feature that it uses is the VLOOKUP function, which extracts values from a lookup table. Its usage is detailed in the Excel help system.

Validation of the stand projection concept

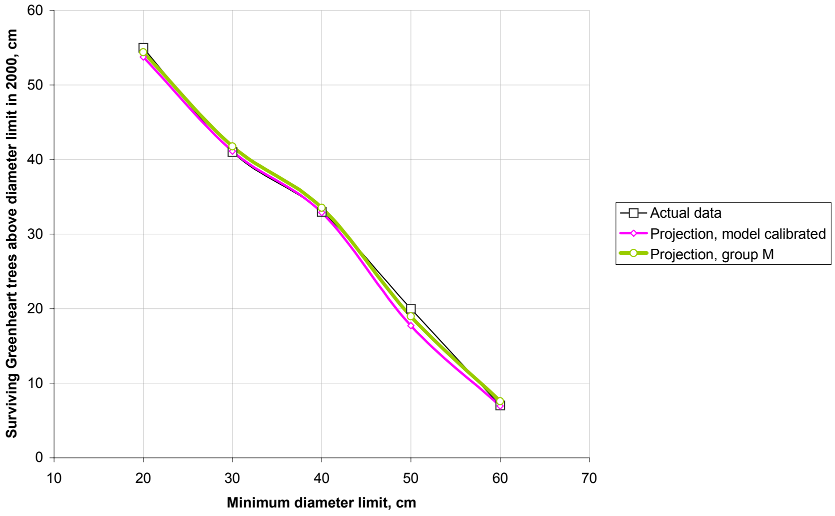
Stand projection is a simple and logical concept that has been widely used as the basis of yield regulation and management in tropical forestry since the time of Brandis in 1857 (Dawkins & Philip, 1999). Yet one sees very few examples of side-by-side comparisons of projected stands with actual stand growth which may serve to validate the method. This is due to the fact that growth data over periods of several decades that can be used in such comparisons is very difficult to find.

A sample plot in the Essequibo Nature Reserve established in 1964 has been partially re-measured under the present project, and the various data analysed in an Excel file (Bird, 2000c). This data provides 36 years measurements on Greenheart with good information on increment, and indicative levels or mortality. The plot needs to be more fully and carefully re-measured, as the data gathered so far is from an exploratory study that only attempted to locate and re-measure Greenheart.

This data has been used to test how well the stand projection concept works. Figure 10 compares three sets of data: The actual stock in 2000, projections made using increment and mortality figures estimated from the plot itself, and projections made using the growth model in Table 4 applicable to Greenheart. Each point on the figure represents the total number of trees above a given diameter limit.

It can be seen that the projections and actual data are practically identical. From the sample tree measurements themselves, mean increment for trees ranging down to 7.9 cm dbh was 0.186 cm yr^{-1}, compared with 0.218 cm yr^{-1} as the mean of group M (see Table 4) which only includes trees above 20 cm dbh. Missing trees on the plot were construed as mortality, although it may be that some of these trees could be re-

Figure 10 Actual and projected stem numbers of Greenheart over 36 years



located with a more detailed survey (Bird, *pers. comm.*). On this basis, observed mortality on the plot was an average of 1.36% yr^{-1}, whereas for the Group M model it is 0.82% yr^{-1}. Evidently, the slightly higher mortality and lower growth from the plot estimates, relative to the Group M figures, compensate each other so that the net predictions over 36 years are almost identical to the actual stocking.

However, this test is a powerful validation of the stand projection approach, and suggests that it may be used with confidence for yield planning. It also emphasises that even a single long-term PSP may have, and suggests that further resources allocated to recovering a re-demarcating and documenting this and other plots will be very well deployed.

Recruitment

As has been noted, time has not permitted the analysis of recruitment, and hence the completion of a more general model along the lines of SIRENA, that might allow projections over long periods. At present, with a species such as Baromalli growing at 0.5 cm yr^{-1}, potential tree stocks above 50 cm cannot be projected more than 80 years from inventory data assessed down to 10 cm, or for more than 40 years for silvicultural survey data, assessed down to 30 cm.

Recruit trees are flagged in the original data files by codes. They can also be detected as trees which occur in later plot measurements but not earlier ones. In some cases recruits may be 'false recruits' – larger trees that were missed when the plot was established, edge trees that have 'moved' into the plot, or trees that have changed number (giving a false death and false recruit). Careful screening is necessary to detect and manage these events.

Recruitment is associated with disturbance, and for PSPs which are six years old, as are many of the BCL plots and all the Tropenbos ones, it will be necessary to evaluate the data files for trees down to 5 cm dbh. It is also desirable to bring this data into the increment and mortality analysis. The processes involved in these steps, especially in reconciling species and inconsistent measurements, are time-consuming, probably involving a further two weeks work to achieve some usable summaries.

Stand density and site effects

Stand density and site effects on growth have been studied through a residual analysis based on the average growth rates and species groups in Table 4. The steps involved mirror those reported in Alder (1998) for the PNG plots, and show that a useful reduction in residual variance can be accounted for by a stand density factor based on the number of trees above 30 cm dbh on a plot. Site effects on the residuals are not obvious, as they are partially incorporated into species differences through sharp distinctions of forest types that occur in Guyana.

The possible utility of height, either plot mean height, height of indicator species, or site form (*vide* Vanclay, 1988) were all examined in relation to the residuals of plot mean growth from that predicted by the general model. Correlations, although significant and of the correct sign (increased growth rate with increased height), were too weak to be of practical value (R^2 less than 15% for the best case).

Like the work on recruitment, this aspect of the study is incomplete. In the PNG analysis, projections of plot basal area were compared with actual values, and the residuals progressively reduced by incorporating stand density and site effects. This strategy has also been partially followed for the present model, but there are large discrepancies in the basal area growth of some PSPs which need to be examined in detail at the level of individual trees in the raw data. They are due to oddities of measurement or data which need to be accounted for and rectified before this analysis can be completed.

Figure 11 Predicted and observed plot basal area increments

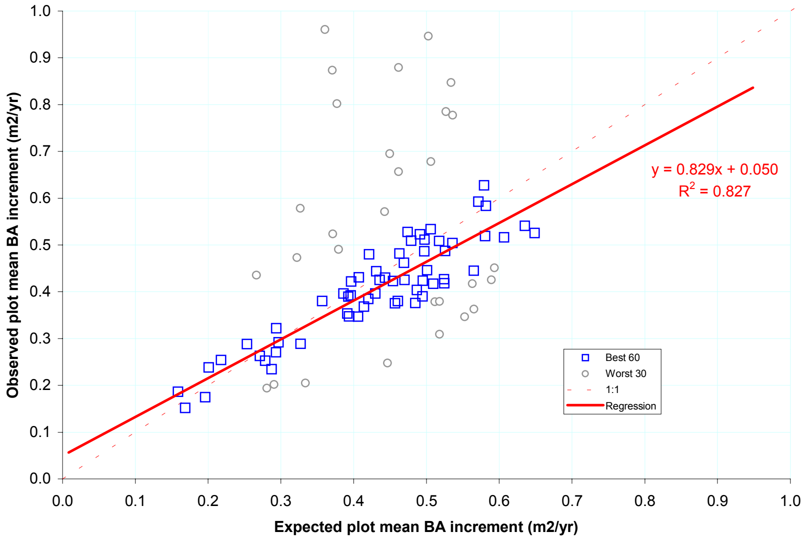


Figure 11 shows this, with the best sixty plots, in terms of their precision giving an R^2 of 83%. The discrepancies in some of the 'worst' plots are too large to be accounted for by inefficiencies in the model, and there is a need to review the data for each plot to assess the origin of the deviation.

Towards an integrated planning package : GEMFORM

An objective of this assignment was to produce a SIRENA-type model that could make long-term projections, including the various effects noted above. That has not been achieved, primarily due to that fact that much time was spent meeting the expressed need for a simpler type of stand projection model that could operate on the silvicultural survey data (SSD). SIRENA, or a similar model, could not work with the SSD because it is incomplete, in terms of both species and size classes.

However, much of the ground work for an integrated model has been done, including a programming framework that is able to read inventory files, and so on. This integrated model has been provisionally called GEMFORM (Guyana Empirical Model for Forest Management).

The model as envisaged will operate on stand tables of forest types, and should be understood primarily as a *concession planning model*. In order to be effective and useful to the GFC and wider forestry community in Guyana, it needs to be linked with the developing GIS and forest resource database within the GFC in specific ways. The diagram overleaf illustrates these linkages, which are described in more detail below. The ◎ refer to their equivalents on the diagram.

- The starting point for a planning or forest projection exercise are the GIS coverages for the area concerned ①. These include the forest type map, a km^2 graticule for management blocks, and the concession boundary. These are intersected in ArcView ② and a table generated of forest areas labelled by block and forest type code③. With experience, this process can be made more sophisticated, intersecting also stream buffer zones and slope constraints, for example, to further adjust forest areas.

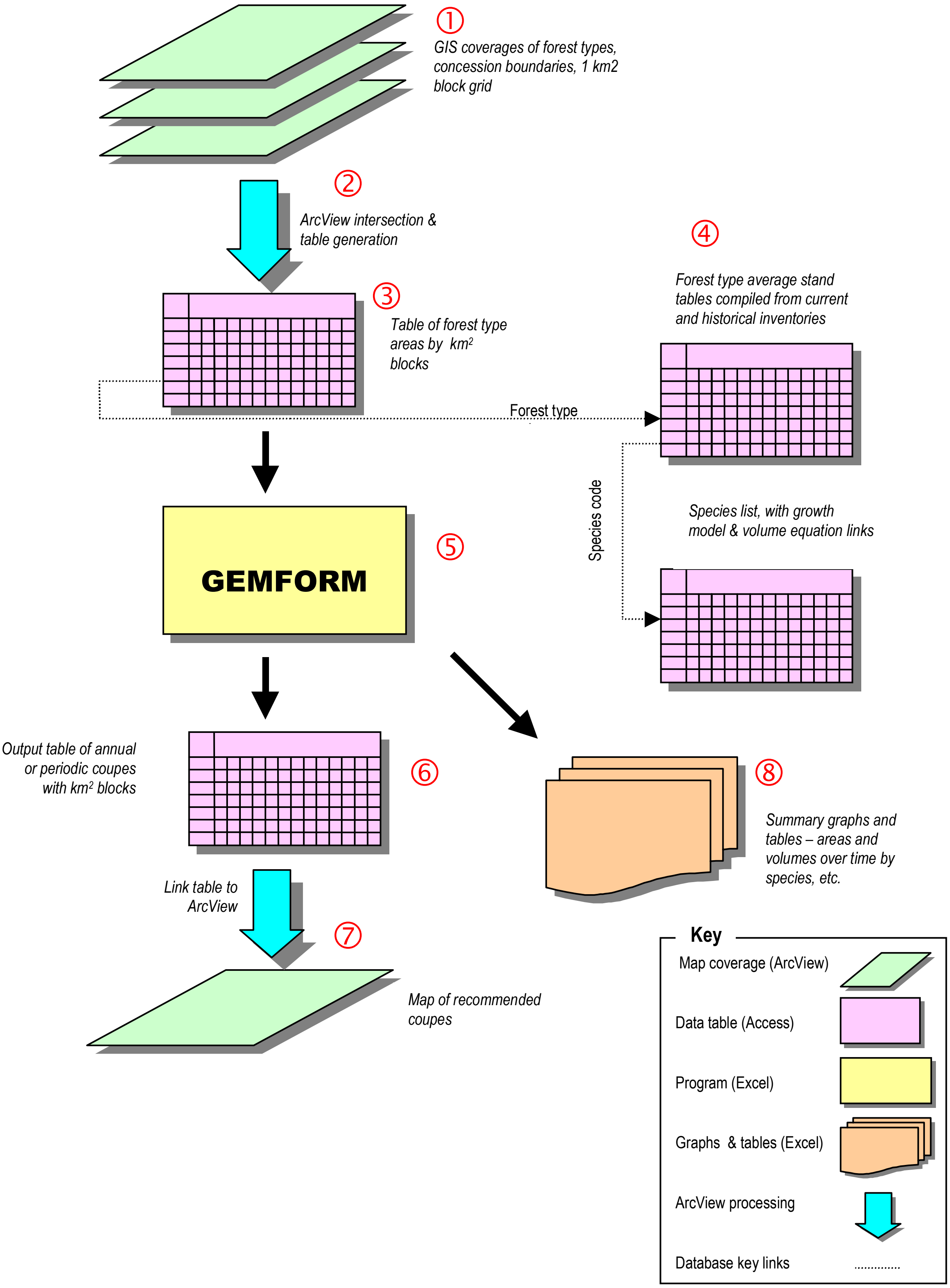
- From the existing archived datasets, and additional forest inventories as necessary, a table of typical stand tables for each forest type is developed ④. Linked to this by species code is the species list, which contains in turn references to tables of growth functions and volume equations (not shown).

- The ArcView generated table of forest areas by felling blocks and types is read by the forest model, GEMFORM ⑤. This also accepts some interactive options regarding management criteria (felling cycles, diameter limits, retention levels, etc.). The model will calculate yields by forest types and will group adjacent felling blocks into coupes of equal yield. It will produce a series of output graphs ⑥ summarising forest development over time for each forest type. It will also generate an output table giving coupe identities and dates to each of the felling blocks.

- Finally in ArcView ⑦, the output table from GEMFORM⑥ is converted into a coverage and printed as a map that provides the essential information for forest monitoring and certifcation – a map of coupes with operating dates. This will have been calculated by GEMFORM to provide equal volume yields over time within constraints of sustainability.

Although described in this way as a tool for concession planning for sustainable management , this system can also be applied to issues of valuation – essentially a similar task – and for strategic planning at the regional or national level. In the latter case, forest areas would not be intersected with a km^2 graticule, and the outputs ⑥ and ⑦ would not be produced. Instead only graphs of national production over time would be generated under constraints of sustainability.

Figure 12 Diagram of planning system incorporating GIS, inventory database and a forest model



Many of the elements of this system are in place. The GIS is already functioning, with the FAO forest type map and other coverages installed. The original data sets that can be compiled into the stand table database are available in digital format. Most of the work for the model has been completed.

It remains to be decided whether this type of system corresponds to objectives and outputs envisaged within the project logical framework, whether the resources exist to complete the system, and most importantly, whether this conception coincides with GFCs own vision of its function.

The modelling inputs required to complete and test GEMFORM given the various associated tables (ie ③ and ④) are limited – probably about 1 month of consulting time. However, there is much more work involved in organising data properly into stand tables, ensuring consistent usage of forest type codes and species codes, and perfecting the GIS techniques for intersecting these files. Most of these stages do not need external consultancy, but can be handled by existing personnel, possibly supported by some local consultancy. However, some specification and training work is required relative to the file formats in ③, ④ and ⑥. In addition, further local training and consultancy relative to the use of ArcView is probably desirable.

Outside the context described above, the consultant sees little practical use for a SIRENA-type model beyond what is offered by the facilities provided under this assignment. Projection of single stands does not greatly take forward the achieving sustainable forest management, which is largely an issue of coupe delineation and strict monitoring. Because of the many sharply differentiated forest types in Guyana, and the way these form a mosaic on the map, a simple model does not lead directly to any very useful result, unless it is combined, as described above, with a well-organised GIS, resource information, and planning objective.

Conclusions

Consultancy outputs

This consultancy has produced the tables of mortality and increment rates by species, as listed in Appendix A, a summarisation and grouping system for increment and mortality, as given in Table 4, with mean group statistics, and a list of volume trees with gross and net volumes, dbh, bole length and stump diameter that can be used for further volume studies. These data tables are presented in clean digital form in an Excel file called *Guyana growth & volume.xls*.

The assignment has also produced the system for entering and processing silvicultural survey data, comprising a workbook called *Silvicultural survey macros.xls*, and several data files including an empty template file, *silvicultural survey data template.xls* which can be used as abasis for new data entry.

A stand model is incorporated into the silvicultural survey macros workbook as a series of visual basic macros. The same model is presented in a more open format in the workbook *standproj.xls*. This does not include any Visual Basic, but calculates all projection process using worksheet functions. It should therefore be more accessible to persons wishing to study these procedures.

In addition the assignment has produced a number of analyses of data and data files which are preparatory steps towards further, more detailed modelling work if required. These analyses have been described in this report.

Further work

As a specialist in forest biometrics and information systems I can see a number of areas where the project could benefit from further assistance. However, it is obviously necessary that the project stakeholders and resource providers have a concordant view and agree relative priorities.

Issues that could be addressed include:

- The development of the system shown in Figure 12. This will tend to evolve naturally in any case in response to the functional demands of the timber sector, but the project could assist, accelerate and formalise this process.

- Training in Visual Basic and database design using Access with a bias towards forestry applications. This would assist the efficiency of the staff in the Forest Information Services Unit.

Conclusions

This assignment has hopefully taken forward the practical aspects of growth and yield work for forest management in Guyana. By consolidating and summarising the data from the Tropenbos and BCL PSPs, practical methods of yield projection and regulation have been provided and embodied in software. Although further work in information systems development, and training is naturally desirable and would improve GFC's functionality, the assignment as it stands can be regarded as complete and having fulfilled its objectives.

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Georgetown
1st November 2000

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Appendix A : Species statistics

The *Tim.* column is ticked for commercial species. If more than one local name is used for the same species, they are separated by semi-colon (;). Where two species names are shown joined by an ampersand (&), different nomenclature is used by Barama and Tropenbos for the same local name. *N* shows the total number of trees on all PSPs. *Dinc* is mean diameter increment in cm yr^{-1}. *SE%* is the standard error of Dinc as a %. Annual mortality is shown as % yr^{-1}. The defective tree value includes damaged or decaying trees, but not simply poor form. *Dmax* is the 95% percentile of the cumulative diameter distribution. *Model* shows the growth model group. This table only includes species above 20 cm dbh occurring on the PSPs.

Species identification			**Trees**	**Diameter increment**		**Annual mortality rate**		**Dmax**	**Model**
Tim.	*Common name*	*Botanical name*	*N*	*Dinc*	*SE%*	*Sound*	*Defective*	*P .95*	
✓	Huruasa	*Aberema jupunba*	18	0.566	12.1%	2.56%	14.29%	87.0	N
	Limonoballi	*Achrouteria pomifera*	1					29.4	A
✓	Haiariballi	*Alexa*	1906	0.631	1.4%	2.03%	4.31%	56.2	G
	Ubudi	*Anacardium giganteum*	1	0.276	10.5%		0.00%	23.6	C
	Gale, almond	*Aniba citrifolia*	1	0.624	23.8%	0.00%		27.5	F
	Gale, greenheart	*Aniba excelsa*	5	0.284	15.6%	0.00%	0.00%	37.5	D
	Silverballi, yellow	*Aniba hypoglauca*	1	0.061	55.4%	0.00%		33.1	A
	Gale, ginger	*Aniba kappleri*	1	0.066	52.1%		0.00%	25.5	A
	Mababalli	*Aparisthmium cordatum*	2	0.182	42.9%	0.00%	33.33%	23.8	A
	Duru	*Apeiba echinata & petoumo*	126	0.529	5.5%	2.62%	0.00%	63.4	K
✓	Shibadan	*Aspidosperma cruentum & album*	221	0.540	3.7%	1.07%	0.00%	83.2	P
	Yaruru	*Aspidosperma exselsum*	82	0.356	6.8%	0.00%	13.33%	69.7	L
	Cowwood	*Bagassa tiliafolia*	32	0.487	12.3%	2.00%	0.00%	56.1	E
	Manariballi, common	*Balizia pedicellaris*	11	0.680	15.8%	3.57%	0.00%	81.1	P
	Arara, fine leaf	*Bocageopsis multiflora*	17	0.220	12.9%	0.00%	10.53%	38.6	D
	Silkcotton	*Bombax*	20	0.982	9.5%	4.17%	0.00%	73.6	R
	Wild Cocoa	*Bombax jermanii*	23	0.441	19.9%	1.85%	8.33%	63.2	E
	Leopardwood; Tibokushi	*Brosimum guianense*	10	0.175	23.7%	0.00%	11.11%	32.7	B
	Dukaliballi	*Brosimum rubescens*	12	0.384	16.0%	0.00%	0.00%	43.6	E
	Arikadako	*Byrsonima aerugo*	1	0.111	13.2%	0.00%		23.4	A
	Hicha	*Byrsonima spicata*	54	0.983	7.6%	4.76%	9.09%	40.6	H
	Kanoaballi	*Byrsonima stipulacea*	4	0.425	26.9%	25.00%		40.3	C
	Wild Guava	*Calycolpus goetheanus*	4	0.228	39.0%	0.00%		30.7	B
	Kakirio	*Calyptranthes forsteri*	5	0.207	59.7%	7.69%		43.3	D
✓	Crabwood	*Carapa guianensis*	490	0.548	2.9%	1.88%	7.12%	61.8	K
	Sawari	*Caryocar nuciferum*	3	0.227	32.7%	0.00%	0.00%	80.0	M
	Warua	*Cassia cowanii*	3	0.470	34.1%	11.11%		40.2	C
✓	Baromalli, swamp	*Catostemma commune*	1072	0.510	2.1%	0.74%	2.94%	75.5	P
✓	Baromalli, sand	*Catostemma fragrans*	480	0.220	3.4%	1.42%	14.73%	43.0	D
	Congo Pump	*Cecropia angulata & obtusa*	160	1.073	4.1%	3.35%	6.90%	50.1	H
✓	Red Cedar	*Cedrela odorata*	3	0.823	42.2%	0.00%		65.2	G
	Kumaka	*Ceiba pentandra*	4	0.872	22.6%	0.00%		45.2	H
	Ruri	*Chaetocarpus schomburgkianus*	126	0.171	11.1%	2.04%	1.59%	37.9	D
	Hiwaradan	*Chaunochiton kappleri*	25	0.078	15.7%	1.69%	0.00%	25.3	A
✓	Greenheart	*Chlorocardium rodiei*	1070	0.218	1.4%	0.48%	1.57%	70.8	M
	Paripiballi	*Chrysophyllum pomiferum*	1	0.116	24.8%	0.00%		63.7	J
	Barataballi	*Chrysophyllum sanguinnolentum*	3	0.481	12.0%	0.00%		46.7	E
✓	Aromata	*Clathotropis*	153	0.653	5.5%	2.33%	2.13%	37.4	F
	Iron Mary	*Clathotropis paradoxa*	14	0.309	18.2%	0.00%	6.67%	71.2	L
	Table tree	*Cordia exaltata*	9	0.161	36.8%	0.00%	12.50%	30.9	B
	Antswood	*Cordia nodosa*	17	0.402	20.1%	2.63%	0.00%	28.5	C
	Gamma Cherry	*Cordia tetrandra*	97	0.358	7.7%	0.00%	14.29%	44.3	E
	Aruadan	*Couepia exflexa*	41	0.310	7.7%	1.02%	15.38%	50.4	E
✓	Wadara	*Couratari guianensis*	60	0.516	10.1%	0.65%	4.00%	78.1	P
	Kulishiri, hairy black	*Cupania hirsuta*	6	0.073	39.9%	0.00%	20.00%	27.4	A
	Barabara	*Diospyros*	59	0.332	11.3%	1.31%	0.00%	50.1	E
✓	Tatabu	*Diplotropis purpurea*	33	0.391	9.5%	0.00%	0.00%	67.0	L
✓	Tonka Bean	*Dipteryx odorata*	16	0.425	25.9%	0.00%	0.00%	54.6	E

Species identification			**Trees**	**Diameter increment**		**Annual mortality rate**		**Dmax**	**Model**
Tim.	*Common name*	*Botanical name*	*N*	*Dinc*	*SE%*	*Sound*	*Defective*	*P .95*	
	Yarriyarri, White	*Duguetia*	3	0.437	23.6%	0.00%		46.3	E
	Hishirudan	*Dulacia guianensis*	3	0.156	23.2%	0.00%		29.5	B
	Bartaballi	*Ecclinusa guianensis*	199	0.395	5.5%	1.10%	0.92%	67.4	L
	Manobodin	*Emmotum fagifolium*	7	0.211	25.8%	14.29%	50.00%	58.6	J
	Devil's ear	*Enterolobium cyclocarpum & barbebianum*	2	0.418	53.7%	0.00%	0.00%	75.8	P
	Wallaba, Hill	*Eperua*	1	0.450	43.4%		0.00%	79.9	P
✓	Wallaba, Soft	*Eperua falcata*	211	0.215	4.1%	2.56%	7.45%	68.5	M
	Kakaralli	*Eschweilera spp.*	4527	0.384	1.2%	0.73%	2.34%	51.0	E
	Banyaballi?	*Eugenia coffeifolia*	30	0.237	27.1%	0.00%	7.14%	41.9	D
	Wild Cherry	*Eugenia patrisii*	50	0.300	12.5%	1.64%	0.00%	42.6	D
	Wild Fig	*Ficus*	5	1.424	26.5%	0.00%	0.00%	65.0	R
	Kumakaballi	*Ficus mathewsii*	2	0.657	62.1%	0.00%	0.00%	90.5	N
	Manyokinaballi	*Geissospermum sericeum*	18	0.210	11.4%	0.00%	6.67%	74.2	M
	Devildoor tree	*Glycydendron amazonicum*	15	0.279	13.3%	0.00%	0.00%	110.5	S
✓	Kabukalli	*Goupia glabra*	125	0.562	7.1%	1.80%	1.59%	90.0	N
	Karababalli	*Guarea guidonia*	37	0.640	8.5%	0.00%	5.08%	81.4	P
	Arara, smooth skin	*Guatteria*	75	0.255	9.5%	3.59%	8.70%	29.4	B
	Shiballidan	*Hebapetalum humiriifolium*	5	0.281	14.3%	0.00%		28.5	C
	Ituri-ishi-lokodo	*Helicostylis tomentosa*	4	0.258	28.0%	0.00%		31.5	B
	Jack-in-the-box	*Hernandia giunensis*	3	0.676	27.4%	0.00%	0.00%	37.9	F
	Wild Rubber	*Hevea*	30	0.461	10.3%	2.11%	0.00%	63.1	K
	Mabwa	*Himathanthus articulatus*	3	0.079	39.3%	0.00%	0.00%	34.9	A
	Suradan	*Hyeronima laxiflora*	93	0.594	6.4%	2.86%	6.98%	72.1	P
✓	Locust	*Hymenaea coubaril*	17	0.455	10.4%	2.50%	25.00%	103.0	N
	Darina	*Hymenolobium flavum*	1	0.282	34.6%		0.00%	62.9	L
	Koraroballi	*Hymenolobium sp.*	16	0.690	14.2%	0.00%	0.00%	143.5	S
	Kakotaro	*Ilex martiniana*	1	0.000		0.00%		23.8	A
	Warakosa	*Inga*	58	0.282	9.9%	1.63%	13.79%	36.8	D
✓	Maporokon	*Inga alba*	34	1.301	7.3%	3.19%	0.00%	91.8	R
	Waiki	*Inga rubiginosa*	691	0.787	2.2%	2.24%	6.17%	52.5	G
✓	Futui	*Jacaranda copaia*	62	0.619	8.8%	6.21%	9.09%	55.9	G
	Warakaioro	*Laetia procera*	65	0.480	8.0%	0.54%	6.06%	51.8	E
	Wirimiri	*Lecythis confertiflora*	807	0.174	2.9%	1.62%	7.49%	52.9	J
	Wina	*Lecythis corrugata*	2	0.180	49.1%	33.33%	0.00%	38.7	D
	Monkey Pot	*Lecythis davisii & zabucajo*	130	0.327	8.3%	1.09%	5.00%	58.9	E
	Haudan	*Lecythis holcogyne*	6	0.217	31.3%	8.33%	0.00%	31.9	B
	Kautaballi	*Licania alba & majuscula*	207	0.167	4.0%	2.00%	4.96%	39.9	D
	Marishiballi	*Licania canescens & micrantha*	205	0.204	3.5%	1.68%	6.76%	35.5	B
	Kauta	*Licania guianensis & laxiflora*	2299	0.306	1.8%	1.21%	4.03%	48.9	E
	Buruburuli	*Licania heteromorpha & divaricata*	340	0.259	4.2%	2.47%	8.70%	46.5	D
	Unikiakia	*Licania hypoleuca*	28	0.243	9.0%	1.45%	25.00%	37.3	D
	Konoko	*Licania sp.*	30	0.262	24.0%	1.82%	3.70%	57.5	J
✓	Silverballi, brown	*Licaria cannella*	5	0.323	31.3%	0.00%	12.50%	51.8	E
✓	Hububalli	*Loxopterygium sagottii*	3	0.652	23.5%	8.33%		88.3	N
	Swizzle Stick	*Mabea*	165	0.347	6.7%	3.88%	4.23%	31.2	C
	Baririkuti	*Mabea piriri*	1					24.9	A
	Wallaba Water	*Macrolobium*	1	0.139	47.9%	0.00%		24.8	A
✓	Bulletwood	*Manilkara bidentata*	64	0.566	7.7%	0.00%	0.00%	114.7	S
	Kulishiri, white	*Matayba oligandra*	4	0.159	34.2%	11.11%	33.33%	26.8	A
	Kairima	*Maytenus myrsinoides*	3	0.255	42.9%	20.00%	0.00%	41.5	D
	Waraia, punctata	*Miconia punctata*	1	0.254	33.8%	0.00%		28.0	B
	Kudibiushi	*Micropholis venulosa*	53	0.242	9.5%	3.19%	7.14%	35.2	D
	Wanania	*Minquartia guianensis*	2	0.047	64.7%	0.00%		46.3	D
✓	Mora	*Mora excelsa*	5	0.163	26.7%	0.00%	0.00%	60.5	J
✓	Morabukea	*Mora gongrijpii*	295	0.299	3.9%	0.87%	7.47%	72.4	L

Species identification			**Trees**	**Diameter increment**		**Annual mortality rate**		**Dmax**	**Model**
Tim.	*Common name*	*Botanical name*	*N*	*Dinc*	*SE%*	*Sound*	*Defective*	*P .95*	
	Mamuriballi	*Mouriria huberi*	16	0.561	15.2%	0.00%		122.9	S
	Silverballi, pear leaf	*Ocotea acutangula*	2	0.274	23.3%	0.00%		21.7	C
	Silverballi, sawari skin	*Ocotea canaliculata*	3	0.577	16.0%	0.00%		49.3	G
	Silverballi, "pea's" leaf kere	*Ocotea floribunda*	4	0.609	11.8%	0.00%		37.7	F
	Silverballi, Shirua	*Ocotea guianensis*	15	0.399	10.4%	0.00%	0.00%	58.3	E
	Silverballi, Kereti	*Ocotea puberula*	197	0.576	4.6%	2.49%	7.92%	45.5	F
	Baradan	*Ocotea tomentella*	37	0.600	13.7%	2.63%	0.00%	94.4	N
	Lu	*Oenocarpus bacaba*	10	0.019	48.0%	4.55%	50.00%	34.7	A
✓	Barakaro	*Ormosia coccinea*	14	0.198	20.3%	6.06%	40.00%	60.7	J
	Korokororo	*Ormosia coutinhoi*	3	0.159	35.7%	0.00%		62.5	J
	Lancewood; Kar-ishiri	*Oxandra asbeckii*	57	0.300	8.9%	0.79%	0.00%	41.5	D
	Mahoballi	*Panopsis sessilifolia*	1	0.033		50.00%		55.5	J
✓	Dukali	*Parahancornia fasciculata*	1	0.094	52.2%	0.00%		36.3	A
✓	Burada	*Parinari campestris*	84	0.598	6.6%	2.46%	3.45%	98.0	N
	Hipanai	*Parkia pendula*	1	0.332	52.1%		0.00%	101.7	N
	Uya	*Parkia ulei*	5	0.506	26.8%	22.22%	0.00%	49.7	E
	Adebero	*Paypayrola guianensis & longifolia*	1	0.050	50.9%	0.00%		23.8	A
✓	Purpleheart; Saka	*Peltogyne*	55	0.632	6.6%	1.94%	2.78%	109.0	S
	Trysil	*Pentaclethra odorata & macroloba*	1352	0.495	2.0%	1.71%	3.77%	41.2	F
✓	Hachiballi	*Pera*	5	0.211	33.8%	0.00%		39.5	D
	Manariballi	*Pithecellobium pedicellare*	16	0.677	17.1%	3.13%	0.00%	91.2	N
	Soapwood	*Pithecelobium jupunba*	53	0.620	8.7%	1.69%	1.92%	97.1	N
✓	Buruma	*Pourouma essiquiboensis & guianensis*	20	0.787	11.4%	1.89%	14.29%	37.6	F
	Kamahora, fine leaf	*Pouteria filipes & venosa*	6	0.226	29.0%	0.00%		40.2	D
	Asepokoballi, fine leaf	*Pouteria caimito*	2	0.329	22.7%	0.00%		27.1	C
	Aiomorakushi	*Pouteria cladantha*	35	0.256	10.2%	0.00%	3.13%	34.3	B
	Asepoko	*Pouteria guianensis*	149	0.385	8.3%	0.66%	4.00%	55.0	E
	Moraballi	*Pouteria minutiflora & coriacea*	235	0.499	4.5%	1.49%	3.41%	56.5	K
	Kokoritiballi	*Pouteria reticulata*	165	0.445	7.1%	1.01%	2.22%	61.4	E
✓	Suya	*Pouteria speciosa*	18	0.212	12.5%	0.00%	0.00%	60.1	J
	Kamahora, medium leaf	*Pouteria trigonosprema*	1	0.908	44.9%	0.00%		34.9	H
	Haiawaballi	*Protium beglectum & tenuifolium*	19	0.289	15.7%	0.00%	0.00%	70.7	L
✓	Kurokai	*Protium decandrum*	880	0.728	1.7%	2.33%	5.81%	48.4	G
✓	Haiawa	*Protium guianense*	24	0.375	10.4%	1.89%	0.00%	28.7	C
	Manariballi , like	*Pseudopiptadenia suavolens*	2	1.014	45.8%	0.00%		56.1	H
	Corkwood	*Pterocarpus officinalis*	65	0.998	7.6%	0.56%	0.00%	60.5	H
	Okokonshi	*Quiina obovata & indigofera*	14	0.273	12.5%	0.00%	11.11%	30.0	C
	Muneridan	*Ruizterania albiflora*	4	0.196	44.1%	0.00%	33.33%	84.7	M
	Dukuria	*Sacoglottis guianensis*	10	0.543	9.8%	0.00%	20.00%	58.3	K
✓	Karohoro	*Schlefflera morototoni*	53	0.705	8.3%	4.07%	0.00%	67.7	G
✓	Kaditiri	*Sclerolobium guianense*	32	1.299	8.8%	6.58%		66.3	R
✓	Hachiballi	*Simaba multiflora*	5	0.207	21.3%	14.29%	0.00%	43.0	D
✓	Simarupa	*Simarouba amara*	26	0.937	9.6%	2.44%	12.50%	85.4	R
	Muniridan	*Siparuna sp.*	1	0.000		33.33%		22.4	A
	Aruadan	*Sloanea guianensis*	57	0.153	8.1%	1.77%	3.92%	42.3	D
	Black Maho	*Sterculia exsucca*	30	0.685	13.0%	7.25%	14.29%	39.6	F
✓	Maho	*Sterculia pruriens & rugosa*	343	0.558	3.9%	2.23%	5.36%	64.7	K
✓	Itikiboroballi	*Swartzia benthamiana*	53	0.192	7.3%	0.00%	8.82%	58.8	J
	Parakusan	*Swartzia jenmanii*	52	0.746	8.4%	5.95%	6.67%	127.1	S
✓	Wamara	*Swartzia leiocalycina*	194	0.170	4.8%	0.50%	4.84%	55.7	J
	Serebedan	*Swartzia oblanceolata*	9	0.205	33.0%	0.00%	0.00%	52.2	J
✓	Manni	*Symphonia globulifera*	19	0.960	8.9%	0.00%	0.00%	76.6	R

Hakia	*Tabebuia*	23	0.363	15.7%	0.00%	4.35%	104.1	N

Species identification			**Trees**	**Diameter increment**		**Annual mortality rate**		**Dmax**	**Model**
Tim.	*Common name*	*Botanical name*	*N*	*Dinc*	*SE%*	*Sound*	*Defective*	*P .95*	
	Waiaballi	*Tapura guianensis*	26	0.146	11.0%	0.00%	0.00%	25.2	A
✓	Fukadi	*Terminalia amazonia*	8	0.220	25.5%	0.00%	0.00%	94.1	M
	Coffee Mortar	*Terminalia dichotoma*	28	0.497	17.2%	0.00%	11.11%	71.0	P
	Awasokule	*Tovomita*	82	0.391	10.1%	3.43%	13.64%	29.2	C
	Wild Mangrove	*Tovomita obovata*	1	0.216	36.2%	0.00%		25.0	B
✓	Ulu	*Trattinickia demerarae & rhoifolia*	10	0.163	21.4%	0.00%	7.69%	31.4	B
	Long John	*Triplaris surinamensis*	14	0.560	16.4%	7.14%	14.29%	107.5	S
	Pasture tree	*Trymatococcus paraensis*	1	0.022	100.0%	0.00%		33.9	A
	Arara, broad leaf	*Unonopsis sp.*	1	0.028	100.0%		0.00%	20.7	A
	Arisauro	*Vatairea guianensis*	25	0.752	11.2%	0.00%	0.00%	79.7	N
✓	Dalli	*Virola surinamensis & sebifera*	73	0.547	9.2%	3.41%	9.09%	47.8	F
	Bloodwood	*Vismia angusta*	14	0.799	10.8%	0.00%	16.67%	43.4	F
	Wild Calabas	*Vitex compressa*	32	0.514	9.6%	0.00%	0.00%	83.7	P
	Iteballi	*Vochysia surinamensis*	3	0.616	22.9%	0.00%	50.00%	68.8	K
✓	Sarebebeballi	*Vouacapoua macropetala*	138	0.186	5.9%	0.00%	5.99%	41.8	D
✓	Kuyama, white	*Xylopia nitida*	1	0.141			0.00%	21.5	A
	Tureli	*Zygia racemosa*	11	0.390	17.8%	0.00%		46.8	E
	Pencilwood		64	0.466	7.8%	2.36%	4.00%	69.8	P
	[Unknown species]		352	0.420	3.9%	1.85%	4.29%	53.0	E