MYRLIN

Simple tools for yield regulation in natural tropical forests

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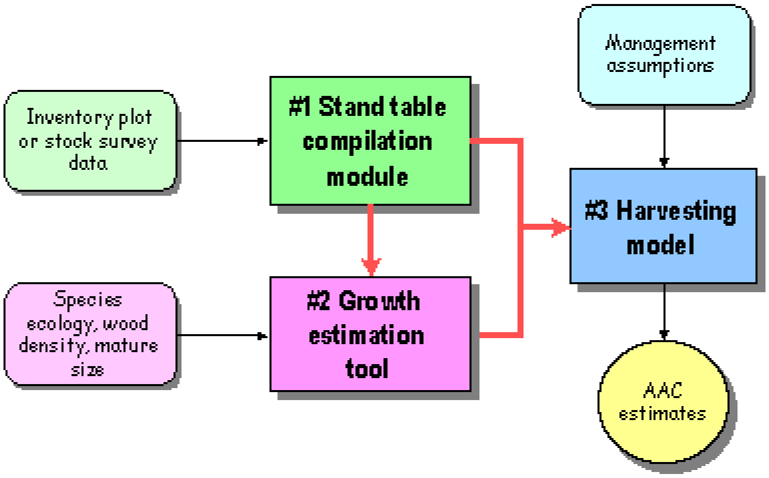
Methods of Yield Regulation with Limited Information

for natural tropical forests

MYRLIN is an acronym for **M**ethods of **Y**ield **R**egulation with **L**imited **In**formation.

Yield regulation is the process of calculating a sustainable timber yield from a forest by species, location, and year, specifying it in forest management plans, and monitoring the actual harvest to ensure compliance.



MYRLIN is a set of three simple software tools designed to assist this process in natural tropical forest. These tools are directed at the needs of organisations and enterprises which have only a limited research base of information on forest dynamics in their locality.

Although tropical forests are very diverse, actual tree growth rates fall into a narrow band of values and can be reasonably estimated from features of species ecology and wood properties. The MYRLIN tools and the information on this web site provide a basis for this estimation process.

The three MYRLIN tools follow a logical sequence. MYRLIN#1 organizes forest inventory and stock survey data into stand tables useful for planning, and required for the growth modelling. MYRLIN#2 assists in the process of estimating increments and mortality rates for species. MYRLIN#3 is a model that uses the inventory and growth tables to estimate sustainable yield and give a detailed list of coupes and quantities by year. These outputs are designed to form the basis for a management plan and a monitoring and control system.

Each MYRLIN module comprises a Microsoft Excel workbook with embedded macros. The user will need to have MS Excel version 2000 or later fully installed on their computer in order to be able to use the tools. This website provides documentation on how to use them, and it is recommended that each section is worked through carefully in conjunction with the relevant MYRLIN module.

The software tools and documentation at this site have been developed under the project *"Yield regulation for tropical moist forests with minimal data"* at the Oxford Forestry Institute. An inaugural workshop for the project was held in Costa Rica in 1999. The papers from the workshop contain background information that can be viewed or downloaded here. A training workshop in the use of the MYRLIN tools was also held in Oxford in September 2001.

The project was supported through the Forest Research Programme of the UK Department for International Development. The software and information at this site are provided freely as a service towards improving the sustainable management of natural tropical forest. However, it is a condition of use that software is not incorporated in whole or in part into any commercial product that is subsequently re-sold; and that reports, plans or presentations of information acknowledge this website (www.myrlin.org) as the source.

The following citations should be given in formal publications:

Alder, D, Baker, N, Wright, HL (2002) *MYRLIN: Methods of Yield Regulation with Limited Information*. University of Oxford, Oxford Forestry Institute. http://www.myrlin.org.

Wright, HL & Alder,D [Editors] (2000) *Proceedings of a workshop on Humid and semi-humid tropical forest yield regulation with minimal data.*University of Oxford, Department of Plant Sciences, Oxford Forestry Institute. OFI Occasional Papers 52. (ISBN 0 85074 152 1)

MYRLIN Training workshop

held at Oxford University,10-14 September 2001

A training workshop in the use of MYRLIN was held at Oxford University from 10-14th September 2002. There were 17 participants from 9 countries (Indonesia, Malaysia, Uganda, Ghana, Cameroon, Ecuador, Argentina, Costa Rica, Guyana). Training was provided by three Oxford Forestry Institute staff (*Denis Alder, Nell Baker, Howard Wright*). The Edinburgh Centre for Tropical Forestry provided two staff for a presentation of SYMFOR (*Paul van Gardingen, Paul Phillips*).

A detailed report on the workshop topics and discussions,with participants contact addresses can be downloaded here (34 kb, MS Word format).

Participants and staff, left to right:
Redhahari, Gavin Nicol, Tasreef Khan, David Thomas, Dejan Lewis, Paul van Gardingen, Miguel Romero, Francis Odoom, Putera Parthama, Nsita Steve, Ismail bin Harun, Howard Wright, Ernest Foli, Paul Phillips, Charles Dei-Amoah, Mauricio Sanchez, Denis Alder, Marcos Costa, Ridwan, Jagdesh Singh (Photo: Nell Baker)

MYRLIN Stand tables

The stand table module of MYRLIN is an Excel workbook, which when downloaded is called *MYRLIN#1 (Stand tables)*. This name can be changed as required when the workbook is saved locally, without affecting its function.

Its purpose is to produce tables of species groups (rows) by size classes (columns) for forest strata, according to flexible criteria. This module is directly useful as a simple forest inventory summarising tool. The table format produced is also compatible with the harvest modelling tool (MYRLIN#3), whilst the plot data and options are used by the tree growth tool (MYRLIN#2) to estimate typical size parameters for species groups.

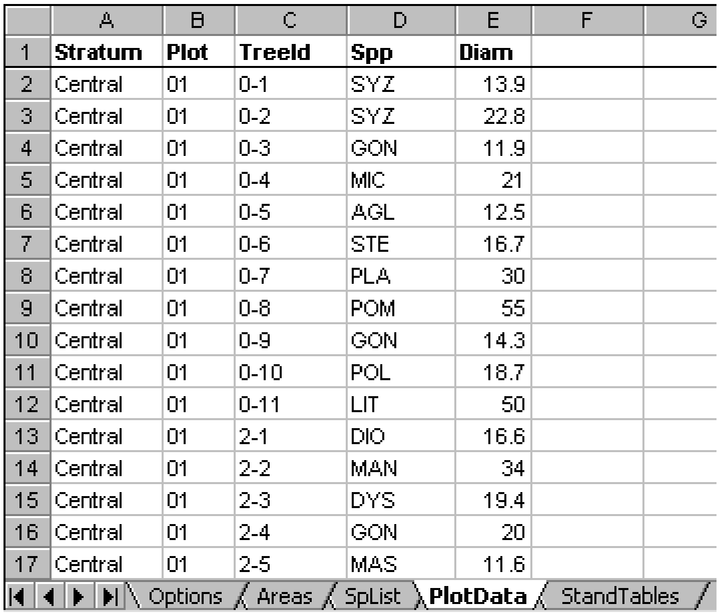
The workbook includes initially demonstration data, as used in the examples in this web site. This data comprises worksheets for:

- Tree measurements from sample plots and/or stock survey data
- A species list, with codes that link to the tree data
- A list of stratum or block codes and areas
- Options that define sheet names, columns used, and sampling design
- An output table that is generated from the data

The workbook also contains a macro or program in Visual Basic called *MakeStandTables*. This updates the stand table from the supplied data.

MYRLIN Stand tables - Tree data

The tree data worksheet contains measurements from sample plots, a stock survey, or a mixture of both (ie. a stock survey with a sub-sample of plots). Four columns are required for the data. Other data may be present but are not used by MYRLIN. These items are:



	A	B	C	D	E	F	G
1	**Stratum**	**Plot**	**TreeId**	**Spp**	**Diam**		
2	Central	01	0-1	SYZ	13.9		
3	Central	01	0-2	SYZ	22.8		
4	Central	01	0-3	GON	11.9		
5	Central	01	0-4	MIC	21		
6	Central	01	0-5	AGL	12.5		
7	Central	01	0-6	STE	16.7		
8	Central	01	0-7	PLA	30		
9	Central	01	0-8	POM	55		
10	Central	01	0-9	GON	14.3		
11	Central	01	0-10	POL	18.7		
12	Central	01	0-11	LIT	50		
13	Central	01	2-1	DIO	16.6		
14	Central	01	2-2	MAN	34		
15	Central	01	2-3	DYS	19.4		
16	Central	01	2-4	GON	20		
17	Central	01	2-5	MAS	11.6		

- Stratum or block ID
- Plot ID
- Species code
- Tree Dbh

The order of the columns is set on the *Options* sheet, and is not important. The data should however be sorted by *Stratum* and *Plot ID*. If this is not done, the data may not be processed correctly. For sample plot data, the *Plot ID* field must contain the plot number. For stock surveys, this field should be left blank. If stock survey data is mixed with sample plot data (a stock survey with sub-sampling), then the *Plot ID* should be completed for tree records from the sample plots, and left blank for those outside the plots. For stock surveys, 100% coverage of the entire block is assumed; the area of each block (stratum) must be given correctly in the Areas table.

The *stratum or block ID* must match an entry in the *Areas* table. It can be numeric or text. The *Plot ID* may also be numeric or text, but should in either case be formatted as text.

The species code column contains entries that must match entries in the first column of the species list. The codes can be numeric or text, but again, should be forced to a standard format to avoid ambiguity if numeric codes are used.

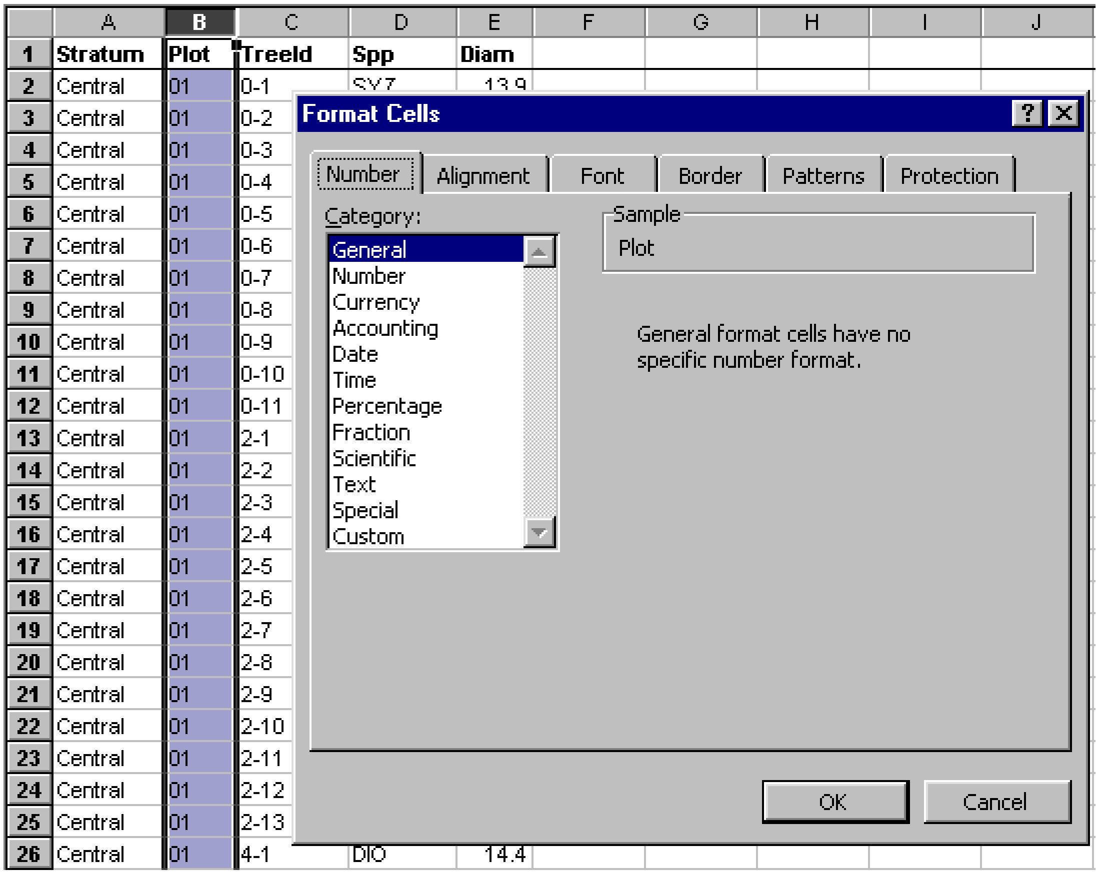
Tree diameter must be in cm and in numeric form. Any text data in this column will cause an error.

It may be noted that the column headings are not important, but must not occupy more than one row at the top of the sheet. The sheet name can also be changed. The sheet name has to be indicated on the *Options* sheet.

Forcing data to text

and other formatting problems

To force a column of data to text, select it, as shown below. Press **Ctrl-1** or pick **Format Cells** from the menu. The dialog box shown will appear. Pick the *Number* tab on the dialog box, and select the *Text* format option in the list of formats.



Sample: Plot

General format cells have no specific number format.

	A	B	C	D	E
1	Stratum	Plot	TreeId	Spp	Diam
2	Central	01	0-1	SYZ	13.9
3	Central	01	0-2		
4	Central	01	0-3		
5	Central	01	0-4		
6	Central	01	0-5		
7	Central	01	0-6		
8	Central	01	0-7		
9	Central	01	0-8		
10	Central	01	0-9		
11	Central	01	0-10		
12	Central	01	0-11		
13	Central	01	2-1		
14	Central	01	2-2		
15	Central	01	2-3		
16	Central	01	2-4		
17	Central	01	2-5		
18	Central	01	2-6		
19	Central	01	2-7		
20	Central	01	2-8		
21	Central	01	2-9		
22	Central	01	2-10		
23	Central	01	2-11		
24	Central	01	2-12		
25	Central	01	2-13		
26	Central	01	4-1	DIO	14.4

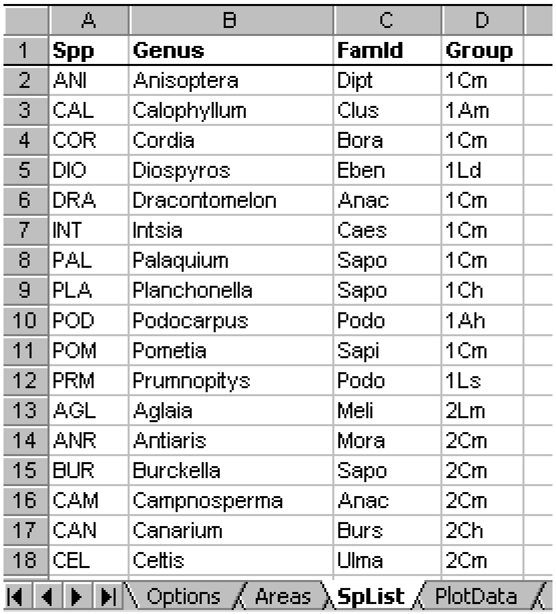
Other formatting problems which can arise are due to leading or trailing spaces in a field. These may not be visually obvious, but can prevent a species code or stratum code being recognized

Obscure mistakes, such as typing 2O.3, instead of 20.3 ('O' instead of zero) can cause data reading problems that are hard to locate.

MYRLIN detects the end of lists (plot data, species lists, stratum list, etc.) by looking for an empty cell. If the cell in fact contains one or more spaces, the program may try to continue and give an error message. To ensure cells are truly empty at the end of a list, select them and press the **Del**(Delete) key

The MYRLIN species list

The species list can contain several columns of information, but MYRLIN requires two columns to work with. The first column must be the species code used in the tree data. This can be either a numeric or alphabetic code, but should be set to text format to avoid ambiguity.



	A	B	C	D
1	**Spp**	**Genus**	**FamId**	**Group**
2	ANI	Anisoptera	Dipt	1Cm
3	CAL	Calophyllum	Clus	1Am
4	COR	Cordia	Bora	1Cm
5	DIO	Diospyros	Eben	1Ld
6	DRA	Dracontomelon	Anac	1Cm
7	INT	Intsia	Caes	1Cm
8	PAL	Palaquium	Sapo	1Cm
9	PLA	Planchonella	Sapo	1Ch
10	POD	Podocarpus	Podo	1Ah
11	POM	Pometia	Sapi	1Cm
12	PRM	Prumnopitys	Podo	1Ls
13	AGL	Aglaia	Meli	2Lm
14	ANR	Antiaris	Mora	2Cm
15	BUR	Burckella	Sapo	2Cm
16	CAM	Campnosperma	Anac	2Cm
17	CAN	Canarium	Burs	2Ch
18	CEL	Celtis	Ulma	2Cm

A species group column is also needed. Several grouping columns could be present, and used for alternative output tables. However, for effective growth projection, the species group needs to reflect differences in both species ecology and economic value (more...). In the example shown, *Genus* or family code (*FamId*) could also be used to group the stand table outputs.

Other columns, such as the species name, family, common name, *etc.*, may be given, but are not used by MYRLIN unless selected for grouping.

The column headings to the species list must not occupy more than one row. The list proper must start in row 2. The text of the headings can be changed as appropriate for the contents of the list.

Criteria for grouping species

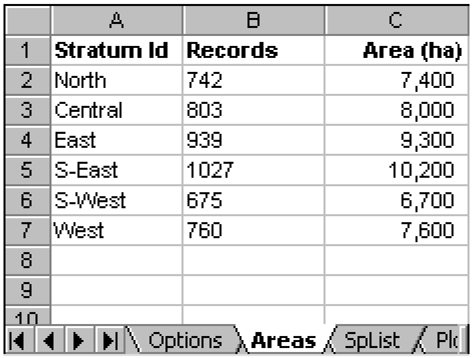
An effective scheme for species grouping needs to meet the needs of silviculture and forest management. Simple commercial groups are not adequate for this purpose. A scheme which applies the following criteria based on tree size and ecology, wood density and durability, and commercial status will distinguish species sufficiently for practical management and planning. The following is an example of a classification and coding system.

Economic status	Tree size	Timber type
1 High-value timber	A Emergent, large trees	d Hard, dense, durable
2 Low-value timber	C Upper canopy trees	h Medium hard, durable
3 Non-economic	L Lower canopy trees	m Medium density, non-durable
	U Understorey trees	s Soft, non-durable
	X Pioneer species	v Very soft, low density

Thus a code such as 2Ah indicates a species that typically occurs as a large emergent, has moderately dense, durable timber, and is marginally economic in the market. The code letters and numbers in this scheme have been arranged so that they will sort into a natural order. It is generally better to have the economic code first, as this will give best results in the MYRLIN tables.

Stratification, blocks and forest areas

The *Areas* sheet lists the forest strata that occur in the Tree data table, and gives their areas in ha. In this sheet, the stratum ID must be in column A, and the areas in hectares in column C. Column B is not required, but is used in this case to check the number of records in each stratum in the tree data. This can be done using the macro *StratumRecordCount*.



	A	B	C
1	**Stratum Id**	**Records**	**Area (ha)**
2	North	742	7,400
3	Central	803	8,000
4	East	939	9,300
5	S-East	1027	10,200
6	S-West	675	6,700
7	West	760	7,600
8			
9			
10			

The MakeStandTables macro will compile the tree data into per ha (or per km^2) summaries without reference to the area table if only sample plot data is present. However, for stock survey data, the areas are required, otherwise correct per unit area statistics cannot be compiled. Also, for the harvesting model, correct areas must be given in this table.

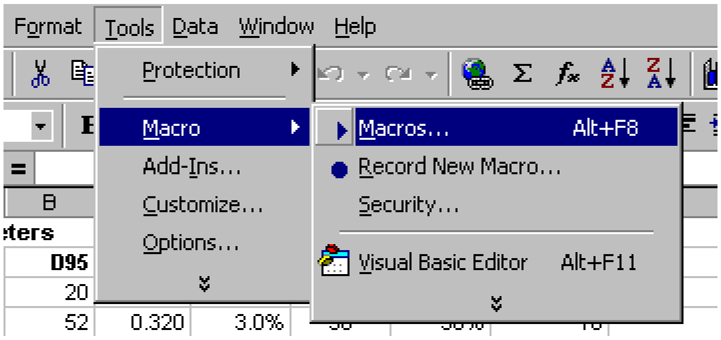
The strata may represent either statistical strata used as a basis for stratifying a forest inventory, such as forest types, soil associations, *etc*, or real administrative and management units. For stand tables, either type of usage is equally valid and acceptable. However, for the Harvest model, the strata should represent contiguous blocks that will be felled, wholly or partially, in defined sequence over the felling cycle. They should therefore be administrative units such as compartments or periodic blocks.

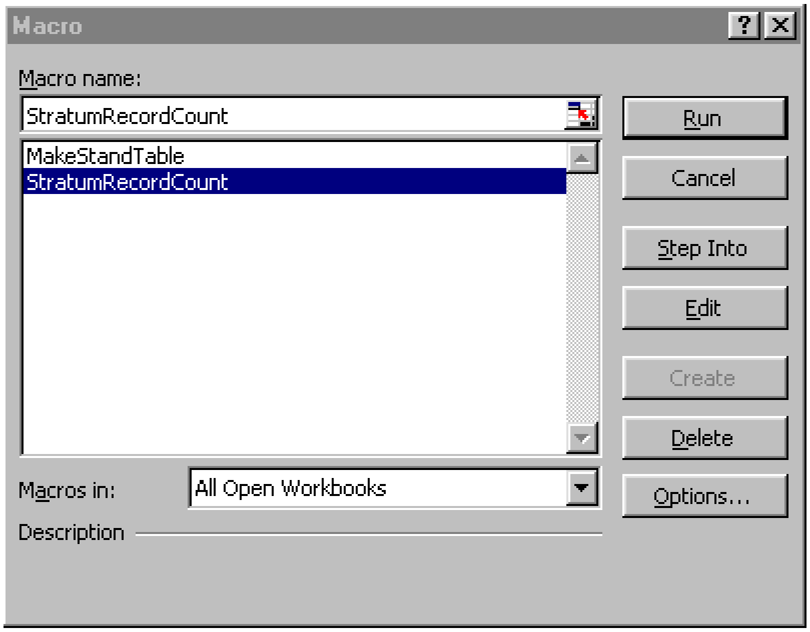
It should also be noted that a single stratum or block is a perfectly valid basis for either stand tables, or for the harvest model.

Excel macros

Macros in Microsoft Excel are programs written in Visual Basic. These form part of the workbook in which they are created. The list of available macros can be viewed in one of two ways:

- By pressing the **Alt-F8** key
- Via the menu selection **Tools→Macro→Macros**





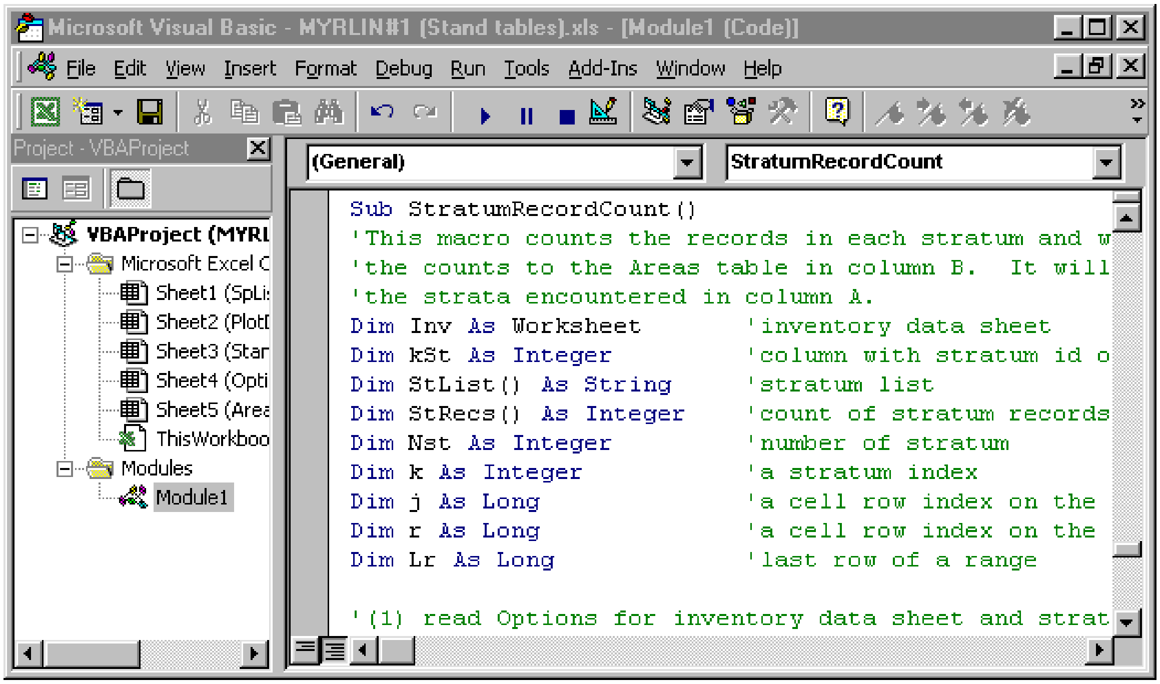
Macro name: StratumRecordCount

Macros in: All Open Workbooks

Either method will bring up a list of available macros to run, as shown at the left. Selecting the required macro and clicking the *Run* button will execute it.

When any of the MYRLIN workbooks are opened, Excel will report the presence of macros, and request whether you wish to enable them. It is always necessary to select the *Enable macros* option or they will be unable to run.

The *Edit* button can be used to view the Visual Basic code of the macro, and to make amendments if required. Note that if you are not familiar with Visual Basic, *even very minor changes to the macro may render it unable to run*, or even *cause Excel to crash with a loss of unsaved data*. It is therefore very important if experimenting with Visual Basic to work on a second copy of the MYRLIN file, not an original one containing valuable data. The appearance of the Visual Basic editor screen, with the start of the *StratumRecordCount* macro, is shown below.



```
Sub StratumRecordCount()
'This macro counts the records in each stratum and w
'the counts to the Areas table in column B.  It will
'the strata encountered in column A.
Dim Inv As Worksheet       'inventory data sheet
Dim kSt As Integer         'column with stratum id o
Dim StList() As String     'stratum list
Dim StRecs() As Integer    'count of stratum records
Dim Nst As Integer         'number of stratum
Dim k As Integer           'a stratum index
Dim j As Long              'a cell row index on the
Dim r As Long              'a cell row index on the
Dim Lr As Long             'last row of a range

'(1) read Options for inventory data sheet and strat
```

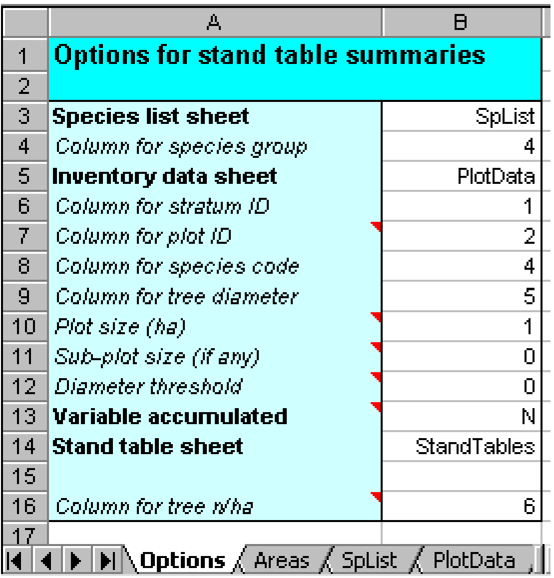
Options for MYRLIN stand tables

The **Options** tab of the *Stand Tables* workbook defines the sheet names and columns for the data, the sample plot design, and the variable to be tabulated.

Cell **B3** gives the sheet name for the species list. Cell **B4** gives the column number on the list that is used for species groups. The species groups define the rows in the stand table.

Cell **B5** give the name of the sheet containing tree measurements from stock survey and/or sample plots. The subsequent cells **B6:B9** give the column numbers used for *stratum ID*, *plot ID*, *species code* and *tree diameter*, respectively.

Cell **B10** gives the *plot size* in hectares if sample plots are being used. If only stock survey data is present, it can be left blank. If a mixture of stock survey and sample plot data is used, the plot size should be filled in. For point sampling or complex plot designs not catered for by the sub-sampling option in **B11:B12**, -1 should be entered.



	A	B
1	**Options for stand table summaries**	
2		
3	**Species list sheet**	SpList
4	*Column for species group*	4
5	**Inventory data sheet**	PlotData
6	*Column for stratum ID*	1
7	*Column for plot ID*	2
8	*Column for species code*	4
9	*Column for tree diameter*	5
10	*Plot size (ha)*	1
11	*Sub-plot size (if any)*	0
12	*Diameter threshold*	0
13	**Variable accumulated**	N
14	**Stand table sheet**	StandTables
15		
16	*Column for tree n/ha*	6
17		

A single level of sub-sampling on the plot can be specified directly. The total sub-sample area within the plot, in hectares, should be given cell **B11**. The minimum measurement diameter for the main plot should be given in cell **B12**. For example, suppose plots are a circular, 0.1 ha design, on which trees are measured down to 20 cm dbh. One quarter of this plot comprises a sub-sample, for trees down to 5 cm dbh. In this case, the plot area is 0.1 ha (**B10**). The sub-sample size is 0.025 ha (**B11**). The threshold diameter is 20 cm. See the complex plots topic for further examples and diagrams.

The variable being accumulated in the stand table is indicated by the entry in **B13**. A value of N, H, or G can be used. Any other entry is equivalent to N. These codes have the following meanings:

N	Stems numbers per km^2
H	Stem numbers per ha
G	Basal area per ha

The name of the stand table sheet is given in cell **B14**. This can be changed in order to save existing stand tables with alternative options. Otherwise, when the MakeStandTables macro is run, the current stand table, as defined by cell **B14**, will be overwritten.

The data column indicated by **B16** is only used if the plot size setting is -1, and relates to data handling for point samples and complex plot designs. For simpler cases, where **B10** is empty or a positive value, it will be ignored.

Complex plot designs

for MYRLIN stand tables

MYRLIN can accommodate one level of sub-sampling on a simple fixed area plot within the normal options specification.

However, there are many other ways in which sample plots may be designed. These include:

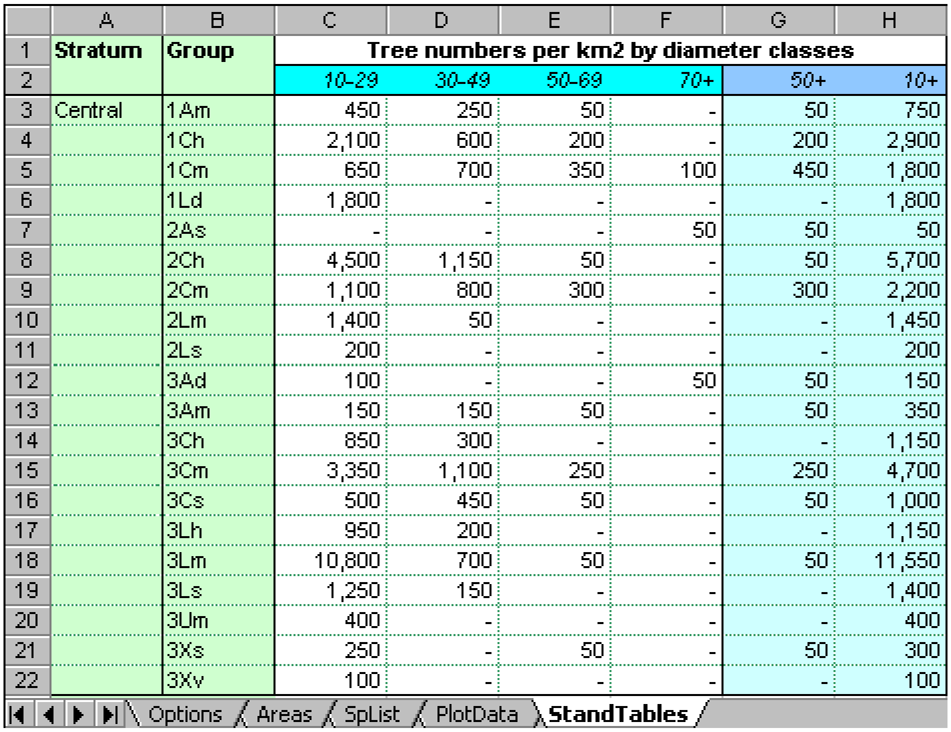
- Two or more sampling levels within each plot.
- Sub-sampling on every nth plot.
- Point sampling or basal area sweeps.
- Plot sizes that vary between sample unit.

To accommodate these, an additional column can be specified on the Tree data sheet, which must contain the number of trees per ha each observed tree is equivalent to. This is referred to as the *tree area weight*. This column can usually be filled in using an appropriate Excel formula, based on either tree diameter, or a sub-plot ID column. This column number must be filled in on the Options sheet in cell B16. The plot size on the *Options* sheet must be set to -1. Examples are given in the table below:

Two or more sampling levels within each plot	Use an IF() function in Excel together with the diameter column to give the area weight according to the tree diameter. For example, if trees of 40 cm plus are sampled on 1 ha, 20 cm plus on 0.1 ha, and 10 cm plus on 0.05 ha, and diameters are in column D, then the formula: =IF(D2>=40,1,IF(D2>=20,10, 20)) will give area weights of 1, 10 and 20 trees/ha for each tree sampled, based on its size, and hence the size of sub-plot in which it occurs. Generally, area weight is derived from plot or sub-plot size as: Area weight = 1/(Plot size in ha)
Sub-sampling on every nth plot	This can be accomodated by a similar method to that above, by treating groups of *n* plots as a cluster. If the frequency of sub sampling is *n*, the threshold diameter is *d*, and the plot area is *p*, then the general area weight formula would be: =IF(D2>=*d*,1/*p*,*n/p*) For example, suppose normal plots are sampled to 20 cm,and one in 10 are also sampled down to 5 cm dbh. Plot size is 0.1 ha. Then the required IF statement should be: =IF(D2>=20, 10 , 100) In other words, trees on the normal plots would have an area weight of 10, and those below 20 cm dbh on the sub-sample plots would have area weights of 100 trees/ha.
Point sampling	With point sampling, the area weight depends on tree diameter and the basal area factor *F* used. If tree basal area is *g* m^2/ha, then effective plot area for each tree is *g/F*. Area weight is the reciprocal of this. Hence the general formula is $w = F/(k.d^2)$ where *w* is the area weight and *d* is diameter in cm, and *k* is the constant 0.00007854. The basal area factor *F* must be metric, in m^2/ha. This equation can be put directly into an Excel formula. For example, with diameter in column D, and a basal area factor of 4 m^2/ha, the formula would be: =(4/(0.00007854*D2^2)

Plot sizes or basal area factors that vary between sample unit	It sometimes happens that different plot sizes or basal area factors are used on different sampling areas, to reflect large changes in forest type or density. This could be combined with any of the above schemes (sub-sampling, clustering,point sampling). In this case an additional column is required to give the plot size as well as the plot ID. This is then used to construct the above formulae, instead of using a constant value. For example, suppose different basal area factors were used in different stages of an inventory, and are entered in column C of the data, with diameter as before in column D. Then the area weight formula from the above case would become: =(C2/(0.00007854*D2^2)

Stand tables produced by MYRLIN



	A	B	C	D	E	F	G	H
1	**Stratum**	**Group**	**Tree numbers per km2 by diameter classes**					
2			*10-29*	*30-49*	*50-69*	*70+*	*50+*	*10+*
3	Central	1Am	450	250	50	-	50	750
4		1Ch	2,100	600	200	-	200	2,900
5		1Cm	650	700	350	100	450	1,800
6		1Ld	1,800	-	-	-	-	1,800
7		2As	-	-	-	50	50	50
8		2Ch	4,500	1,150	50	-	50	5,700
9		2Cm	1,100	800	300	-	300	2,200
10		2Lm	1,400	50	-	-	-	1,450
11		2Ls	200	-	-	-	-	200
12		3Ad	100	-	-	50	50	150
13		3Am	150	150	50	-	50	350
14		3Ch	850	300	-	-	-	1,150
15		3Cm	3,350	1,100	250	-	250	4,700
16		3Cs	500	450	50	-	50	1,000
17		3Lh	950	200	-	-	-	1,150
18		3Lm	10,800	700	50	-	50	11,550
19		3Ls	1,250	150	-	-	-	1,400
20		3Um	400	-	-	-	-	400
21		3Xs	250	-	50	-	50	300
22		3Xv	100	-	-	-	-	100

The stand tables produced by the MYRLIN stand table module (MYRLIN#1) appear as shown above. The first column contains the block or stratum. One table is produced for each block. The second column contains the species groups. Individual species tables can be produced by selecting the species as the grouping column on the Options form.

The diameter classes used are flexible, and are determined by the headings in row 2. These can be edited to contain values in either of the following formats:

Normal diameter classes	In this format, the class will include all trees from a lower diameter to an upper diameter. For the example, if 20-39 is specified, then trees from 20.00 to 39.99 would be included in the class. Columns C:E in the above table are in this format. Consecutive class could overlap, although this would result in double counting of trees. Equally there could be gaps between classes, so that some trees are not shown. Classes do not need to be in ascending order. MYRLIN will process the data in either case. Normal usage requires that adjacent classes should be in ascending order, without gaps or overlaps in the size ranges, as in the above example.
Cumulative diameter classes	These classes will include all trees of and above the specified size limit. Columns F:H in the above example are of this type. For example, 70+ will include any tree of 70.00 cm or larger. The cumulative classes do not need to be in ascending order.

The colouring and outlining in the *StandTables* worksheet shown above is done manually, after the table has been produced. Existing formats and colours will be left unchanged when a table is updated.

MYRLIN#1 is designed as a flexible stand table tool. However, if the stand table is to be copied into the MYRLIN#3 harvesting model, some restrictions must be applied to column formats:

- Normal diameter classes must be in ascending order.
- Class width should not be more than 10 cm or less than 5 cm.
- The last class should be a cumulative class to catch the largest trees.

A good set of class specifications for modelling purposes is

10-19, 20-29, 30-39, 40-49,50-59, 60-69, 70-79, 80-89, 90+.

The downloaded version of MYRLIN#1 has these classes set up in the StandTables sheet.

However, for publication of growing stock information, for example in a management plan, it is clearer to use fewer classes. These should correspond to significant silvicultural and harvesting sizes. The example shown in the figure above would be more appropriate for such a context. Both sets can be maintained in the MYRLIN#1 tool, and updated by changing the stand table sheet name on the Options form, cell B14.

Note that when entering some range values, eg *10-19*, Excel may attempt to convert them to a date, giving *19-Oct*, or a large integer number, depending on the cell format being used by default. To prevent this, start the entry with a single apostrophe, as: *'10-19*. This will always be correctly rendered.

Updating MYRLIN stand tables

The stand tables sheet can be updated by running the macro *MakeStandTables*. This will use the settings on the *Options* sheet to read and process the tree data, linking it to the species list, and summarising results by diameter classes and species groups. If the options, species list, areas table, or tree data are not properly defined, then various kinds of execution error messages may arise at this point (troubleshooting guide).

If persistent problems occur, refer to the Help section.

The MYRLIN growth estimation tool

The MYRLIN growth estimation tool is an Excel workbook with facilities designed to help in estimating growth and mortality rates for natural forest species. It is intended for cases where no direct information is available from permanent sample plots or research records.

It links to and reads the options, species and inventory data from the MYRLIN stand table module. It is necessary therefore to set up the stand table module correctly before using the growth estimation tool.

The growth estimation tool is based on the premise that for a large, broadly based sample of tree increment measurements, there is a relationship between typical size, expressed as the 95% point on the cumulative diameter distribution, and mean species increment. This relationship depends also on other indicators of growth rate, such as ecological guild and wood properties. It is also influenced by site characteristics such as soil fertility. The Reference section discusses the empirical basis for this proposition.

The workbook comprises three sheets and two macros,as follows:

{Table} worksheet	Contains a list of species groups extracted from MYRLIN#1, with their mean number per ha, 95% cumulative diameter, mean basal area per ha, and an initial estimate of diameter increment and annual mortality rate based on a pan-tropical regression of increment on typical size.
{Fig1} chart	Plots species group typical size on mean increment. Has background lines indicating size-increment relation for ecological guild/wood property groups. Allows initial estimates of increment to be adjusted manually according to knowledge of ecology or wood properties. Has handle to adjust overall graph scaling for site indicators.
{Model} worksheet	Provides summary data of increment-size groupings based on ecological/wood property characters, as noted in the Reference section. Used to provide background lines, site scaling, and increment-size regression on *{Fig1}*. The worksheet is protected as it should not normally be edited.
MakeD95List macro	This macro updates the *{Table}* worksheet from a selected MYRLIN#1 wortkbook, using the current Options, species list and data settings in that workbook.
UpdateLabels macro	If the groups are re-sorted or group labels are amended manually, this macro must be run to reflect changes in the data labels on the chart *{Fig1}*. This is not done automatically by Excel. It can also be used to limit the number of groups displayed on the graph, for greater clarity.

The procedure for using this workbook is as follows:

- The *{Table}* worksheet is updated from a MYRLIN#1 workbook using the *MakeD95List* macro to provide initial estimates of growth and mortality.

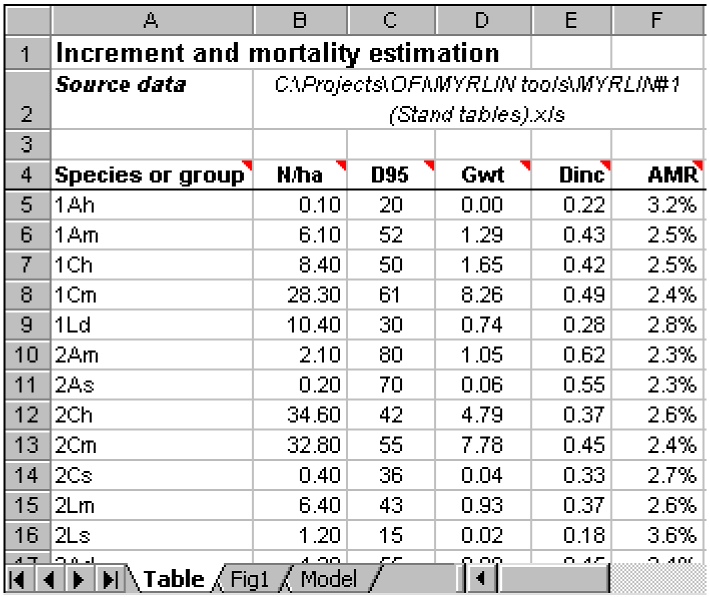
- Groups are examined on *{Fig1}*, and knowledge of ecology and wood properties applied to refine the growth rate estimates. Site adjustments can also be applied if there is some supplementary information.

- The *Group, D95, Dinc* and *AMR* columns on the *{Table}* worksheet are then copied or linked to the harvesting model MYRLIN#3 .

Initial tree growth estimates

obtained from inventory data

When the MYRLIN#2 workbook module opens, three sheets will be seen, as indicated on the diagram opposite. The first of these is called *{Table}*. It is derived from the data in a MYRLIN#1 workbook. Selecting **Alt-F8** or **Tools/Macro/Macros** from the Excel menu brings up the macro dialog window. Selecting and running the macro *MakeD95List* will update the *{Table}* sheet.



	A	B	C	D	E	F
1	**Increment and mortality estimation**					
2	***Source data***	*C:\Projects\OFI\MYRLIN tools\MYRLIN#1 (Stand tables).xls*				
3						
4	**Species or group**	**N/ha**	**D95**	**Gwt**	**Dinc**	**AMR**
5	1Ah	0.10	20	0.00	0.22	3.2%
6	1Am	6.10	52	1.29	0.43	2.5%
7	1Ch	8.40	50	1.65	0.42	2.5%
8	1Cm	28.30	61	8.26	0.49	2.4%
9	1Ld	10.40	30	0.74	0.28	2.8%
10	2Am	2.10	80	1.05	0.62	2.3%
11	2As	0.20	70	0.06	0.55	2.3%
12	2Ch	34.60	42	4.79	0.37	2.6%
13	2Cm	32.80	55	7.78	0.45	2.4%
14	2Cs	0.40	36	0.04	0.33	2.7%
15	2Lm	6.40	43	0.93	0.37	2.6%
16	2Ls	1.20	15	0.02	0.18	3.6%

When the macro is run, a standard Windows *Open file* dialog box will appear. From this select the MYRLIN#1 workbook to be opened. If the file is already open, Excel will warn of this and will then close and re-open it. If the file opened is not properly constructed according the MYRLIN#1 format, Visual Basic error messages will result. If this appears to be happening with a file that ought to be acceptable, review the information in the stand tables section, and ensure that the MYRLIN#1 macro *MakeStandTables* is running within that workbook.

If the data file is correctly formatted, then the *{Table}* sheet will be updated to reflect the chosen groups. The data file name used will be shown in cells B2:F2. The columns on the worksheet above are as follows:

Species group	Species group codes from the species list in MYRLIN#1, using the column selected on the Options sheet for that module. These groups could in fact be individual botanical species, or trade name groups, as well as more general groups. The species grouping topic gives more information about the groups shown in the example.
N/ha	This shows the mean number of trees per ha of the species group across all the inventory data. It is an indicator of abundance, and can be used to sort the groups to show the most important. However, N/ha is relatively strongly influenced by small trees, and *Gwt* (see below) may be a better indicator of importance.
D95	This gives the diameter below which 95% of the trees in the group fall. 5% of the trees are larger. It is an indicator of the typical size of the species, provided that the inventory sample is broadly based (*eg* a regional or national inventory). This is used to provide an initial estimate of increment.
Gwt	This is the mean basal area in m^2/ha of the trees across all inventory plots. It is closely related to volume abundance, and is a better indicator of the importance of groups than N/ha. It can be used to sort the groups so that the most abundant are seen at the top of the list.
Dinc	This is an estimate of the mean diameter increment of the species groups, in cm/yr. When the *MakeD95List* macro is run, this figure is generated from a linear regression of increment on tree size, using as data the pan-tropical group means listed on the *{Model}* sheet. The Reference section gives further information.
AMR	This is an estimate of the mean annual mortality rate, in %/yr, for the species group. It is based on the assumptions discussed in the Mortality estimation topic of the Reference section. The cell contains a formula rather than a calculated value, and care must be taken when copying and pasting to paste the value, using *paste special/values*, rather than an adjusted formula.

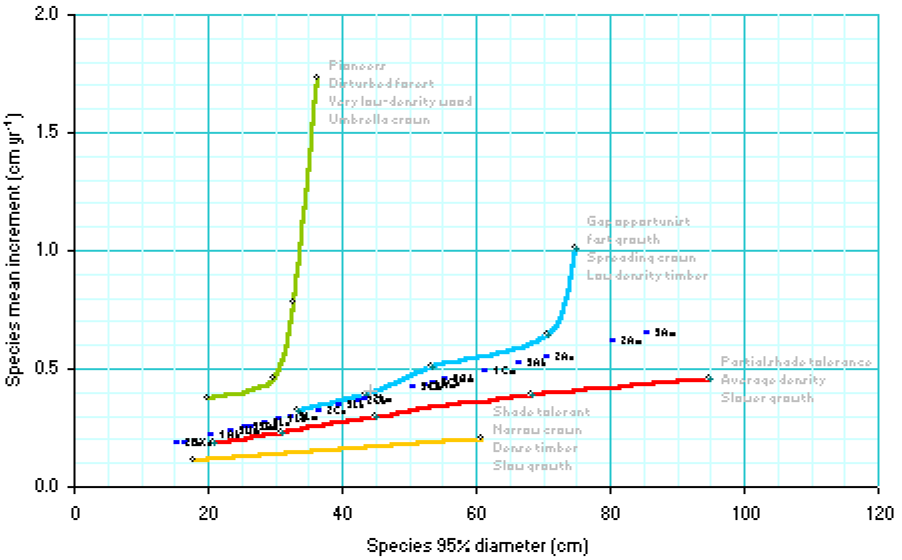
It is important to note that when the *MakeD95List* macro is run, any adjustments made manually to the values in the *{Table}* sheet or to their sorting order will be overwritten.

Refining tree growth estimates

using ecological and wood property information

When the *Tree growth* module is updated from forest inventory data, initial estimates of increment will be made from a regression function, and fall on a straight line. This is shown in the *{fig1}* sheet of the module, as illustrated opposite.

The graph shows the species groups as points, labelled with their codes. The coloured lines link pan-tropical groups with some similar characteristics, as discussed in the Reference section. These '*metagroups*' can be defined as follows:



- Green Pioneer species, very fast growth, occur on large heavily disturbed clearings, low density non-durable timber, fast growth, small maximum size, limited lifespan.

- Blue Semi-pioneer, non-pioneer light demanders, gap opportunists, regenerate in larger gaps, favoured by moderate disturbance, wide spreading, phototropic crowns, lower density, less durable timber, moderately fast growth but may reach large sizes and be relatively long lived.

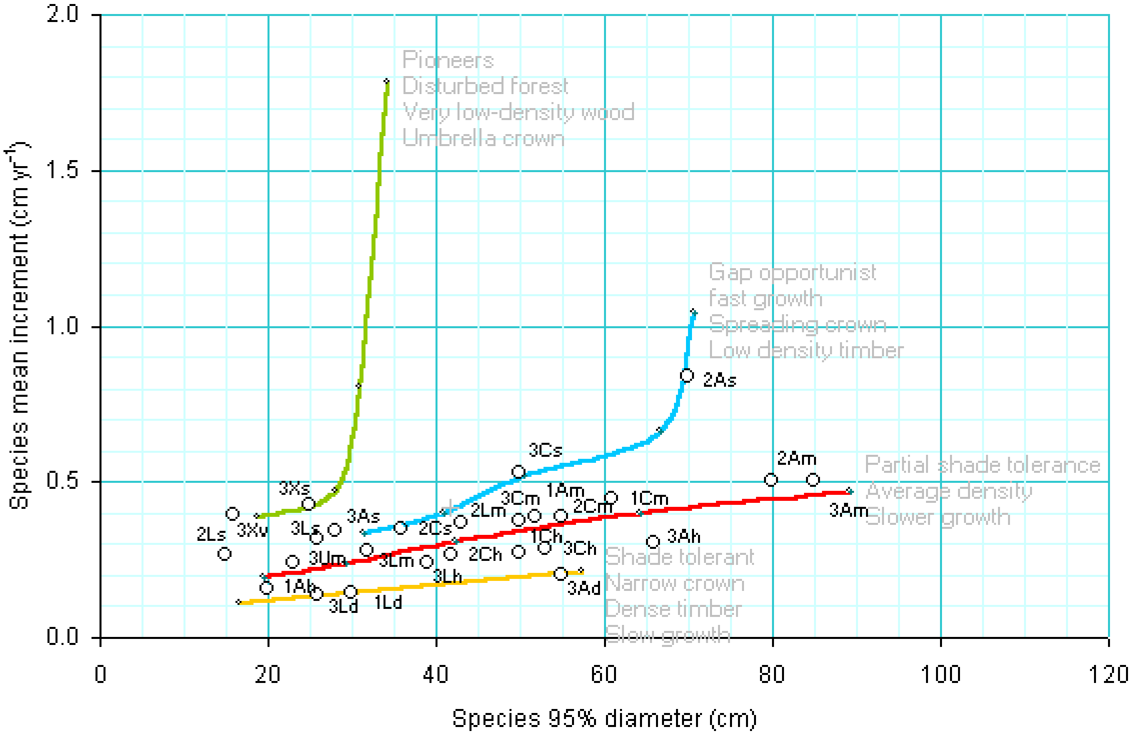
- Red Partially shade tolerant, narrow crowns, moderately dense and durable timbers, long lived, typical of less disturbed forest, may be large canopy emergents or smaller persistent mid-canopy and upper canopy species. Growth rates slower than average.

- Yellow Shade tolerant, narrow crowned, very slow growing and long lived species. Very dense and durable timber.

Average growth rates lie somewhere between the red and blue lines, and this is where MYRLIN provides its first estimate.

These group positions can be adjusted manually to reflect knowledge of ecology or wood density properties. This requires as a preliminary that the formulae inserted into column E of the *{table}* sheet are replaced by the actual values. (How...).

On the graph it is then possible to select individual points and adjust their vertical position according to a perception of ecology, wood density, or growth rate. (How...), using as a guide the indicators in the table above.



With the species groups used in this example (Review) it is possible to position the points based on the last letter. The *s* suffix for low density timbers probably approximates Blue line species. The *m* suffix for species of average density is likely to be intermediate between the Blue and Red lines. The species groups with an *h* suffix for moderately dense, durable timbers, have been set between the Red and Yellow metagroups. The *d* suffix for very dense, hard timbers has been used to move species to the Yellow line. The extreme pioneer *X* and *v* groups have been moved to the Green line. The final results are indicated in the figure above. Note that the point symbol has also been enlarged for greater clarity, and labels positioned for good results when the graph is printed.

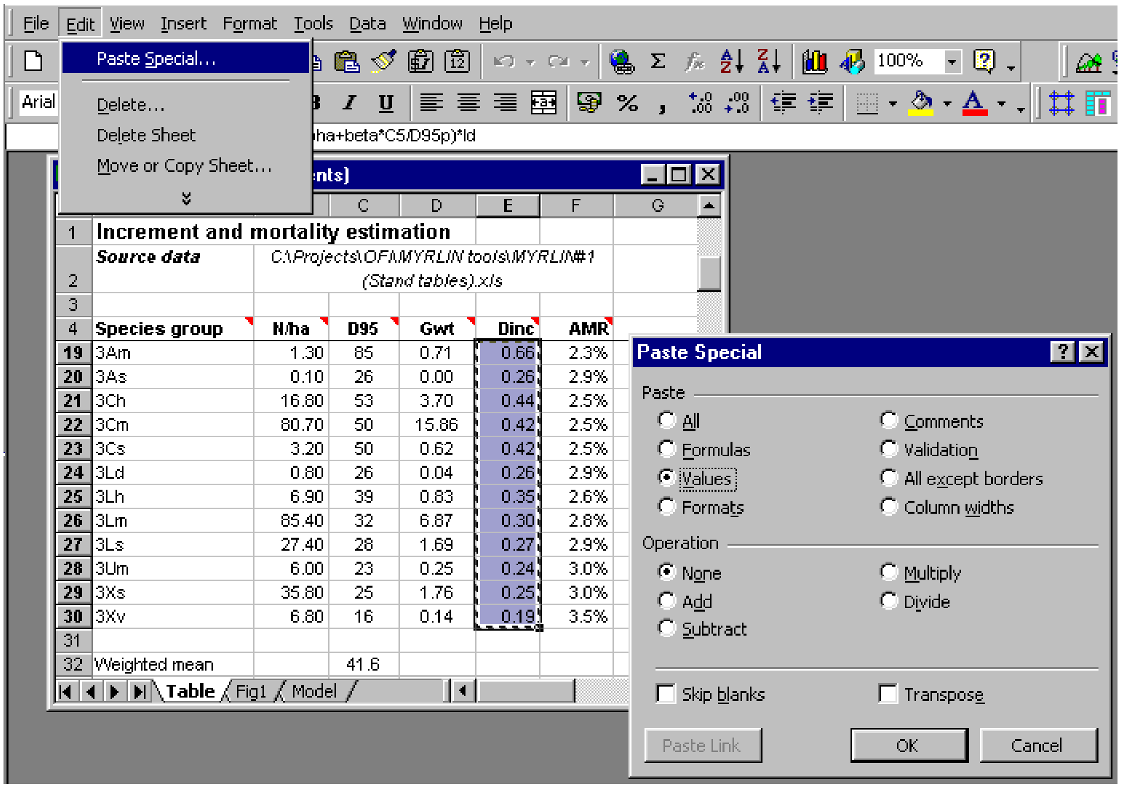
It should also be noted that there are forbidden zones above and to the right of the metagroup to which points should not be moved (View...). Species are very unlikely to occur in these zones.

In the absence of any information about species ecology or wood density, the data points should be left unchanged from the positions initially estimated.

Once all adjustments have been made, then the model parameters can be copied or linked to the Harvesting Model.

Replacing increment formulae by values

as a preliminary to adjusting growth rates graphically



ha+beta*C5/D95p)*ld

			C	D	E	F	G
1	**Increment and mortality estimation**						
2	***Source data***	*C:\Projects\OFI\MYRLIN tools\MYRLIN#1 (Stand tables).xls*					
3							
4	**Species group**	**N/ha**	**D95**	**Gwt**	**Dinc**	**AMR**	
19	3Am	1.30	85	0.71	0.66	2.3%	
20	3As	0.10	26	0.00	0.26	2.9%	
21	3Ch	16.80	53	3.70	0.44	2.5%	
22	3Cm	80.70	50	15.86	0.42	2.5%	
23	3Cs	3.20	50	0.62	0.42	2.5%	
24	3Ld	0.80	26	0.04	0.26	2.9%	
25	3Lh	6.90	39	0.83	0.35	2.6%	
26	3Lm	85.40	32	6.87	0.30	2.8%	
27	3Ls	27.40	28	1.69	0.27	2.9%	
28	3Um	6.00	23	0.25	0.24	3.0%	
29	3Xs	35.80	25	1.76	0.25	3.0%	
30	3Xv	6.80	16	0.14	0.19	3.5%	
31							
32	Weighted mean		41.6				

Paste Special

Paste

○ All ○ Comments
○ Formulas ○ Validation
● Values ○ All except borders
○ Formats ○ Column widths

Operation

● None ○ Multiply
○ Add ○ Divide
○ Subtract

☐ Skip blanks ☐ Transpose

To replace the formulae in the diameter increment column by values, proceed as follows:

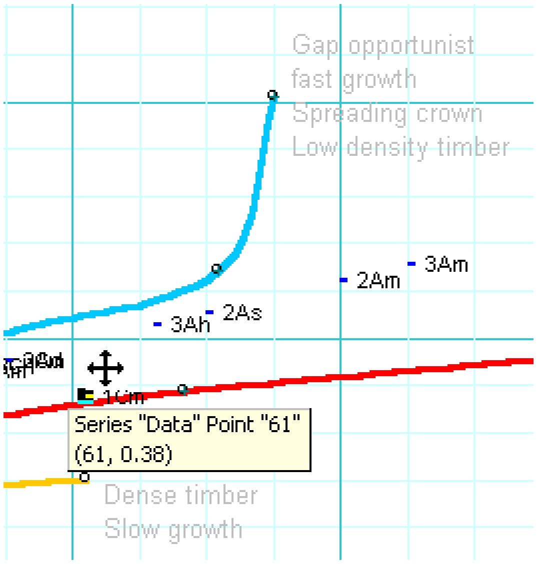
- Select the cells from E5 to the end of the data (here E5:E30)
- Copy them to the clipboard
- Select *PasteSpecial* from the *Edit* menu.
- Click *Values* on the dialog box, as shown above.
- Click *OK*.

The formulae in column 5 will now be found to have been replaced by their equivalent values.

Adjusting points on the graph

using the mouse to select and drag them

Species group points on the graph can be moved by selecting them with the mouse. This takes a little practice. Proceed as follows:



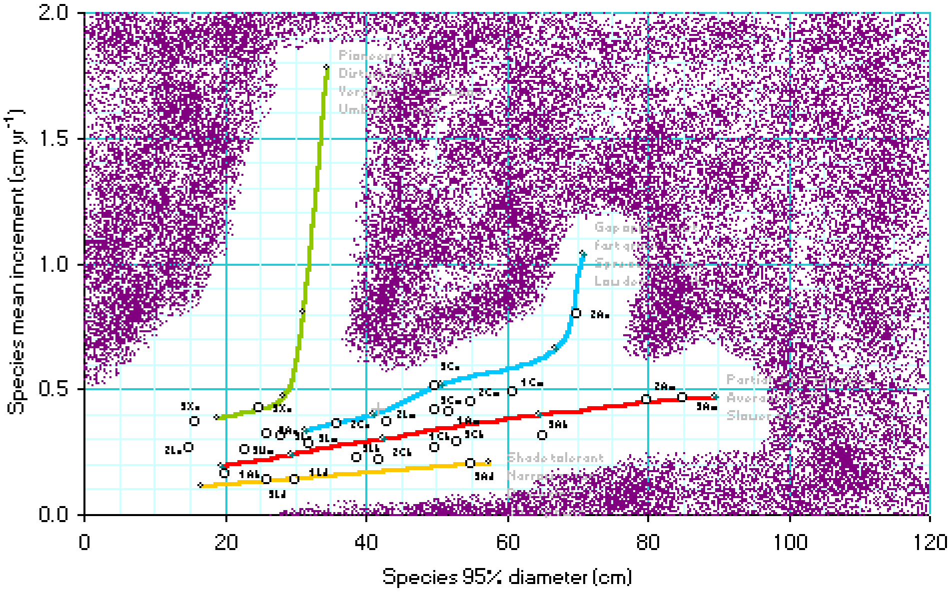
- Click on a selected point *once* only. The whole series will be initially highlighted.
- Click on the point once more. Do not double click. Wait about one second and the cursor will change to the double headed arrow symbol.
- Move the point *up or down* the graph towards the required metagroup line by dragging with the mouse. *Do not* move the point left or right (this will change the D95 value).

As the point is dragged up or down, the *Dinc* value in the *{table}* sheet will change to reflect the point's position. Successive points can be selected and moved in this way. Double-clicking will bring up a format dialog box for the point or series of points, and should be avoided by allowing a pause of about 1 second between successive mouse clicks.

It is also necessary to take care not to select the point label instead of the point. If the label is selected, it can also be moved, but this will not affect the *Dinc* value, only the appearance of the graph. When the label is selected, it becomes surrounded by a small shaded frame. The double arrow cursor will not be seen.

Diagram of forbidden zones

for species growth and size groups



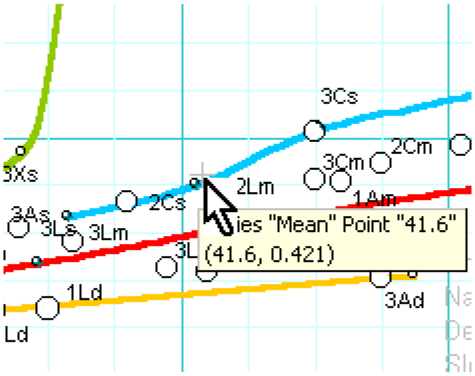
The shaded areas on the diagram are those in which species are not normally seen to occur. Moving species into these areas would not be realistic.

See the Reference section for examples of real species on growth-size diagrams. The unpopulated areas of the graph will be clearly seen.

Site quality and history adjustments

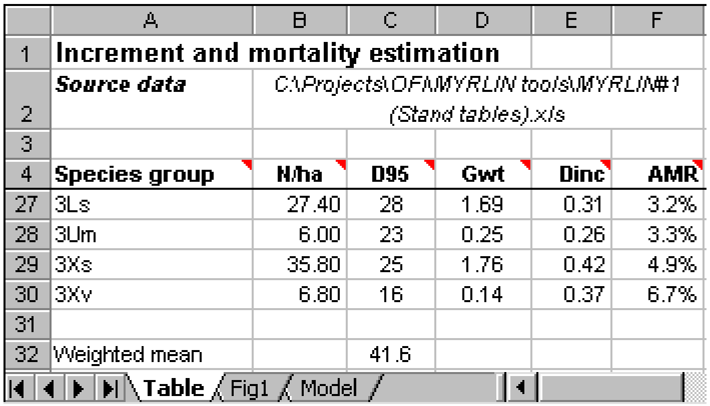
Modifying the tree growth rates for site history or productivity

The species metagroups which are described empirically in the Reference section, and shown on *{Fig1}* of the Myrlin Tree growth tool, are based on relative scales for tree size and increment. These scales can be adjusted for factors that effect them. On the *{fig1}* sheet is a control point marked by a grey cross (see detail at right). This should be located at coordinates of about (42,0.40). This point is linked to cells G3:H3 on the *{models}* sheet.



Moving the control point left or right with the mouse (how...) will adjust the metagroups on the diameter axis. Moving it up or down will adjust them on the increment axis.

The data in the reference section suggests that in spite of wide variations in forest history and environments, the actual mean point for *D95* and mean *Dinc* varies little, so large scale changes in the axes are not likely to be empirically justifiable. It is best that, unless there is clear evidence for differences from the mean values, the control point is left at (42, 0.42).



	A	B	C	D	E	F
1	**Increment and mortality estimation**					
2	***Source data***	*C:\Projects\OFI\MYRLIN tools\MYRLIN#1 (Stand tables).xls*				
3						
4	**Species group**	**N/ha**	**D95**	**Gwt**	**Dinc**	**AMR**
27	3Ls	27.40	28	1.69	0.31	3.2%
28	3Um	6.00	23	0.25	0.26	3.3%
29	3Xs	35.80	25	1.76	0.42	4.9%
30	3Xv	6.80	16	0.14	0.37	6.7%
31						
32	Weighted mean		41.6			

The *{Table}* sheet gives the calculated mean *D95* for the inventory or stock survey data (see cell C32 in the example at the left). This mean value is weighted by the number of trees in each species group. It can be used to adjust the horizontal scale, either by adjusting the control point, as noted above, or by simply copying this directly onto cell H3 of the model sheet.

Direct guidance as to how the vertical scale may be adjusted for site conditions is less easy to obtain, and requires some prior increment information, preferably for several common species with known ecological/wood property attributes. These can then be placed as a series of points on the graph, and the vertical and horizontal scaling adjusted so that they occur more or less as expected in the appropriate metagroups.

In general, as the examples in the Reference section indicate, the scaling on *{fig1}* is robust and fairly typically representative for moist tropical forest, and should not be adjusted unless there is a clear base of evidence on which to do it.

Linking tree growth to the harvest model

Once the species group increment estimates have been made, the *{table}* sheet data should be copied to the MYRLIN#3 Harvest Model module. The following data needs to be copied from the *{table}* sheet of MYRLIN#2 to the *{models}* sheet of MYRLIN#3:

Parameter	**Description**	**Copy from** in MYRLIN#2 *{table}*	**Copy to** in MYRLIN#3 *{models}*
Spp	Species group code	A5:A5+n	A11:A11+n
D95	Typical size (95% of cumulative diameter distribution	C5:C5+n	B11:B11+n
Dinc	Mean diameter increment, in cm/yr	E5:E5+n	C11:C11+n
AMR	Annual mortality rate, in %/yr	F5:F5+n	D11:D11+n

In the above table, *n* is the number of species groups less 1. In the sample data provided with the MYRLIN#2 download, for example, there are 26 groups, with ranges from A5:A30 *etc*. These should be copied to A11:A36 *etc.* in MYRLIN#3 modules.

The copying should be done using the Paste Special option in Excel, either to paste values, or to paste a link. Direct pasting with the default Windows option will cause difficulties if the *AMR* values, and possibly also *Dinc*, are represented by formulae. The formulae will no longer be correct after pasting, and will give wrong results.

Using *Paste Special/Values* is the safest option. The numerical values of the data will be copied, and no automatic updates will occur if MYRLIN#2 is changed. *Paste Special/Paste Link* will put in the address of the originating cell into the target cell, so that the data is automatically kept up to date as MYRLIN#2 is altered. This may not always be desirable however, as changes may be made to the model unintentionally and without being noticed.

For further information see the Harvest model topic.

MYRLIN Harvesting model

The MYRLIN harvesting model is contained in the module MYRLIN#3. It comprises a simple stand projection model that simulates growth and harvesting on coupes of equal areas. The harvested quantities are displayed by year and by coupe. Rules for harvesting such as felling cycle, diameter limit, and the percentage of commercial stems to be conserved during felling, can be specified. Felling damage factors can be varied. The growth models used are those copied from the MYRLIN#2 module. The initial stand table for each forest stratum is taken from MYRLIN#1.

The outputs produced by the model include:

- the detailed areas and volumes felled from each stratum in each year;
- a summary table of volumes felled by years, with equivalent AAC (annual allowable cut);
- a graph that shows harvests and standing volume by years over time.

The objective of the model is to provide projections of sustainable harvesting that is possible, subject to:

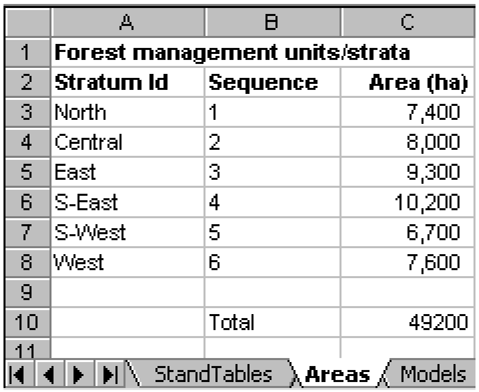
- Species occurrence and distribution, indicated by the stand tables;
- Growth and mortality rate information;
- Logging damage levels;
- Harvesting prescriptions and rules, including diameter limit and felling cycle;

The detailed outputs from the model, by coupe, sub-coupe and year, can form the basis of a management plan schedule. Together with the indicated harvest volumes, these physical quantities can be monitored in a straightforward and inexpensive way to ensure compliance with the plan. The sustained yield volumes also provide a sound basis for investment and financial planning.

Forest areas and growing stock

specification for the MERLYN harvesting model

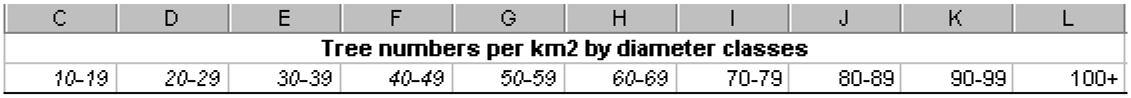
The MYRLIN Harvest Model has two worksheets which describe the initial condition of the growing stock. These are the *{Areas}* and *{StandTables}* sheets. The *{Areas}* sheet (right) lists the forest blocks, and gives their areas in ha. The sequence number can be used for sorting the block list in Excel. Fellings are actually scheduled according to the list order. The areas input must be net forested areas. This table can be copied from the *{Areas}* sheet in the MYRLIN#1 module .



	A	B	C
1	**Forest management units/strata**		
2	**Stratum Id**	**Sequence**	**Area (ha)**
3	North	1	7,400
4	Central	2	8,000
5	East	3	9,300
6	S-East	4	10,200
7	S-West	5	6,700
8	West	6	7,600
9			
10		Total	49200
11			

The *{StandTables}* sheet is identical in general format to the stand tables produced by the MYRLIN#1 module. There must be one table for each block in the areas list, with the lines of the table representing species groups consistent with the growth model data supplied.

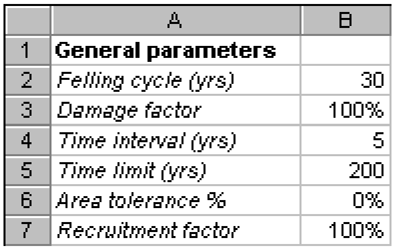
However, the diameter class requirements are more rigid. They must be in ascending sequence without gaps or overlaps, and only the last class may be a cumulative class. 10-cm classes are suggested. Larger classes may degrade model performance. The example below shows appropriate settings.



C	D	E	F	G	H	I	J	K	L
Tree numbers per km2 by diameter classes									
10-19	*20-29*	*30-39*	*40-49*	*50-59*	*60-69*	70-79	80-89	90-99	100+

It will also be noted that whereas MYRLIN#1 can compile stand tables of N/ha, m^2/ha or N/km^2, the stand table in MERLIN#3 must be based on N/km^2 or results will be incorrect.

The *{Models}* sheet sets both general model parameters, and the species group models. The general parameters which may be set are shown at the right as they occur in the worksheet from cells B2:B7:



	A	B
1	**General parameters**	
2	*Felling cycle (yrs)*	30
3	*Damage factor*	100%
4	*Time interval (yrs)*	5
5	*Time limit (yrs)*	200
6	*Area tolerance %*	0%
7	*Recruitment factor*	100%

Felling cycle: This determines the area of the forest harvested in each year. The total area is calculated as the sum of the block areas. This area divided by the felling cycle gives an annual coupe. The model actually works with periodic coupes, and multiplies the annual area by the time interval given in B4.

Damage factor: The logging damage factor is a multiplier applied to the ratio of harvested volume over standing volume to calculate damage in each size class as a percentage of the number of stems. For example, if 20% of the stand volume is harvested, and the damage factor is 1 (or 100%), then 20% of each size class (after felling removals) will be assumed to die or be severely damaged during felling. The formula used in the model is:

$$f = F.V_h / V_{st}$$

where f is the damage % applied to each size class, F is the damage factor entered as a model parameter, V_h is volume harvested, and V_{st} is volume before harvest. A damage factor of 1 (100%) is suggested as an appropriate rule-of-thumb if no better information is available from local damage studies. Note that the damaged trees include non-commercial stems and smaller sizes classes, so the actual impact on advance growth of commercial species may be minimal.

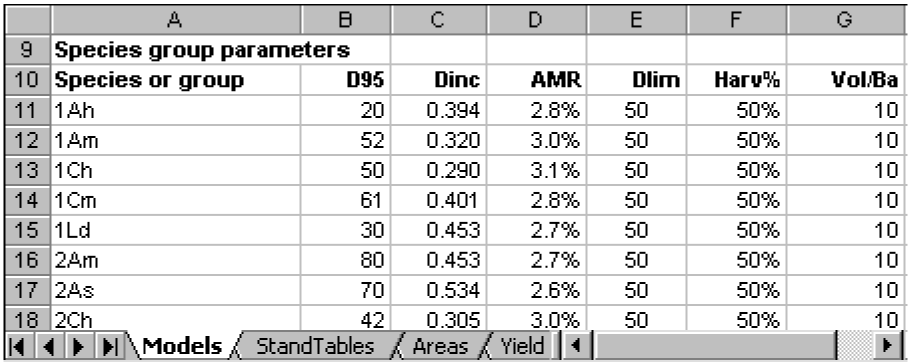
Time interval: The model works by projecting growth cumulatively over short intervals of time from one year upwards. It is recommended that a 5-year interval is normally used, unless there are strong reasons to the contrary. The number of lines of output will increase as time interval is shortened. An interval longer than 5 years may result in some degradation of performance.

Time limit: This defines the total period over which simulations should run. Up to about 100 years, the model will be projecting the growth of existing small trees as they reach commercial sizes, and can be regarded as likely to give reasonable results. Longer projections depend totally on the recruitment assumptions, and must be regarded as increasingly uncertain. It is not recommended that projections beyond 200 years are made except for testing purposes.

Area tolerance: The model will determine a coupe area based on the felling cycle. The area tolerance is the percentage deviation in coupe area that may be allowed in order to make coupes correspond as much as possible with forest blocks. By setting it to a value of around 5%, the model avoids dividing blocks into sub-blocks that are small slivers of forest of a few ha.

Recruitment factor: The model assumes that each tree that dies or is felled will be a replaced by a number of recruits at the smallest measured size. A recruitment factor of 100% means 1:1 replacement, and gives a stable tree population over the long term.

Below the general parameters come settings for each species group. These are illustrated below:



	A	B	C	D	E	F	G
9	**Species group parameters**						
10	**Species or group**	**D95**	**Dinc**	**AMR**	**Dlim**	**Harv%**	**Vol/Ba**
11	1Ah	20	0.394	2.8%	50	50%	10
12	1Am	52	0.320	3.0%	50	50%	10
13	1Ch	50	0.290	3.1%	50	50%	10
14	1Cm	61	0.401	2.8%	50	50%	10
15	1Ld	30	0.453	2.7%	50	50%	10
16	2Am	80	0.453	2.7%	50	50%	10
17	2As	70	0.534	2.6%	50	50%	10
18	2Ch	42	0.305	3.0%	50	50%	10

The *D95*, *Dinc* and *AMR* figures are copied from the MYRLIN#2 {table} sheet, or can be entered directly from other sources. They give, respectively, the 95% cumulative diameter for the species, as a measure of mature size; the mean diameter increment, in cm/yr, and the annual mortality rate, in %/year. *Dlim* and *Harv%* are forest management factors for the species group, and are discussed elsewhere. The *Vol/BA* ratio is the form height for the species (or ratio of volume to basal area), and is used in the model to calculate volume. If this is not known, a rule of thumb applicable to moist tropical forest is that it is likely to be about 10 for many species.

Forest management options

for the MERLYN harvesting model

Forest management, in the MYRLIN harvesting model, can be varied through the following factors:

Felling cycle This is set at cell B2 on the *{models}* sheet. It determines the area of forest felled during any one period, and the return period to a given coupe. Longer felling cycles allow more growth to accrue above the felling limit, but cut smaller areas; the two effects approximately balance, so the influence of felling cycle on average yield is not strong, and simulations across a range of values may not show any definite optimum.

Diameter limits The minimum size below which a species may not be felled is set in column E from row 11 downwards, on the *{models}* sheet. Increasing the diameter limit will reduce the number of trees which may be felled, and will therefore directly reduce yields.

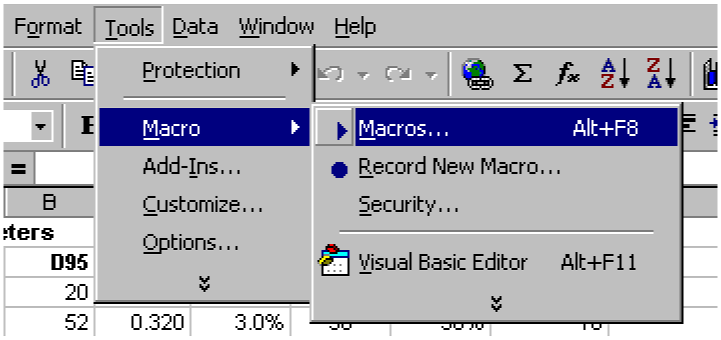
Harvest % The percentage of trees above the minimum diameter limit which may be felled is set in column F from row 11 downwards, on the *{models}* sheet. This will directly influence available yield: Reducing harvest % will proportionately reduce yield. This factor can simulate conservation measures to protect seed trees, and may also reflect the reality that for many species, form and decay defects do not permit 100% of available stems to be economically harvested.

Logging damage The logging damage factor set at cell B3 of the *{models}* sheet can be used to simulate the effect of RIL. However, because of the dilution effect of the non-commercial and small size trees, the impact on future yields of even quite large changes in the logging damage factor will be found to be small.

A stand projection model such as MYRLIN is not sensitive to some dynamic aspects of stand behaviour. For example, lower diameter limits may reduce seed trees on species under heavy commercial pressure. The model does not account for this. Heavy logging may induce more frequent fires, erosion, nutrient losses, and pioneer re-growth that impedes valuable trees. Some important commercial species require disturbance in order to regenerate properly. None of these factors are accounted for in the model. It should therefore not be seen as a decision-making tool about silviculture. It is rather, a useful calculating system for yield estimation given moderate, mainstream management practices. It will estimate yields over time subject to species distribution by blocks and through size classes, and will account for the main effects of increment and mortality on yield.

Running the MYRLIN harvesting model

The harvesting model is started by running the macro *RunModel*. To do this, with MYRLIN#3 as the active workbook, either press **Alt-F8**, or select **Tools, Macro, Macros** from the menu, as shown at the right. (Note that Excel 2000 and Excel XP can vary the order in which bars appear in each menu according to frequency of use).



Provided the setup sheets *{Areas}*, *{StandTables}* and *{Models}* are correctly specified, the model will then run and update the output sheets. These are called *{Yield}*, *{Fig1}* and *{Table1}*.

If difficulties occur in running the macro *RunModel*, please refer to the troubleshooting guide in the Help topic.

Volume and allowable cut

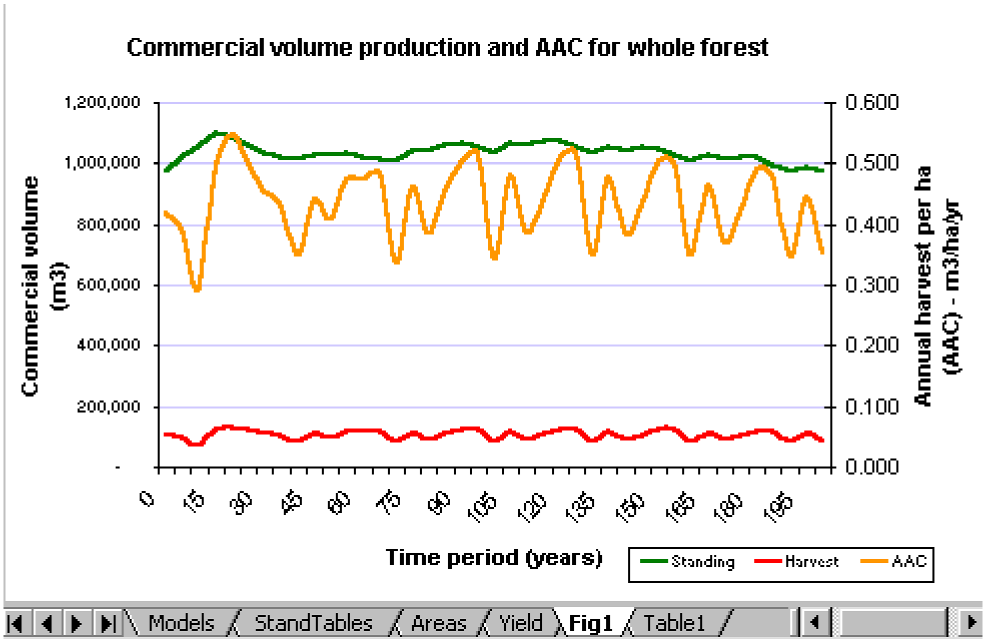
Yield estimates from the MERLYN harvesting model

Yields over time estimated by MYRLIN#3 are shown graphed on the sheet *Fig1*, as for the example below. Three lines are shown:

Standing commercial volume This is shown as a green line, read from the left axis, in total m3. This is the volume above the minimum felling diameter, for the species groups indicated as commercial.

Harvested volume This is shown in red against the left axis, in m3. It shows the actual volume removed during each simulation period. In the example shown this will be 5 years.

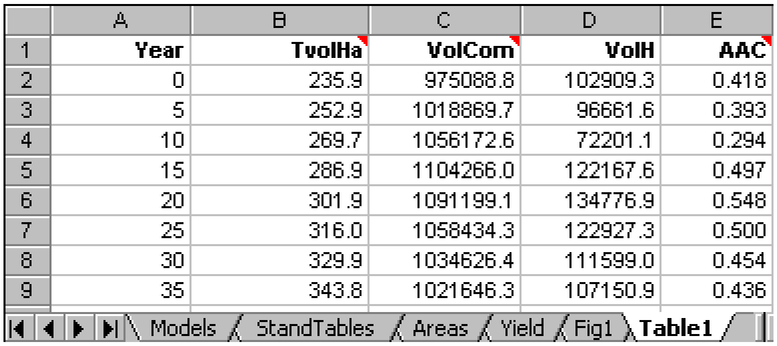
Annual allowable cut (AAC) This is indicated by a yellow line. It is read from the right axis, and shows the harvest removed in terms of m3/ha/year.



The harvest and AAC are the same data but on different scales. To obtain AAC, the actual harvest is divided by the harvested area and the time interval for the model, to obtain a figure in m3/ha/yr.

The figures shown fluctuate from period to period because the MYRLIN#3 model controls felling on an area rather than a volume basis. Having determined the area of a periodic coupe, it will then work through the blocks in the sequence given felling this area. Because of differences in growing stock between blocks, fluctuations will occur.

The graph lines on *{Fig1}* correspond to the columns on the worksheet *{Table1}*, part of which is shown at the right. The columns headed VolCom, VolH and AAC correspond to the standing commercial volume (green), harvested volume (red) and AAC (yellow) lines on the *{fig1}* sheet. The column headed TvolHa gives the total volume of all species in the model in terms of m3/ha. This is not plotted on the graph or shown as an area total as the figure is often so large relative to commercial volume that it would suppress the scale of the latter and make it unreadable.

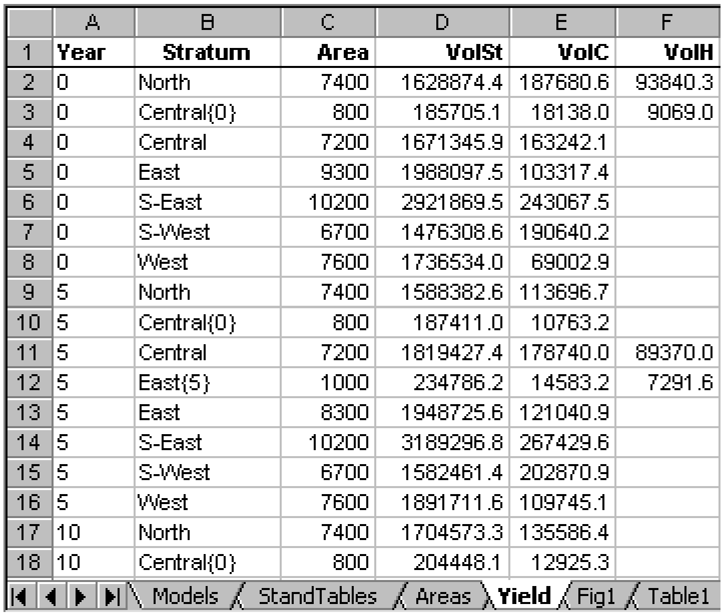


	A	B	C	D	E
1	**Year**	**TvolHa**	**VolCom**	**VolH**	**AAC**
2	0	235.9	975088.8	102909.3	0.418
3	5	252.9	1018869.7	96661.6	0.393
4	10	269.7	1056172.6	72201.1	0.294
5	15	286.9	1104266.0	122167.6	0.497
6	20	301.9	1091199.1	134776.9	0.548
7	25	316.0	1058434.3	122927.3	0.500
8	30	329.9	1034626.4	111599.0	0.454
9	35	343.8	1021646.3	107150.9	0.436

Coupe schedule by years

from the MERLYN harvesting model

A schedule of coupes is produced by the MYRLIN#3 model on the worksheet *{yield}*. An example of this output is shown at the right. The column headed <u>VolSt</u> gives the total standing volume of the block, for all species and size classes in the model. Column <u>VolC</u> shows the volume of commercial species, above the minimum felling diameter, before harvesting. <u>VolH</u> shows the volume actually harvested. Within each time period, there is one line for each coupe, which also gives the coupe area in hectares.



	A	B	C	D	E	F
1	**Year**	**Stratum**	**Area**	**VolSt**	**VolC**	**VolH**
2	0	North	7400	1628874.4	187680.6	93840.3
3	0	Central{0}	800	185705.1	18138.0	9069.0
4	0	Central	7200	1671345.9	163242.1	
5	0	East	9300	1988097.5	103317.4	
6	0	S-East	10200	2921869.5	243067.5	
7	0	S-West	6700	1476308.6	190640.2	
8	0	West	7600	1736534.0	69002.9	
9	5	North	7400	1588382.6	113696.7	
10	5	Central{0}	800	187411.0	10763.2	
11	5	Central	7200	1819427.4	178740.0	89370.0
12	5	East{5}	1000	234786.2	14583.2	7291.6
13	5	East	8300	1948725.6	121040.9	
14	5	S-East	10200	3189296.8	267429.6	
15	5	S-West	6700	1582461.4	202870.9	
16	5	West	7600	1891711.6	109745.1	
17	10	North	7400	1704573.3	135586.4	
18	10	Central{0}	800	204448.1	12925.3	

The model harvests a fixed area in each simulation period. In this case, the felling cycle is 30 years, the time period is 5 years, and total forest area is 49,200 ha, so 8,200 ha are felled in each period (*ie.* 49,200/30 x 5). It will be seen that where a block is more or less than this amount, then a block is subdivided into a smaller coupe so that the exact area can be felled. In the example shown, the entire area of the *North* block is felled in years 0-4 (7,400 ha), together with 800 ha from the next block, *Central*. This sub-block is labelled *Central{0}* to show its parent block, and the year it was originally separated out in order to meet the area control criteria. In years 5-9, the remainder of the *Central* block are felled (7,200 ha) plus 1,000 ha from block *East*; this latter partial felling is called *East{5}*.

In the course of a simulation, it is possible for a sub-block to be further subdivided. In this case, the year of further sub-division will again be added, so you could have *Central{0}{35}*, for example. This would occur commonly if the blocks are few in number (maybe only a single block initially) and the number of growth periods large.

This table is designed to be used as a schedule directly in a management plan for both area control, and volume monitoring and control. If the plan is being adhered to, the specified blocks and areas should be felled in the given years.

This table can be manipulated in various ways using standard Excel tools and functions to provide other information and graphs. For example, by sorting on the *Stratum* field, then on *Year*, the history of each block and its sub-divisions will be seen more clearly. In the planning process, these sub-divisions need to be converted into map units, through a consideration of the developing forest transport network.

Reference: Pan-tropical species groups

Methods and data for pan-tropical growth estimation

The underlying thesis of MYRLIN is that diameter increment patterns for tropical forest species have broad similarities from region to region. This allows general assumptions to be made about growth rates in the absence of direct observations from permanent sample plots.

This section presents the empirical basis for this approach. It presents summaries of species mean increment and typical size data from four regions: Eastern Amazonia, Northern Costa Rica, Papua New Guinea, and Guyana. These are shown in both graphical and tabular form. The tables list about 100 of the most common species from the PSPs in each zone, with their growth statistics.

For each regional data set, the species are grouped using a simple ordination technique. A detailed description of the method is given. It allows a common set of group seeds to be applied to each region, but the actual result will depend on the local distribution of species frequency-increment-size relationships. Using 16 standard 'seed' groups (designated by the letters A-S with I,O and Q not used), common patterns emerge, which form the basis for a generalized analysis.

In the general analysis, the data are standardized using the local mean increment and mean size of all species, except for those of Guyana. The grouping is re-applied to these standardized data to form general pan-tropical groups. The group characteristics are illustrated by reference to key species from the regions to show typical ecological and wood properties. The predictive power of the method is tested by its accuracy in predicting the Guyana group means.

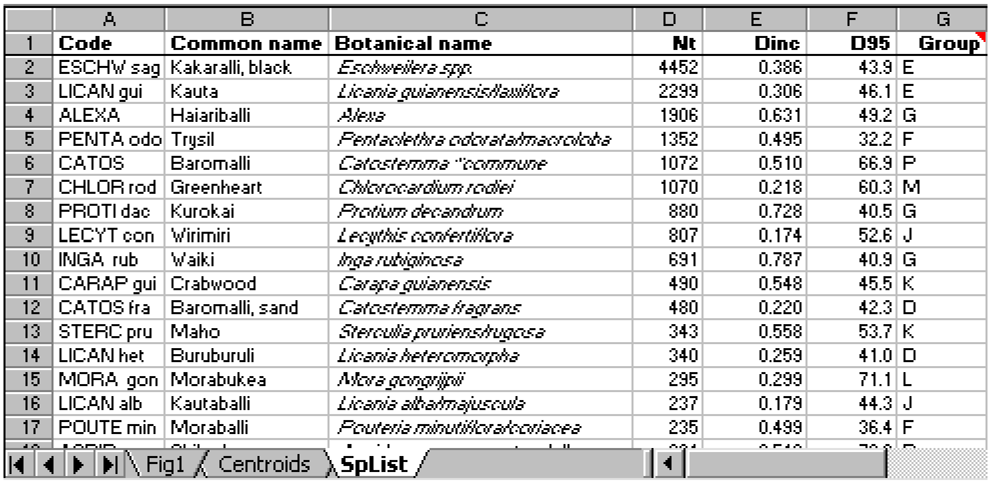
Method of forming species groups

The method of grouping species that is used in the following examples is based on an ordination of species mean increment (*Dinc*) on typical size. Typical size is given by the 95% point on the cumulative diameter distribution (*D95*). This allows each species to be represented as a point on a graph, with mean increment on the y-axis, and 95% diameter on the x-axis.

The groups are formed by starting with a number of seed points, which are located manually on the graph to represent the apparent clustering of the data. Then each species is examined in turn, and assigned to the nearest seed point (group centroid). Having found the nearest, the group centroid is then updated to reflect the contribution of that species. The process is repeated until all species have been assigned to groups. The centroid of each group tends to wander a little as new species are added in, and the final value will depend to some degree on the order species are added, and the starting values used. These effects are reduced if the species are sorted to add in the most common first, and the starting values are refined iteratively. For the latter, the final group centroids of the first trial are used as initial seed values for a second trial, and so on until there is no further change in the group centroid values.

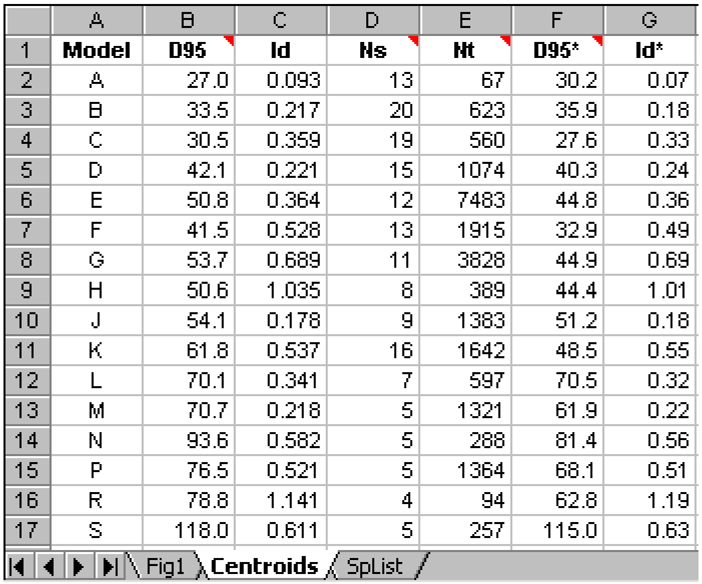
The 'distance' from a species to a group centroid can be scaled or transformed in various ways. In this study, each axis is standardized by dividing by the mean *D95* or *Dinc* for all the species, and then applying a logarithmic transformation.

An Excel workbook can be downloaded which contains the necessary macros to carry out these procedures, and also prepare graphs to the same standard as those shown in the examples. This workbook is not a formal part of the MYRLIN tools, as it requires summaries from permanent sample plots, giving measured species increments. However, given such data, it does provide a simple species grouping tool. The workbook, called *Species Grouping Algorithm* comprises two worksheets and a graph.



	A	B	C	D	E	F	G
1	**Code**	**Common name**	**Botanical name**	**Nt**	**Dinc**	**D95**	**Group**
2	ESCHW sag	Kakaralli, black	*Eschweilera spp.*	4452	0.386	43.9	E
3	LICAN gui	Kauta	*Licania guianensis/laxiflora*	2299	0.306	46.1	E
4	ALEXA	Haiariballi	*Alexa*	1906	0.631	49.2	G
5	PENTA odo	Trysil	*Pentaclethra odorata/macroloba*	1352	0.495	32.2	F
6	CATOS	Baromalli	*Catostemma "commune*	1072	0.510	66.9	P
7	CHLOR rod	Greenheart	*Chlorocardium rodiei*	1070	0.218	60.3	M
8	PROTI dac	Kurokai	*Protium decandrum*	880	0.728	40.5	G
9	LECYT con	Wirimiri	*Lecythis confertiflora*	807	0.174	52.6	J
10	INGA rub	Waiki	*Inga rubiginosa*	691	0.787	40.9	G
11	CARAP gui	Crabwood	*Carapa guianensis*	490	0.548	45.5	K
12	CATOS fra	Baromalli, sand	*Catostemma fragrans*	480	0.220	42.3	D
13	STERC pru	Maho	*Sterculia pruriens/rugosa*	343	0.558	53.7	K
14	LICAN het	Buruburuli	*Licania heteromorpha*	340	0.259	41.0	D
15	MORA gon	Morabukea	*Mora gongrijpii*	295	0.299	71.1	L
16	LICAN alb	Kautaballi	*Licania alba/majuscula*	237	0.179	44.3	J
17	POUTE min	Moraballi	*Pouteria minutiflora/coriacea*	235	0.499	36.4	F

The first worksheet, illustrated here, is called *SpList*. It has 6 columns of data, which must be summarized from permanent sample plot analysis. The first three columns are for species code, common and botanical name; however, these data are not used by the macro, and could represent any type of species identification information. Column D however must represent a count of the number of trees of that species observed on the PSPs, or another abundance index that can be effectively represented as an integer value. Column E should contain the mean increment for the species in cm/yr. Column F should contain the 95% cumulative diameter in cm. Column G should be an empty column that will be written with the group code assigned to the species. The macro expects the data to start in row 2, and terminates reading when a blank cell is encountered in column 4.

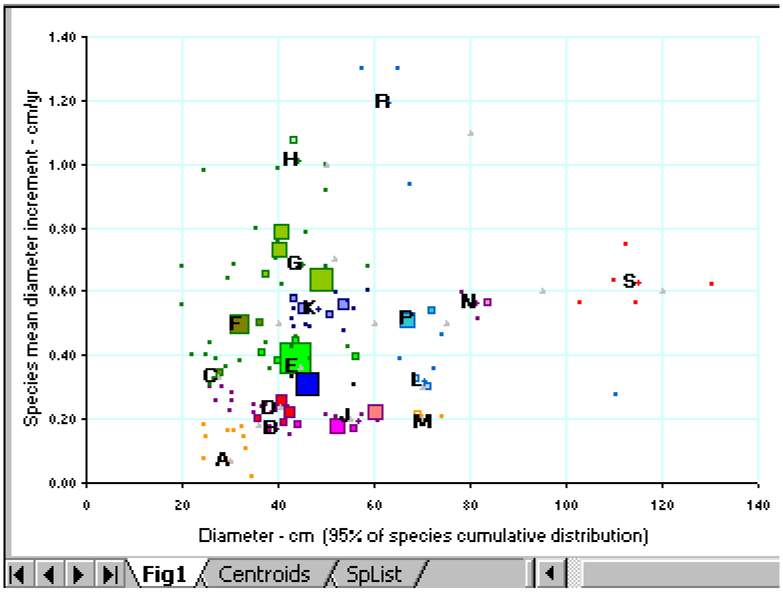


	A	B	C	D	E	F	G
1	**Model**	**D95**	**Id**	**Ns**	**Nt**	**D95***	**Id***
2	A	27.0	0.093	13	67	30.2	0.07
3	B	33.5	0.217	20	623	35.9	0.18
4	C	30.5	0.359	19	560	27.6	0.33
5	D	42.1	0.221	15	1074	40.3	0.24
6	E	50.8	0.364	12	7483	44.8	0.36
7	F	41.5	0.528	13	1915	32.9	0.49
8	G	53.7	0.689	11	3828	44.9	0.69
9	H	50.6	1.035	8	389	44.4	1.01
10	J	54.1	0.178	9	1383	51.2	0.18
11	K	61.8	0.537	16	1642	48.5	0.55
12	L	70.1	0.341	7	597	70.5	0.32
13	M	70.7	0.218	5	1321	61.9	0.22
14	N	93.6	0.582	5	288	81.4	0.56
15	P	76.5	0.521	5	1364	68.1	0.51
16	R	78.8	1.141	4	94	62.8	1.19
17	S	118.0	0.611	5	257	115.0	0.63

The second worksheet is called *Centroids*, and appears as shown. Columns A-C are completed by the user. The others should be left blank, as they are over-written by the macro. Column A contains the group code to be used. This could be any text code, of any length. Within the context of MYRLIN, a standard system of group codes based on a single capital letter is used, but the macro is not restricted to this. Column B and C contain initial group locations, as estimated by a visual examination of the data, in terms of the D95 and Diameter increment values for the group mean. These are best arrived at graphically, by plotting a set of arbitrary group coordinates on top of the data (See *Fig1* below), and then using the mouse to drag the centroid into a suitable point to represent a group. Excel will automatically adjust the table accordingly.

When the macro has been run, column D shows the number of species in each group; column D gives the total number of trees; Columns E and F give the group centroid X and Y values (*D95* and *Dinc*).

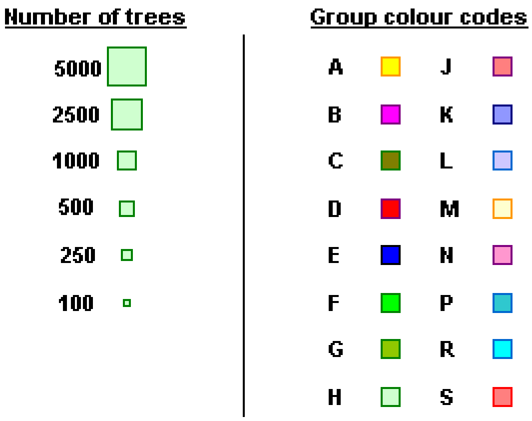
The macro is called *MakeGroups*, and is run in the same way as the MYRLIN macros, using the *Alt-F8* key, or the **Tools→Macro→Macros** menu selections. It will run through the algorithm described at the top of the page, assigning each species to a group, and updating the group centroids iteratively as species are added. The group codes from the *Centroids* table are written into column G of the *SpList*
sheet as it proceeds.



Sheet *Fig1* overlays three data series. The first uses the species data from sheet *SpList*, with *D95* on the x-axis, and *Dinc* on the y-axis. The points are shown as coloured squares whose size is proportional to the number of trees (*Nt*) in the species sample. The colours correspond to the species groups assigned.

The second data series shows the group codes in bold letters, with the centroid of each group marked with a +. These are the final calculated groups, taken from columns F:G on sheet *Centroids*. The third series, not visible in the example, gives the original centroid positions and labels in pale grey (columns B:C on sheet *Centroids*). These latter can be manipulated with the mouse to test the effect of different starting positions.

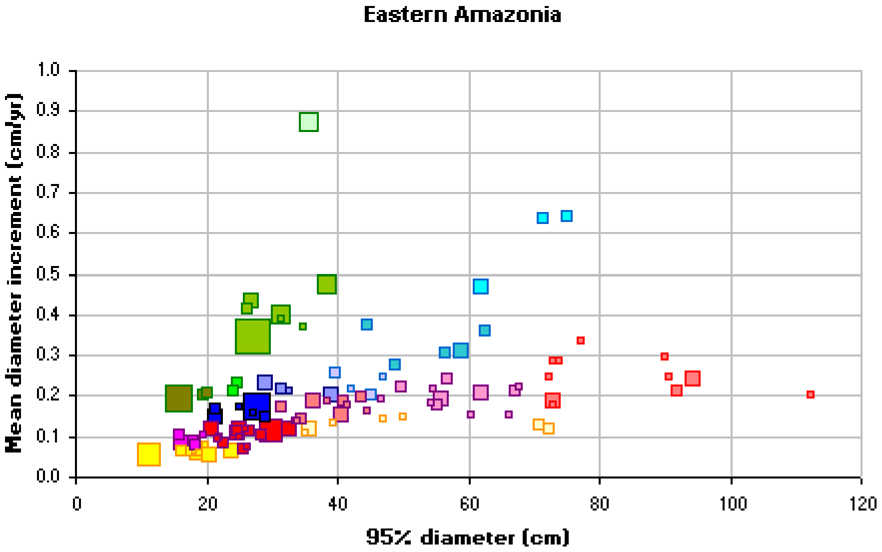
The marker labels, colours, and sizes are not maintained automatically by Excel, but are updated by a macro called *UpdateFig*. This has been set up to use the size and colour scheme shown in the key opposite, and would need modification if a different scheme of group codes were used. *UpdateFig* is run automatically when *MakeGroups* is run; it should also be run directly if the data in the *SpList* of *Centroids* sheet are sorted or otherwise modified.



To download the workbook and its macros, see the Downloads page. The Visual Basic macros can be reviewed via the *Excel Visual Basic Editor* (Alt-F11) to see the detailed techniques employed. The macro is quite generic, and can be applied to any weighted ordination problem in two dimensions; it is only necessary to change the *Dinc* and *D95* labels at appropriate places on the worksheets and chart.

Eastern Amazonia

Species growth summaries from 136 permanent plots



The figure above shows summary growth data from 105 species from the eastern Amazon. The x-axis gives species cumulative 95% diameter (typical size) in cm; the y-axis shows species mean increment in cm/yr. Each point represents a single species. The data are taken from permanent sample plots and experimental plots at Jari and Tapajos forests. These plots have been measured and managed by EMBRAPA-Amazonia Oriental. The data comprises in total 96 ¼-ha plots, measured over 14 years at Tapajos, and 40 1-ha plots measured over 10 years at Jari. All plots were located on *Terra firme* forest, and included both heavily logged, lightly treated, and unlogged virgin forest areas. The species were selected as those most abundant on the PSPs. Plot designs, background information and preliminary results are given in the articles listed below.

The colours indicate species from similar species groups, as determined by an ordination process. Symbol size corresponds to the number of trees sampled for each species(see key). The individual species names and detailed statistics can be viewed by clicking on parts of the graph above, or by browsing the data table for the graph. In the table, *Nt* is the number of trees sampled for each species; *D95* is the 95% cumulative diameter; *Id* is mean increment in cm/yr.

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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.

List of species from Eastern Amazonia permanent sample plots

Botanical name	Family	Nt	D95	Id	Group
Rinorea flavescens	Viol.	1681	11.4	0.053	A
Duguetia echinophora	Annon.	871	18.8	0.065	A
Guarea kunthiana	Meli.	474	23.7	0.063	A
Talisia longifolia	Sapind.	438	20.4	0.055	A
Coussarea paniculata	Rubi.	394	17.5	0.066	A
Sagotia racemosa	Euphorbi.	260	18.5	0.067	A
Theobroma speciosum	Sterculi.	248	16.3	0.064	A
Paypayrola grandiflora	Viol.	181	16.2	0.066	A
Pausandra densiflora	Euphorbi.	110	18.8	0.060	A
Eugenia lambertiana	Myrt.	411	16.3	0.084	B
Casearia favitensis	Flacourti.	238	18.1	0.088	B
Quararibea guianensis	Bombac.	223	15.8	0.102	B
Lacunaria jenmanii	Quin.	202	18.4	0.081	B
Casearia javitensis	Flacourti.	97	19.6	0.102	B
Sloanea froesii	Elaeocarp.	1876	15.9	0.193	C
Tachigalia sp	Caesalpini.	370	19.5	0.204	C
Miconia surinamensis	Melastomat.	235	20.3	0.206	C
Rinorea guianensis	Viol.	1749	29.9	0.114	D
Neea sp	Nyctagin.	693	24.9	0.117	D
Eschweilera odora	Lecythid.	629	32.7	0.118	D
Perebea guianensis	Mor.	532	20.8	0.116	D
Myrcia falax	Myrt.	414	24.8	0.107	D
Eperua bifuga	Caesalpini.	368	25.5	0.071	D
Sahagunia racemifera	Mor.	242	26.7	0.113	D
Guarea sp	Meli.	205	24.8	0.114	D
Diospyros spp	Eben.	162	28.4	0.105	D
Myrcia Cf. m paivae	Myrt.	161	22.5	0.084	D
Rinorea lindeniana	Viol.	153	25.1	0.100	D
Licania heteromorpha	Chrysobalan.	142	26.1	0.116	D
Mabea sp	Euphorbi.	121	22.0	0.097	D
Duroia sprucei	Rubi.	107	26.2	0.073	D
Eugenia patrisii	Myrt.	89	21.7	0.094	D
Protium apiculatum	Burser.	2128	27.7	0.174	E
Miconia sp	Melastomat.	616	21.5	0.150	E
Cordia alliodora	Boragin.	311	21.4	0.168	E
Sterculia pilosum	Sterculi.	222	29.0	0.146	E
Paraprotium amazonicum	Burser.	128	25.1	0.174	E

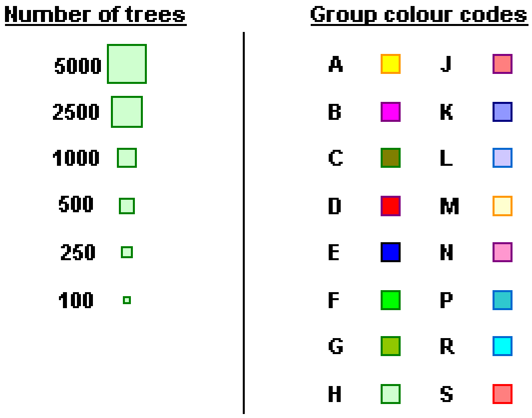
Pithecelobium racemosum	Mimos.	101	27.1	0.159	E
Anaxagorea dolichocarpa	Annon.	197	24.8	0.231	F
Virola cuspidata	Myristic.	191	24.0	0.212	F
Inga spp	Mimos.	3630	27.1	0.346	G
Bixa arborea	Bix.	1127	38.6	0.471	G
Jacaranda copaia	Caric.	876	31.3	0.397	G
Cecropia leucoma	Mor.	747	27.0	0.433	G
Porouma longipendula	Mor.	298	26.4	0.414	G
Jacaratia spinosa	Caric.	107	31.4	0.391	G
Didymopanax morototoni	Arali.	94	34.7	0.367	G
Cecropia sciadophylla	Mor.	1156	35.7	0.874	H
Guatteria poeppigiana	Annon.	646	36.2	0.189	J
Eschweilera amazonica	Lecythid.	629	40.7	0.151	J
Protium sagatianum	Burser.	240	41.0	0.189	J
Ormosia sp	Fab.	188	31.3	0.173	J
Iryanthera sagotiana	Myristic.	179	43.7	0.195	J
Brosimum guianensis	Mor.	173	34.6	0.145	J
Neea constricta	Nyctagin.	125	44.6	0.164	J
Sterculia excelsa var. pilosa	Sterculi.	119	41.5	0.179	J
Diospyros praetermissa	Eben.	103	33.6	0.136	J
Licania spp	Chrysobalan.	102	33.9	0.140	J
Ocotea spp	Laur.	97	38.4	0.186	J
Licaria canella	Laur.	426	39.1	0.202	K
Cordia bicolor	Boragin.	401	29.0	0.232	K
Protium opacum	Burser.	193	31.3	0.218	K
Drypetes variabilis	Euphorbi.	143	32.7	0.211	K
Laetia procera	Flacourti.	231	39.8	0.254	L
Dendrobangia boliviana	Icacin.	210	45.2	0.202	L
Helicostylis pedunculata	Mor.	119	42.2	0.217	L
Enterolobium maximum	Mimos.	94	47.1	0.245	L
Eschweilera blanchetiana	Lecythid.	563	35.7	0.117	M
Iryanthera juruensis	Myristic.	181	70.7	0.126	M
Holopyxidium jarana	Lecythid.	163	72.5	0.117	M
Eschweilera coriacea	Lecythid.	145	47.0	0.142	M
Maytenus floribunda	Celastr.	131	39.4	0.132	M
Mezilaurus lindaviana	Laur.	124	50.1	0.149	M
Eschweilera spp	Lecythid.	117	35.2	0.107	M
Geissospermum sericeum	Apocyn.	700	55.9	0.192	N
Pouteria sp	Sapot.	549	62.0	0.207	N
Minquartia guianensis	Olac.	375	67.3	0.212	N
Eschweilera jurunensis	Lecythid.	233	56.8	0.242	N
Apeiba albiflora	Tili.	182	49.8	0.220	N
Pouteria bilocularis	Sapot.	173	55.3	0.176	N
Chimarrhis turbinata	Rubi.	148	67.8	0.224	N
Maquira sclerophylla	Mor.	137	46.7	0.190	N

Mouriri callocarpa	Melastomat.	102	54.6	0.219	N
Parkia pendula	Mimos.	94	66.4	0.152	N
Lecythis poitequi	Lecythid.	93	60.6	0.151	N
Brosimum lactescens	Mor.	86	54.3	0.184	N
Carapa guianensis	Meli.	458	58.9	0.312	P
Virola melinonii	Myristic.	380	49.0	0.278	P
Tapirira guianensis	Anacardi.	298	44.5	0.373	P
Ocotea douradensis	Laur.	197	56.5	0.305	P
Virola michelli	Myristic.	172	62.7	0.362	P
Sclerolobium chrysophyllum	Caesalpini.	497	62.1	0.466	R
Tachigalia myrmecophylla	Caesalpini.	327	75.1	0.640	R
Sclerolobium tinctorium	Caesalpini.	160	71.5	0.635	R
Couratari oblongifolia	Rubi.	436	73.1	0.185	S
Manilkara huberi	Sapot.	415	94.3	0.243	S
Goupia glabra	Celastr.	260	92.0	0.214	S
Micropholis guianensis	Sapot.	131	74.0	0.284	S
Corytophora rimosa	Lecythid.	125	72.3	0.246	S
Manilkara bidentada	Sapot.	111	90.8	0.248	S
Syzygiopsis oppositifolia	Sapot.	105	90.1	0.297	S
Trattinickia rhoifolia	Burser.	102	73.1	0.288	S
Endopleura uchi	Humiri.	101	77.3	0.337	S
Hymenaea courbaril	Fab.	94	112.3	0.201	S
Astronium gracile	Anacardi.	91	73.1	0.178	S

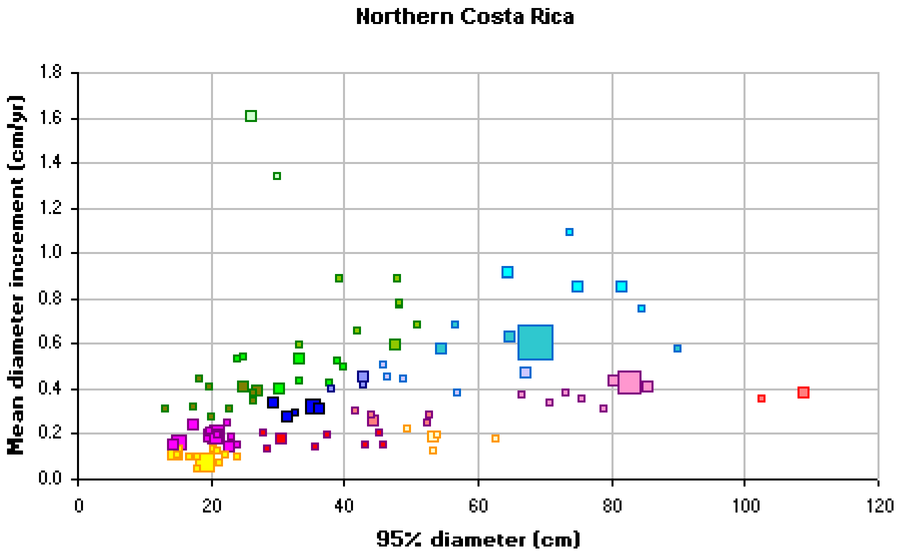
Key for Species Increment-Diameter graphs

Symbol area is proportional to the number of trees in each species sample, according to the scale shown. Samples of less than 100 trees are all shown as the smallest size symbol.

Symbol colour corresponds to the species group letters opposite. The colour classes, based around yellow, red, blue and green, represent the species metagroups:



- Green Pioneer species, very fast growth, occur on large heavily disturbed clearings, low density non-durable timber, fast growth, small maximum size, limited lifespan.
- Blue Semi-pioneer, non-pioneer light demanders, gap opportunists, regenerate in larger gaps, favoured by moderate disturbance, wide spreading, phototropic crowns, lower density, less durable timber, moderately fast growth but may reach large sizes and be relatively long lived.
- Red Partially shade tolerant, narrow crowns, moderately dense and durable timbers, long lived, typical of less disturbed forest, may be large canopy emergents or smaller persistent mid-canopy and upper canopy species. Growth rates slower than average.
- Yellow Shade tolerant, narrow crowned, very slow growing and long lived species. Very dense and durable timber.



The figure above shows summary data from 102 species from the lowland forest of Northern Costa Rica. The x-axis gives species cumulative 95% diameter (typical size) in cm; the y-axis shows species mean increment in cm/yr. The data are taken from permanent sample plots established by CODEFORSA, Portico SA, and ITCR, with some assistance from the DFID. The data comprise 9 1-ha plots, and 27 ¼-ha plots established by CODEFORSA, 17 1-ha plots established by Portico, and 41 plots of 0.49 ha (70 x 70 m) put in by ITCR with DFID support. The CODEFORSA plots were measured over intervals from 6-7 years, the Portico plots over 7 years, and the ITCR plots over 3 years. The CODEFORSA and ITCR plots were located in *Vochysia-Pentaclethra* dominated forest, whilst the PORTICO plots were in a less disturbed, wetter forest dominated by *Carapa guianensis*. The 102 species listed were those most common on the plots. More information on plot designs, background and preliminary results are given in the articles listed below.

The colours indicate species from similar species groups, as determined by an ordination process. Symbol size corresponds to the number of trees sampled for each species(see key). The individual species names and detailed statistics can be viewed by clicking on parts of the graph above, or by browsing the data table for the graph. In the table, *Nt* is the number of trees sampled for each species; *D95* is the 95% cumulative diameter; *Id* is mean increment in cm/yr.

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Common species from Northern Costa Rica permanent sample plots

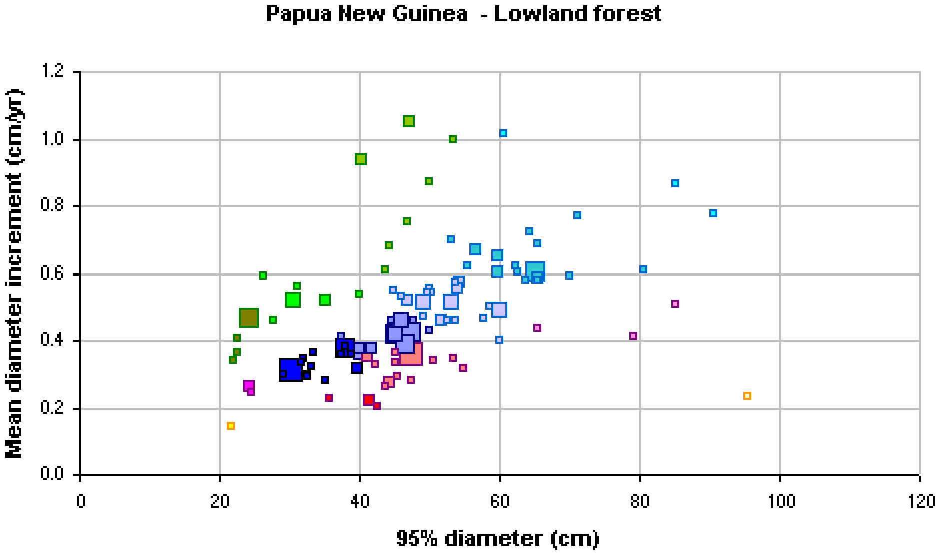
Botanical name	Family	Nt	D95	Id	Group
Welfia georgii	Palmae	930	19.3	0.067	A
Euterpe spp.	Palmae	472	14.8	0.111	A
Borojoa panamensis	Rubi.	138	16.9	0.099	A
Capparis pittieri	Cappar.	107	17.9	0.094	A
Elvasia elvasioides	Ochn.	97	23.9	0.098	A
Hippotis albiflora	Rubi.	96	18.1	0.040	A
Ardisia	Myrsin.	73	20.5	0.131	A
Cassipourea elliptica	Caesalpini.	71	20.9	0.121	A
Ryania speciosa	Flacourti.	65	14.9	0.107	A
Eschweilera pittieri	Lecythid.	64	22.1	0.108	A
Miconia argentea	Melastomat.	59	21.2	0.071	A
Iriartea deltoidea	Palmae	695	20.9	0.206	B
Socratea exorrhiza	Palmae	572	15.3	0.161	B
Ferdinandusa panamensis	Rubi.	511	20.7	0.185	B
Prestoea decurrens	Palmae	381	14.4	0.149	B
Croton schiedeanus	Euphorbi.	188	17.4	0.238	B
Eschweilera calyculata	Lecythid.	166	22.9	0.144	B
Faramea occidentalis	Rubi.	156	19.4	0.179	B
Colubrina spinosa	Rhamn.	146	19.5	0.207	B
Ardisia frimbrillifera	Myrsin.	109	24.1	0.152	B
Warszewiczia coccinea	Rubi.	92	21.0	0.197	B
Pausandra trianae	Euphorbi.	76	19.9	0.212	B
Ardisia palmana	Myrsin.	50	22.5	0.251	B
Garcinia madruno	Guttiferae	50	23.1	0.184	B
Casearia arborea	Flacourti.	200	24.8	0.405	C
Protium glabrum	Burser.	166	26.9	0.387	C
Miconia punctata	Melastomat.	141	18.3	0.442	C
Miconia sp	Melastomat.	125	20.2	0.275	C
Henriettea odorata	Melastomat.	117	22.8	0.313	C
Cupania sp	Sapind.	71	26.4	0.348	C
Guatteria dyospiroid	Annon.	63	13.3	0.312	C

Protium ravenii	Burser.	61	26.5	0.381	C
Chimarrhys latifolia	Rubi.	60	17.4	0.321	C
Lozania pittieri	Flacourti.	53	19.9	0.410	C
Naucleopsis naga	Mor.	180	30.6	0.175	D
Brosimum guianensis	Mor.	148	43.2	0.154	D
Grias cauliflora	Lecythid.	140	37.6	0.194	D
Cupania glabra	Sapind.	122	28.0	0.205	D
Quararibea ochrocalyx	Bombac.	89	28.5	0.137	D
Pouteria torta	Sapot.	79	45.4	0.206	D
Eschweilera integrifolia	Lecythid.	65	35.7	0.146	D
Dussia macroprophyllata	Papilion.	56	46.0	0.149	D
Laetia procera	Flacourti.	443	35.5	0.317	E
Simira maxoni	Rubi.	388	31.4	0.272	E
Dendropanax arboreus	Icacin.	299	36.2	0.314	E
Protium spp	Burser.	282	29.5	0.335	E
Sloanea tuerckheimii	Elaeocarp.	56	32.6	0.294	E
Inga spp	Mimos.	247	33.3	0.530	F
Protium paniculatum	Burser.	169	30.3	0.396	F
Ocotea spp	Laur.	96	37.7	0.426	F
Inga thibaldina	Mimos.	87	23.9	0.533	F
Cordia bicolor	Boragin.	85	39.8	0.496	F
Quararibea bracteolosa	Bombac.	73	39.1	0.522	F
Pourouma minor	Cecropi.	72	33.3	0.437	F
Mosquitoxylon jamaicense	Anacardi.	66	24.9	0.545	F
Pourouma bicolor	Cecropi.	182	47.6	0.596	G
Hampea appendiculata	Malv.	141	39.3	0.889	G
Tapirira guianensis	Anacardi.	102	48.3	0.773	G
Cecropia insignis	Cecropi.	88	41.9	0.652	G
Goethalsia meiantha	Tili.	84	48.3	0.777	G
Simaruba amara	Simarub.	74	48.0	0.887	G
Inga pezizifera	Mimos.	64	51.0	0.679	G
Guatteria aeruginosa	Annon.	52	33.4	0.593	G
Croton smithianus	Euphorbi.	158	26.0	1.606	H
Ochroma lagopus	Bombac.	145	30.0	1.343	H
Pouteria sp	Sapot.	237	44.5	0.258	J
Elaeoluma glabrescens	Sapot.	142	52.9	0.282	J
Brosimum lactescens	Mor.	141	52.4	0.252	J
Cespedesia macrophylla	Ochn.	133	41.7	0.303	J
Pouteria calistophylla	Sapot.	57	44.1	0.284	J
Cordia alliodora	Boragin.	159	43.0	0.455	K
Virola sebifera	Myristic.	156	42.8	0.421	K
Pera arborea	Euphorbi.	46	38.2	0.403	K
Virola koschnyi	Myristic.	214	67.1	0.471	L
Otoba novogranatensis	Myristic.	112	57.0	0.385	L
Dendrobangia boliviana	Icacin.	76	49.0	0.443	L

Lacmellea panamensis	Apocyn.	62	46.4	0.454	L
Clethra mexicana	Clethr.	57	45.9	0.501	L
Guarea sp	Meli.	162	53.5	0.187	M
Licania affinis	Chrysobalan.	101	53.9	0.192	M
Coccoloba tuerckheimii	Polygon.	73	53.3	0.122	M
Pachira aquatica	Bombac.	71	49.4	0.222	M
Pouteria filipes	Sapot.	50	62.7	0.175	M
Carapa guianensis	Meli.	1505	82.9	0.424	N
Dialium guianense	Caesalpini.	295	85.4	0.408	N
Apeiba membranacea	Tili.	255	80.3	0.438	N
Tetragastris paname	Burser.	98	70.8	0.337	N
Minquartia guianensis	Olac.	70	66.5	0.368	N
Tabebuia rosea	Bignoni.	67	75.7	0.357	N
Sacoglottis trichogyna	Humiri.	62	73.2	0.382	N
Vantanea barbourii	Humiri.	49	78.9	0.306	N
Pentaclethra macroloba	Mimos.	3615	68.7	0.603	P
Hernandia didymantha	Hernandi.	243	64.9	0.627	P
Couma macrocarpa	Apocyn.	176	54.6	0.576	P
Hieronyma oblonga	Euphorbi.	59	56.8	0.680	P
Vatairea lundelli	Papilion.	49	90.0	0.574	P
Vochysia ferruginea	Vochysi.	350	81.5	0.847	R
Vochysia allenii	Vochysi.	301	75.0	0.852	R
Qualea paraensis	Vochysi.	224	64.6	0.915	R
Tapirira myriantha	Anacardi.	66	73.9	1.093	R
Sclerolobium costaricense	Caesalpini.	48	84.7	0.751	R
Pterocarpus officinalis	Papilion.	340	108.8	0.379	S
Dipteryx panamensis	Papilion.	81	102.5	0.359	S

Papua New Guinea lowland forest

Species growth summaries from 72 permanent plots



The figure above shows summary data from 103 species from the the lowland forests of Papua New Guinea. The x-axis gives species cumulative 95% diameter (typical size) in cm; the y-axis shows species mean increment in cm/yr. The data are taken from permanent sample plots established by an ITTO-supported project executed by the PNG Forest Research Institute, Lae. in 1992. A total of 72 1-ha PSPs were remeasured twice up to 1997. All the plots were established after logging, and represent more or less disturbed sites.

The colours indicate species from similar species groups, as determined by an ordination process. Symbol size corresponds to the number of trees sampled (see key). The individual species names and detailed statistics can be viewed by clicking on parts of the graph above, or by browsing the data table for the graph. In the table, *Nt* is the number of trees sampled for each species; *D95* is the 95% cumulative diameter; *Id* is mean increment in cm/yr.

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Common species from Papua New Guinea permanent sample plots

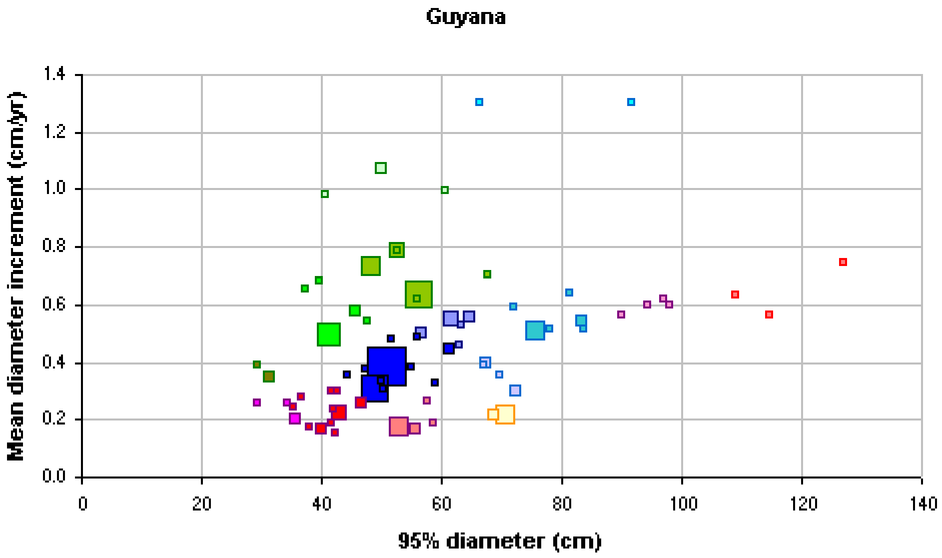
Botanical name	Family	Nt	D95	Id	Group
Zygogynum	Winter.	40	21.6	0.146	A
Timonius	Rubi.	202	24.4	0.264	B
Cleistanthus	Euphorbi.	45	24.6	0.242	B
Macaranga	Euphorbi.	970	24.4	0.464	C
Gnetum gnemon	Gnet.	145	22.7	0.406	C
Dendrocnide	Urtic.	84	22.1	0.339	C
Melanolepis	Euphorbi.	51	22.5	0.363	C
Diospyros spp	Eben.	297	41.5	0.219	D
Kibara	Monimi.	92	42.7	0.204	D
Gonocaryum	Icacin.	47	35.8	0.228	D
Myristica	Myristic.	1319	30.4	0.313	E
Horsfieldia	Myristic.	827	37.9	0.379	E
Barringtonia	Lecythid.	228	39.7	0.319	E
Polyalthia	Annon.	149	32.1	0.349	E
Garcinia latissima	Clusi.	142	38.0	0.384	E
Medusanthera	Icacin.	138	38.9	0.361	E
Semecarpus	Anacardi.	126	33.4	0.362	E
Pouteria luzoniensis	Sapot.	102	29.1	0.299	E
Carallia brachiata	Rhizophor.	87	32.7	0.298	E
Protium macgregorii	Burser.	78	37.3	0.361	E
Citronella	Icacin.	68	32.6	0.292	E
Erythrina	Fab.	55	33.0	0.323	E
Gymnacranthera paniculata	Myristic.	51	31.8	0.335	E
Turpinia	Staphyle.	51	35.0	0.279	E
Microcos	Tili.	423	30.6	0.519	F
Prunus	Ros.	185	35.1	0.518	F
Astronia	Melastomat.	150	40.0	0.535	F
Macaranga aleuritoides	Euphorbi.	140	26.3	0.592	F
Ziziphus	Rhamn.	98	27.6	0.461	F
Polyosma	Grossulari.	46	31.1	0.563	F
Anthocephalus chinensis	Rubi.	194	47.2	1.052	G
Elaeocarpus	Elaeocarp.	189	40.4	0.936	G
Cerbera floribunda	Apocyn.	98	43.8	0.610	G
Galbulimima belgraveana	Himantandr.	55	44.3	0.679	G
Cananga odorata	Annon.	41	46.8	0.750	G
Hibiscus	Malv.	40	53.5	0.999	G

Merrilliodendron	Icacin.	33	50.0	0.874	G
Syzygium	Myrt.	1296	47.3	0.359	J
Aglaia	Meli.	313	41.0	0.352	J
Maniltoa	Caesalpini.	266	44.4	0.277	J
Vatica rassak	Dipterocarp.	126	54.9	0.319	J
Gonystylus macrophyllus	Thymelae.	112	47.5	0.283	J
Parastemon versteeghii	Chrysobalan.	95	45.5	0.292	J
Flacourtia	Flacourti.	85	45.0	0.334	J
Madhuca leucodermis	Sapot.	73	42.3	0.331	J
Hopea papuana	Dipterocarp.	67	45.0	0.363	J
Ilex	Aquifoli.	55	53.3	0.349	
Syzygium brandar	Myrt.	41	43.6	0.260	J
Endiandra	Laur.	40	50.5	0.338	J
Canarium	Burser.	1143	45.0	0.420	K
Cryptocarya	Laur.	903	47.3	0.426	K
Dysoxylum	Meli.	763	46.7	0.387	K
Planchonella	Sapot.	704	45.0	0.417	K
Pimeleodendron amboinicum	Euphorbi.	668	46.1	0.460	K
Garcinia	Clusi.	403	40.4	0.366	K
Chisocheton	Meli.	274	40.0	0.377	K
Blumeodendron	Euphorbi.	194	41.7	0.378	K
Hopea	Dipterocarp.	132	44.6	0.461	K
Flindersia	Rut.	88	47.7	0.462	K
Neoscortechinia forbesii	Euphorbi.	54	50.0	0.428	K
Caldcluvia	Cunoni.	44	37.5	0.410	K
Ficus sp	Mor.	653	60.0	0.488	L
Calophyllum	Clusi.	468	53.0	0.515	L
Litsea	Laur.	443	49.0	0.512	L
Celtis	Ulm.	377	51.8	0.462	L
Dillenia	Dilleni.	238	54.3	0.574	L
Sterculia sp	Sterculi.	224	46.9	0.520	L
Homalium foetidum	Flacourti.	167	53.9	0.554	L
Palaquium	Sapot.	149	57.8	0.468	L
Endospermum	Euphorbi.	140	49.2	0.470	L
Mastixiodendron	Rubi.	137	53.6	0.457	L
Sloanea spp	Elaeocarp.	125	58.5	0.504	L
Platea	Icacin.	101	46.0	0.530	L
Cerbera	Apocyn.	87	44.8	0.548	L
Teijsmanniodendron	Verben.	87	60.0	0.400	L
Celtis philippinensis	Ulm.	64	50.0	0.556	L
Pangium edule	Flacourti.	63	52.5	0.462	L
Heritiera	Sterculi.	54	53.8	0.571	L
Gmelina	Verben.	41	50.2	0.542	L
Canarium indicum	Burser.	39	49.6	0.544	L
Vitex cofassus	Verben.	38	95.5	0.235	M

Xanthomyrtus	Myrt.	55	79.1	0.410	N
Alstonia scholaris	Apocyn.	44	85.0	0.505	N
Neonauclea	Rubi.	41	65.5	0.435	N
Pometia pinnata	Sapind.	1117	65.0	0.605	P
Terminalia spp	Combret.	329	59.8	0.648	P
Euodia	Rut.	257	59.6	0.605	P
Anisoptera thurifera	Dipterocarp.	170	56.5	0.670	P
Pterocarpus indicus	Fab.	159	65.5	0.586	P
Alstonia	Apocyn.	131	80.5	0.608	P
Homalium sp	Flacourti.	122	65.5	0.579	P
Buchanania	Anacardi.	97	55.5	0.621	P
Intsia	Caesalpini.	91	63.6	0.581	P
Artocarpus	Mor.	81	53.2	0.699	P
Nothofagus	Fag.	68	71.0	0.773	P
Campnosperma	Anacardi.	54	64.3	0.722	P
Dracontomelon	Anacardi.	47	70.0	0.594	P
Terminalia complanata	Combret.	45	65.4	0.686	P
Castanopsis acuminatissima	Fag.	40	62.3	0.619	P
Intsia bijuga	Caesalpini.	36	62.7	0.602	P
Vitex	Verben.	117	90.5	0.777	R
Spondias cytherea	Anacardi.	56	85.0	0.864	R
Inocarpus fagiferus	Fab.	45	60.5	1.015	R

Growth data from Guyana

Species growth summaries from 93 permanent plots



The figure above shows summary data from 71 species from Guyana. The x-axis gives species cumulative 95% diameter (typical size) in cm; the y-axis shows species mean increment in cm/yr. The data are from permanent sample plots (PSPs) at two localities: The Barama Company concessions in the north-West, and the Tropenbos plots at Pibiri. The Barama plots were 78 in number, of 1-ha square design, and remeasured over various periods from 1 to 7 years. The Tropenbos plots comprised 15 PSPs of 1.96 ha (140 x 140 m) arranged in an experimental disposition, and measured over 4 years. For both sets of plots, only trees 20 cm and up were included in this analysis.

The two areas have distinct forest types, with many unique species. The Barama area is dominated by *Alexa, Catostemma commune, Eschweilera, Pentaclethra, Protium, Licania* associations. The Pibiri area includes typical Greenheart and White Sand forests, with species such as *Chlorocardium, Eperua, Mora, Swartzia, Lecythis,* and *Catostemma fragrans*.

The colours indicate species from similar species groups, as determined by an ordination process. Symbol size corresponds to the number of trees sampled (see key). The individual species names and detailed statistics can be viewed by clicking on parts of the graph above, or by browsing the data table for the graph. In the table, *Nt* is the number of trees sampled for each species; *D95* is the 95% cumulative diameter; *Id* is mean increment in cm/yr.

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Common species from Guyana permanent sample plots

Botanical name	Family	Nt	D95	Id	Group
Licania canescens & micrantha	Chrysobalan.	205	35.5	0.204	B
Guatteria	Annon.	75	29.4	0.255	B
Pouteria cladantha	Sapot.	35	34.3	0.256	B
Mabea spp.	Euphorbi.	165	31.2	0.347	C
Tovomita	Guttifer.	82	29.2	0.391	C
Catostemma fragrans	Bomb.	480	43.0	0.220	D
Licania heteromorpha & divaricata	Chrysobalan.	340	46.5	0.259	D
Licania alba & majuscula	Chrysobalan.	207	39.9	0.167	D
Vouacapoua macropetala	Caesalpini.	138	41.8	0.186	D
Chaetocarpus schomburgkianus	Euphorbi.	126	37.9	0.171	D
Inga spp.	Mimos.	58	36.8	0.282	D
Sloanea guianensis	Elaeocarp.	57	42.3	0.153	D
Oxandra asbeckii	Annon.	57	41.5	0.300	D
Micropholis venulosa	Sapot.	53	35.2	0.242	D
Eugenia patrisii	Myrt.	50	42.6	0.300	D
Eugenia coffeifolia	Myrt.	30	41.9	0.237	D
Eschweilera spp.	Lecythid.	4527	51.0	0.384	E
Licania guianensis & laxiflora	Chrysobalan.	2299	48.9	0.306	E
Pouteria reticulata	Sapot.	165	61.4	0.445	E
Pouteria guianensis	Sapot.	149	55.0	0.385	E
Talisia squarrosa	Sapind.	145	47.4	0.376	E
Lecythis davisii & zabucajo	Lecythid.	130	58.9	0.327	E
Cordia tetrandra	Boragin.	97	44.3	0.358	E
Laetia procera	Flacourti.	65	51.8	0.480	E
Diospyros	Eben.	59	50.1	0.332	E
Couepia exflexa	Chrysobalan.	41	50.4	0.310	E
Bagassa tiliafolia	Mor.	32	56.1	0.487	E
Pentaclethra odorata & macroloba	Mimos.	1352	41.2	0.495	F
Ocotea puberula	Laur.	197	45.5	0.576	F
Clathrotropis	Papilion.	153	37.4	0.653	F
Virola surinamensis & sebifera	Myristic.	73	47.8	0.547	F

Sterculia exsucca	Sterculi.	30	39.6	0.685	F
Alexa sp.	Fab.	1906	56.2	0.631	G
Protium decandrum	Burser.	880	48.4	0.728	G
Inga rubiginosa	Mimos.	691	52.5	0.787	G
Tapirira marchandii & obtusa	Anacardi.	97	52.5	0.790	G
Jacaranda copaia	Caric.	62	55.9	0.619	G
Schlefflera morototoni	Arali.	53	67.7	0.705	G
Cecropia angulata & obtusa	Mor.	160	50.1	1.073	H
Pterocarpus officinalis	Fab.	65	60.5	0.998	H
Byrsonima spicata	Malpighi.	54	40.6	0.983	H
Lecythis confertiflora	Lecythid.	807	52.9	0.174	J
Swartzia leiocalycina	Caesalpini.	194	55.7	0.170	J
Swartzia benthamiana	Caesalpini.	53	58.8	0.192	J
Licania sp.	Chrysobalan.	30	57.5	0.262	J
Carapa guianensis	Meli.	490	61.8	0.548	K
Sterculia pruriens & rugosa	Sterculi.	343	64.7	0.558	K
Pouteria minutiflora & coriacea	Sapot.	235	56.5	0.499	K
Apeiba echinata & petoumo	Tili.	126	63.4	0.529	K
Hevea	Euphorbi.	30	63.1	0.461	K
Mora gongrijpii	Caesalpini.	295	72.4	0.299	L
Ecclinusa guianensis	Sapot.	199	67.4	0.395	L
Aspidosperma exselsum	Apocyn.	82	69.7	0.356	L
Diplotropis purpurea	Fab.	33	67.0	0.391	L
Chlorocardium rodiei	Laur.	1070	70.8	0.218	M
Eperua falcata	Caesalpini.	211	68.5	0.215	M
Goupia glabra	Celastr.	125	90.0	0.562	N
Parinari campestris	Chrysobalan.	84	98.0	0.598	N
Pithecelobium jupunba	Mimos.	53	97.1	0.620	N
Ocotea tomentella	Laur.	37	94.4	0.600	N
Catostemma commune	Bomb.	1072	75.5	0.510	P
Aspidosperma cruentum & album	Apocyn.	221	83.2	0.540	P
Hyeronima laxiflora	Euphorbi.	93	72.1	0.594	P
Couratari guianensis	Rubi.	60	78.1	0.516	P
Guarea guidonia	Meli.	37	81.4	0.640	P
Vitex compressa	Verben.	32	83.7	0.514	P
Inga alba	Mimos.	34	91.8	1.301	R
Sclerolobium guianense	Caesalpini.	32	66.3	1.299	R
Manilkara bidentata	Sapot.	64	114.7	0.566	S
Peltogyne	Caesalpini.	55	109.0	0.632	S
Swartzia jenmanii	Caesalpini.	52	127.1	0.746	S

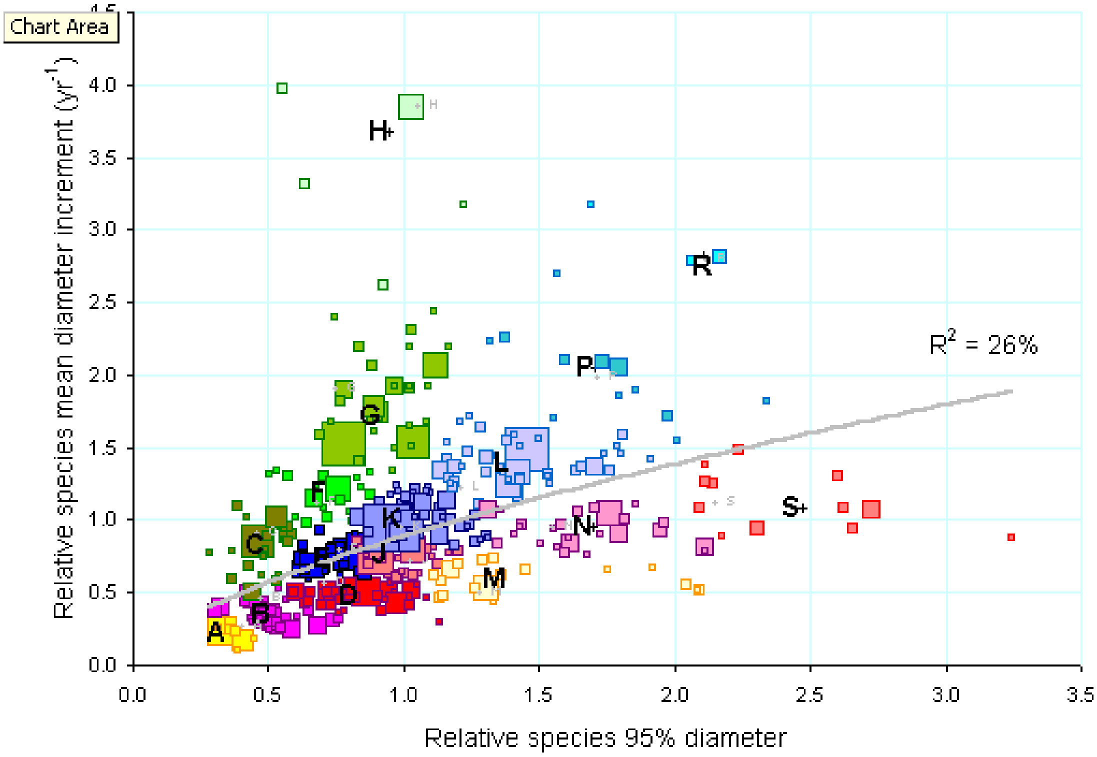
Pan-tropical species groups

based on data from Brazil, Costa Rica and Papua New Guinea

The species groups discussed in the previous sections for individual countries have similar patterns, but cannot be directly compared in overlay form due to scale differences on the 95% diameter (x) and mean increment (y) axes. These scale effects are summarized in the table at the right, which shows the mean value for *D95* and *Dinc* at each location.

	Mean D95	Mean Dinc
Amazonia	34.6	0.228
Costa Rica	47.1	0.405
Papua New Guinea	45.8	0.455
Guyana	54.3	0.410

The differences in D95 are due to a mixture of factors, including measurement standards. In the Brazilian plots, trees down to 5 cm were included; in Guyana, the smallest size was 20 cm. At the other two locations it was 10 cm. This accounts for some of the difference in D_{95} mean values. The difference in increment between locations is most probably related to site factors such as soil fertility. Although the management history of the stands must be an important factor, all the sites were dominantly based on samples from more-or-less disturbed, post-logged forest. None of the sites could be construed as having a large proportion of measurements from virgin forest.



To compare species on a common basis, and develop general pan-tropical groups, the individual species D95 and Dinc values were divided by the mean values of each site, to give relative values. These are referred to as *Rd95* and *Rinc*:

Rd95	Ratio of species *D95* value to the site mean *D95* value.
Rinc	Ratio of species *Dinc* value to the site mean *Dinc* value.

The figure above shows the data from all four regional data sets combined using these relative scales for increment and 95% diameter. The symbol sizes and colours are as used previously (key). The group centroids are shown by bold letters.

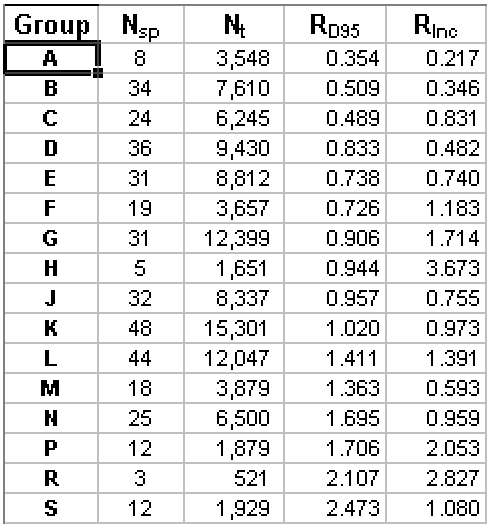
The grey line indicates the general regression between 95% diameter and increment, which has an R^2 of 26% with the equation

$$R_{inc} = 0.891 \ R_{d95}{}^{0.638}$$

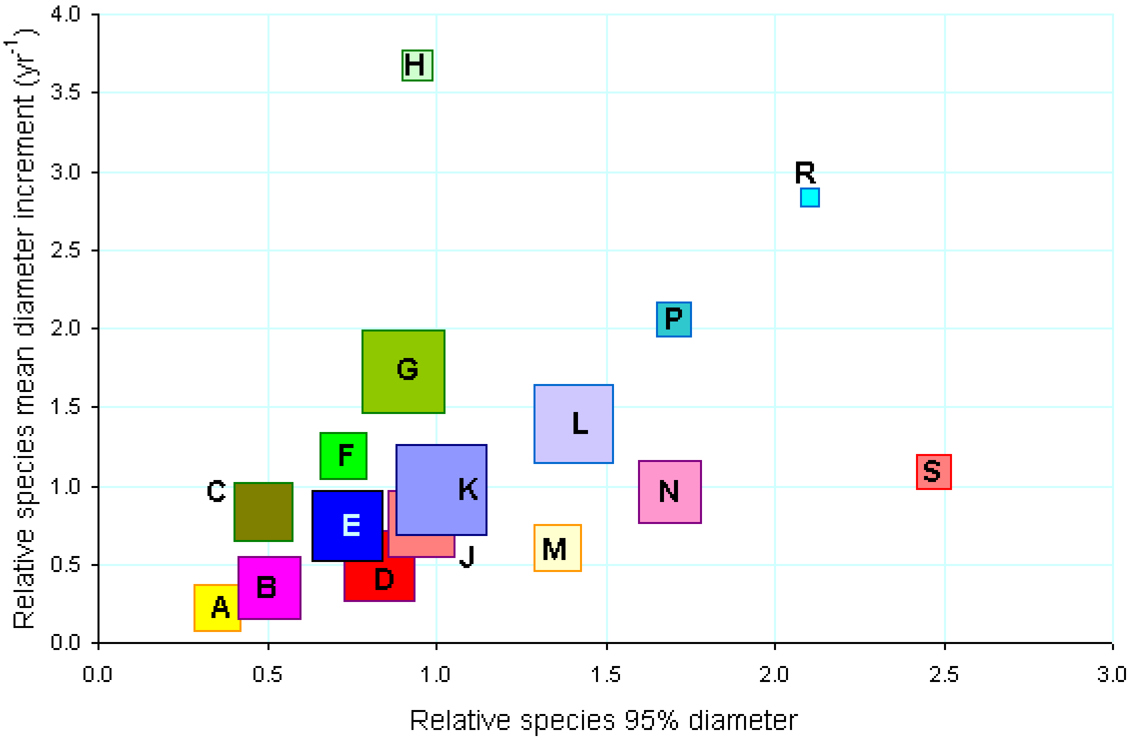
The species below the regression line have lower increments, relative to their size, than the average. These are characterised by **reddish** colours. The **yellowish** colours are applied to groups with very low increments. The species above the line are shown with **blueish** colours, and have higher increments than the average for their typical size. The **greenish** colours are applied to very fast growing species. These are mostly confined to smaller sizes, and are evidently pioneer species.

The table to the right shows the centroid values for the groups based on this scaled, pan-tropical data. In the table, N_{sp} is the number of species in the group, N_t is the number of sample trees, R_{D95} is the relative 95% diameter, and R_{inc} is the relative increment for the group centroid. The graph below shows these groups using the colour and symbol size scheme applied above (key). The R_{d95} and R_{inc} centroid values are used as the basis of the *Model* worksheet in the MYRLIN#2 Tree Growth estimation tool.

Examination of the various species that are most common in these pan-tropical groups shows distinctive characteristics in terms of ecology and wood density. This information is described in the Tree growth: Refining techniques topic.



Group	N_{sp}	N_t	R_{D95}	R_{Inc}
A	8	3,548	0.354	0.217
B	34	7,610	0.509	0.346
C	24	6,245	0.489	0.831
D	36	9,430	0.833	0.482
E	31	8,812	0.738	0.740
F	19	3,657	0.726	1.183
G	31	12,399	0.906	1.714
H	5	1,651	0.944	3.673
J	32	8,337	0.957	0.755
K	48	15,301	1.020	0.973
L	44	12,047	1.411	1.391
M	18	3,879	1.363	0.593
N	25	6,500	1.695	0.959
P	12	1,879	1.706	2.053
R	3	521	2.107	2.827
S	12	1,929	2.473	1.080


Relative species mean diameter increment (yr^{-1})
Relative species 95% diameter
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
A
B
C
D
E
F
G
H
J
K
L
M
N
P
R
S

Mortality estimation method

based on growth rate and typical size

Annual mortality rate (AMR) can be estimated from the 95% diameter and the mean increment based on two simple assumptions:

- Diameter increment is constant over the life of the tree
- Mortality rate is constant over the life of the tree

Although neither of these is likely to be true in practice for a particular tree, variability of both increment and mortality is so high that the average behaviour of increment and mortality for many species does not appear to deviate greatly from these simple assumptions.

Under the first assumption, the time taken by the tree to grow to the D95 diameter can be estimated as:

$$T95 = D95 / Dinc \qquad \{eqn.1\}$$

The number of trees surviving to the D95 diameter also represents 5% of the initial population. In other words:

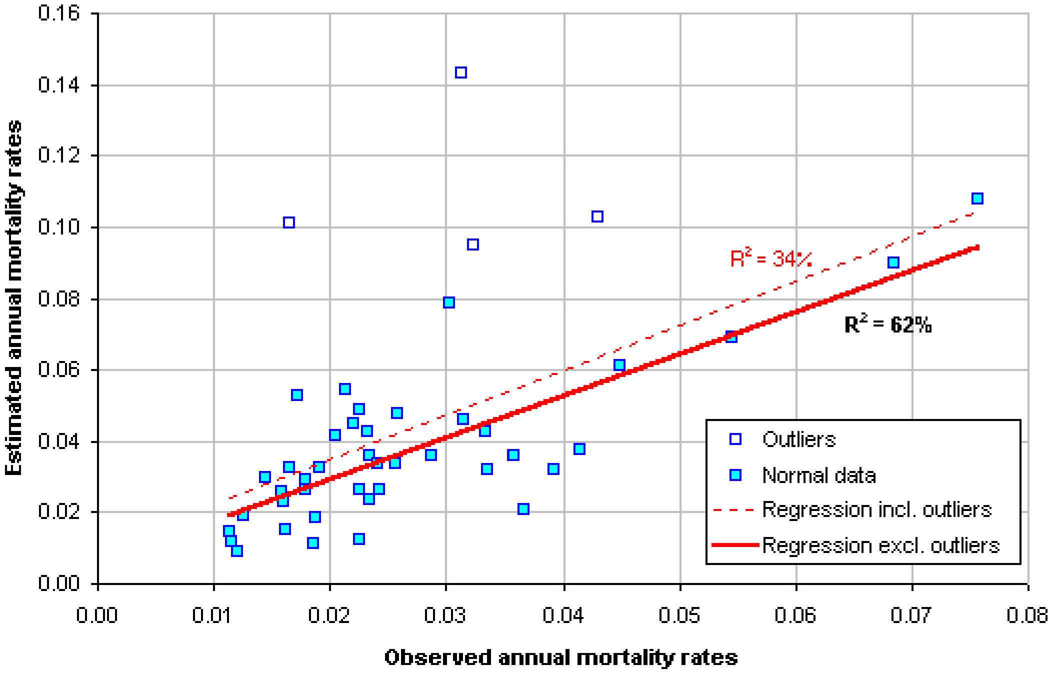
$$0.05 = (1 - AMR)^{T95}$$

Substituting equation {1} for T95 and changing the above expression to give AMR on the left hand side we have:

$$AMR = 1 - 0.05^{[Dinc / D95]} \qquad \{eqn.2\}$$

Equation {2} will be found as the Excel formula in column F of the Table sheet of the MYRLIN#2 Tree Growth module. It gives an estimate of AMR once diameter increment and 95% diameter have been estimated.

For the data from permanent sample plots, the estimated AMR using the above method can be compared with the actual AMRs observed on the plots, to give a test of the validity of the above assumptions. This is shown in figure below, using the group summaries for the data from Brazil, Costa Rica and Papua New Guinea. With all data included, the R^2 is around 34%. If four outlying points are excluded, the R^2 improves to 62%. On the graph, outliers are shown as empty squares, normal points have a sky blue fill; the regression for all data is shown as red . The outlying points are all for G and H groups characterised by low D95 value and high increment. For these species, it appears that the above method tends to substantially overestimate AMR compared with actual observations. It may be noted however that on the PSP data, small sizes are not implicitly included, whereas the method used above is an estimate across all sizes.



The evidence indicates that the estimates of AMR provided by the MYRLIN#2 Tree Growth tool may tend to be a little high, but are generally approximately correct. The overestimation of mortality implies that allowable cut estimates may be a little conservative, and this is probably a more desirable form of bias than one that would tend to encourage over-exploitation of the resource.

Downloading MYRLIN modules

The following items can be downloaded. Note that clicking the download button is an assertion that you accept and agree to abide by the conditions of use. If you have difficulty downloading any item, please see the Help page.

- MYRLIN#1 (Stand tables) (148 kb)
- MYRLIN#2 (Tree growth estimation) (34 kb)
- MYRLIN#3 (Harvesting model) (61 kb)

- Excel species grouping tool (45 kb)
- CATIE workshop reports
- Local copy of this web site (1.60 MB, excludes PDF - see below)
- Web site as a printable manual (MS Word, 115 kb)
- Web site as a PDF document (2.15 MB)

All items except the PDF file are compressed as Zip files, and can be expanded to their original format with WinZip or a similar utility. If you do not have WinZip, it can be downloaded here.

Using the local copy of this web site may be found to be more convenient than browsing online, if you do not have a broadband Internet connection. If it is unzipped in a sub-directory called, for example *C:\MYRLIN\Web*, then clicking on the file *C:\MYRLIN\Web\index.htm* will start a local replica of this web site. Note that this local copy has some external links, which will bring up '*Page not found*' errors if you are not online. This includes links to web sites of some organisations involved with MYRLIN, and the PDF version of the website. All information related to the use of MYRLIN and zipped versions of the MYRLIN modules are available within the local copy.

Web graphics do not print well directly from most browsers, so two printable versions of the website are provided. The PDF file provides a complete version of the website that is both browsable and printable and can be viewed on or off line. Your system may need to download the free Adobe Acrobat reader the first time you activate this file. This should be done automatically if it is needed. However, the file is quite large (2.1 MB) and may be difficult to access if you have a slow Internet connection.

The Word version gives the same document in a much more compressed format (115 kb as a Zip file), but requires that you have MS Word 2000 (or a compatible version) installed.

MYRLIN Help

If you have persistent problems in trying to use MYRLIN, please review carefully the troubleshooting pages on this website:

- Problems setting up or updating stand tables
- Problems using the tree growth module
- Problems running the harvesting module

If all else fails, please contact Denis Alder by email at denis@bio-met.co.uk with a description of the problem. Please attach to the email a zipped-up copy of the module causing the problems. If you do not have WinZip, please see the Downloads page.

If you have serious problems downloading files due to poor telephone links or other network problems, you need to use a Download Manager such as ReGet. These allow interrupted downloads to be resumed after a break in service without repeating material already obtained.

Troubleshooting the Stand Table module

If problems occur running the *MakeStandTables* macro in the MYRLIN#1 modules, work through the various setup sheets in the module, examining the following points:

Options	Have the correct columns and sheet names been specified? Is the plot size correctly specified? Are sub-plot size and diameter correct? Are the options settings in the correct cells?
Species List	Is the species code in column A (it must be)? Is the species code formatted as text? Has a valid column been specified for species grouping?
Tree data	Have correct columns been specified for Stratum, PlotID, Species code and Diameter? Is the data sorted by (1) Stratum, (2)PlotID? Is the Species code formatted as text? Do species codes properly match column A of the species list? Are all diameters in cm (not mm or inches)? Are all diameter entries numeric? If area weight is needed, then: Is the correct column specified? Is the area weight data numeric? If a formula is used to calculate area weight, is it correctly copied down for all tree data records?
Excel	Were *macros enabled* when Excel started? Was the *stand table module* the active workbook when the macro *MakeStandTables* was run?

Troubleshooting the Tree Growth module

The table below shows some of the problems that may be encountered using the Tree Growth module, with possible solutions.

The message *"MYRLIN#1... is already open. Re-opening will cause any changes to be discarded..."* appears when running *MakeD95List*.	This is normal if the MYRLIN#1 file is already open. Click Yes to proceed. However, note that any edits to MYRLIN#1 since it was last saved will be lost. It is better to close MYRLIN#1 before running *MakeD95List*.
A Visual Basic error message occurs when running *MakeD95List*, or results are produced but include unexpected or garbled values.	Ensure that the *MakeStandTables* macro runs normally in MYRLIN#1. It is likely that options in that workbook have not been correctly specified. See the troubleshooting guide for MYRLIN#1.
"Subscript out of range" error occurs when running *MakeD95List*	MYRLIN #2 must have three sheets, labelled Table, Fig1 and Model. If these are re-named, missing, or the macro is run with a different workbook as the active workbook, this error occurs.
The macro *MakeD95List* could not be seen when the Alt-F8 key was pressed.	Macros were not enabled when MYRLIN#2 was opened.
Figures or tables do not appear as shown in the documentation. The graph does not function as explained.	MYRLIN#2 has been modified in a way that prevents it functioning properly. Please download the module again or revert to a saved backup.

Troubleshooting the Harvest Model

The table below shows some of the problems that may be encountered using the Tree Growth module, with possible solutions.

The macro *RunModel* could not be seen when the Alt-F8 key was pressed.	Macros were not enabled when MYRLIN#3 was opened.
A Visual Basic error message occurs when running *RunModel*, with a message such as *'Division by zero'*, *'Overflow', etc.*.	Check the general parameters on the {models} sheet are reasonable. Zero or empty felling cycle, time interval cause these errors. Check the parameters are in the correct cells.
"Subscript out of range" error occurs when running *RunModel*	Various mis-settings to parameters could cause this. If the species groups are absent from the {models} sheet, or do not start in row 11, or refer to group codes unrelated to those in the StandTables sheet this may happen. It will also happen when MYRLIN#3 is not the active workbook when *RunModel* is executed.
The message '*Diameter class out of sequence*' appears when running the model.	The diameter classes must be constructed in ascending order on the StandTables sheet.
Volumes continuously increase over time, or decline rapidly even without harvesting.	The AMR values may be in the wrong column, so that they are read as zero. Diameter increment figures may be absurd or in the wrong column. The recruitment factor should be around 1. If entered as a %, the cell must be formatted for % data. See the Growth Model topic for more information.
The message *'Stratum ... is in the {Areas} list but not in the model'* appears when trying to run the model.	Check the names in the *{Areas}* list correspond with those in column A of the stand table. Leading or trailing spaces, or upper/lower case difference can cause a mismatch. The cell after the last entry in the *{Areas}* list must be empty. If it contains spaces, it may look empty, but will cause this error. See the Forest Description topic for more information.
Figures or tables do not appear as shown in the documentation when the model is run.	MYRLIN#3 may have been modified in a way that prevents it functioning properly. Please download the module again or revert to a saved backup.

The CATIE workshop

An inaugural workshop was held under the project at CATIE, Costa Rica, from 5-9th July, 1999 to define the needs and scope for the manual and training materials on yield regulation. The papers submitted to the workshop were published as:

Proceedings of a workshop on Humid and semi-humid tropical forest yield regulation with minimal data

Wright, HL & Alder,D [Editors] (2000) OFI
Occasional Papers 52
ISBN 0 85074 152 1

Participants in the CATIE workshop
(Top row) Jerry Vanclay, Thorsten Jolitz, David Thomas, Ernest Foli, Simon Armstrong, Mauricio Sanchez, Jose Campos, Howard Wright
(Bottom row) Robert Zagt, Nsita Steve Amooti, Denis Alder, Ismail bin Harun, Putera Parthama
Click the photo to view a higher resolution copy.

The published edition can be obtained from the Oxford Forestry Institute. Abstracts are listed below, and full articles can be downloaded as Word 97 files.

YIELD DETERMINATION IN TROPICAL MOIST FOREST

Howard L Wright

This paper highlights the importance of yield regulation in the management of tropical forests. It emphasises that one of the most important aspects of yield regulation is the determination of the Annual Allowable Cut (AAC) or prescribed yield. It sets out to describe a selection of the classical methods for the estimation of the AAC developed primarily for the even and uneven-aged forests of Europe from the beginning of the last century. In all but the simplest of systems some estimate of the rate of growth of the forest is needed.

Download

SOME ISSUES IN THE YIELD REGULATION OF MOIST TROPICAL FORESTS

Denis Alder

Yield regulation is a central concept in sustainable forest management. Yield usually implies standing volume commercial timber, but can include non-timber products. Allowable cut is the harvest corresponding to sustainable yield. Felling damage must be allowed for in calculating this.

Mean annual increment (MAI) is often confused with current or periodic increment, whilst different volume equations, diameter limits, and the gross or net increment can further confuse the issue. MAI is not sustainable yield as the forest is not normal and an allowance must be made for felling damage. Yield regulation is not sufficiently defined by the classical concepts of felling cycle and minimum felling diameter. Felling cycle does not have a definite optimum in mixed forest, whilst diameter limit alone is too simple a criterion for management. Tropical forests are spatially and structurally diverse, and practically, MAI and annual allowable cut can only be estimated by simulation or stand projection. This should be done stand by stand, with a further calculation to then determine felling series by cutting parts or aggregates of stands. A strategy is discussed for simplifying these steps and applying it where only static inventory data is available, using tabulated data and simplified modelling tools.

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GROWTH AND YIELD PREDICTION: SOME EXPERIENCES FROM THE TROPENBOS PROGRAMME

Roderick J. Zagt, Peter van der Hout, Marc Parren

Tropenbos develops methods for sustainable forest management in its programmes in Guyana and Cameroon. In both countries, growth and yield models are currently not available to guide management decisions, but they are developed as part of the research projects. In Guyana, a population model is available for Greenheart, the major commercial species. In this contribution this model is used to show that yield prediction based on limited data in the form of size class distribution data has limited reliability. Minor variations in dynamic characteristics may lead to substantial differences in expected yield. It is concluded that even in conditions of limited data availability some knowledge about population dynamics is required, but that this requirement can be reduced by classifying species in functional groups.

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SOME THOUGHTS ON TIMBER YIELD REGULATION BASED ON EXPERIENCES IN THE COMMUNITY FORESTS OF NORTH WEST ECUADOR

David Thomas and Thorsten Jolitz

The SUBIR Project is an integrated conservation and development project run by CARE Ecuador with major financing from USAID. The geographical focus is primarily the province of Esmeraldas, north-western Ecuador, working with communities, in the buffer zone of the Cotacachi-Cayapas reserve. The project is made up of five components: social, legal, biodiversity monitoring, improved land use and commercialization. The aim of the project is biodiversity conservation through protecting the reserve and improving livelihoods in the buffer zone.

The province of Esmeraldas is estimated to have up to 300,000 hectares of natural forest designated for production. It has been, and is, the most important source of timber from natural forest in the country, supplying around 70% of national demand. The forest is owned by communities and privately. In theory the state also owns production forest though in practice all has been colonised.

YIELD PLANNING AND CONTROL FOR SUSTAINABLE TIMBER PRODUCTION IN GHANA

Ernest G. Foli

The policy for natural forest exploitation within the forest estates of Ghana is that of sustainable management. In this connection, yield regulation is recognised as an essential component of sustainable management of the forest resources. Several approaches to yield control have therefore been tried in the past, often as a temporary measure until more information on forest dynamics can be obtained to improve the system. Some of these past methods, as well as the current yield regulation protocols are reviewed against the backdrop of the limitations that have rendered them impractical as tools for controlling over-exploitation of the forest resources. The development of a pan-tropical yield regulation system that uses the kind of minimal data that is often available from PSP programmes may enhance the effectiveness of these controls.

YIELD PLANNING AND REGULATION IN THE COMMERCIAL HARVESTING OF TROPICAL MIXED FOREST

Simon Armstrong

Yield regulation in a commercial context. Responsible forest managers need to know if the rate of resource extraction from a given area of forest is sustainable. Sustainability is poorly defined, but does imply a systematic approach to optimising resource utilisation over the long term. If forest managers are to harvest sustainably they need a systematic process by which concepts of yield regulation are included within strategic planning and daily operations.

Before committing capital a commercial forestry enterprise needs an estimate of the available yield that may be expected over the short term, and for long term projections an estimate of the cutting cycle and expected resource availability at the end of the first cycle.

GROWTH AND YIELD MODELLING IN PENINSULAR MALAYSIA: A CASE STUDY, STATUS AND PROBLEMS

Ismail Harun, Abd. Rahman Kassim and S. Appanah

Growth plots to monitor the growth and diameter increment of trees were established as early as 1901 in Peninsular Malaysia however these plots were invalidated later due to non-conformity of measurements. The first endeavour to study growth and yield in Peninsular Malaysia was only started in 1974 when the first permanent sample plots (PSP) were established. The first PSPs in Peninsular Malaysia for this purpose were set up at Terengganu. The study was initially conducted to investigate the economic and silviculture implications of forest management under various cutting intensities and cutting regimes. For this purpose, about 150 ha of PSPs in hill forest were established. Other than that, many more such study areas were established in various parts of Peninsular Malaysia so as to cover the major different forest type of the country.

The concept of growth and yield modelling is indeed new in Malaysian forest management. For Peninsular Malaysia, except for several isolated studies, there is no growth and yield model available that has been used in the current management system. Several documented studies before are FORSTAM, Linear Regression, Individual Tree Distance, Log Production Models, GandY Functions, STANDPRO, DIPSIM, FORMIX and Single Tree Model. The only growth and yield model in Malaysia is DIPSIM (A Dipterocarp Forest Growth Simulation Model for Sabah) and STANPRO (Stand Projection Model for Sarawak). DIPSIM was developed in 1994, and purposely formed for Sabah's mixed dipterocarp. Currently DIPSIM is being modified before it can be used in Peninsular Malaysia. Problems encountered in growth and yield studies in Peninsular Malaysia can be divided into four aspects namely: nature of the forest, management operation, permanent sample plot management and data analysis and modelling aspects.

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THE CODEFORSA NATURAL FOREST MANAGEMENT STANDARDS

Mauricio Sanchez

1. The intensity of the harvesting and silvicultural treatments are determined according to the species abundance. The harvesting intensity will not exceed 60% of the number of trees with diameter at the breast heigth (dbh) of 60 centimetres or bigger, per species. A smaller reference dbh will be established for those species which do not reach a dbh of 60 cm, in this case, a technical justification is needed.

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APPROACHES ADOPTED TOWARDS YIELD REGULATION IN THE BRAZILIAN AMAZON

Silva. J.N.M and van Eldik, T

Roundwood production in the Brazilian Amazon ranks third in the world, only surpassed by Malaysia and Indonesia. In 1996-1997, annual volume of logs produced was c. 28 million m3 corresponding to an annual logging area of 1.0-1.5 million ha (Nepstad et al. 1999). Pará and Mato Grosso States are the main timber producers, accounting for 78% of the total production.

For timber production to be sustained, i.e. employing sound forest management practices, the area of closed forests needed to be under timber production would be around 30-45 million ha, considering a 30 year cutting cycle. The area under forest management plans in 1997 was 1.8 million ha. If we add the area of national forests (meant for production) in the North region, which amounts to c. 15 million ha, we find out that it is necessary to establish a further 13 to 28 million ha of production forests. This emphasises the strong need for establishment of a permanent forest estate in the country.

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YIELD REGULATION IN THE TROPICAL MOIST FORESTS OF UGANDA

Nsita, Steve Amooti

Uganda is a tropical country located between latitudes 1º 30' S and 4º N and longitudes 29º 30' East and 35º E. It covers an area of 24 million hectares, 17% of which is open water and permanent swamp. Altitude averages between 900 - 1500 m above sea level. Rains average 1000 - 1200 mm while average temperatures range between 20ºC - 28ºC.

Population is about 20 million people averaging at about 100 persons per km². The rate of growth is about 2.5% per year.

Uganda's Tropical High Forests (THFs) cover nearly 900,000 ha. About 700,000 ha of these are in Protected Areas (includes patches of grassland). Nearly 60% of the PAs are in Forest Reserves (FR) while the rest are in National Parks.

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YIELD REGULATION PROBLEMS IN INDONESIA

Putera Parthama

No less than anywhere else in the world, ensuring sustainable forest management in Indonesia is a highly pressing issue. The significance of the forest sector in the national economy and the increasing global market demands for eco-labelled forest products have led the Government of Indonesia to pay increased attention to the subject. One of the primary problems surfacing recently is the urgent need for appropriate methods, techniques, or tools necessary for accelerating the progress toward accomplishing sustainable management of natural forests.

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ON YIELD REGULATION FOR SUSTAINABLE FORESTRY, WITH EXAMPLES FROM QUEENSLAND

Jerry Vanclay

Personal anecdotes are used to highlight some important considerations for yield regulation and to introduce some pertinent literature. A checklist of key issues and research needs is offered. Perhaps the most important consideration is to maintain a holistic systems view, and to involve clients and to ensure their needs are met.

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