Some enhancements to the GEMFORM stand table projection model

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Executive summary

GEMFORM is a computer program for processing data from forest inventories and stock surveys. It produces stand tables of species by size or quality classes for tree numbers, volume, or basal area. These tables can also include sampling error and reliable minimum estimates based on the statistical assumptions of stratified random sampling.

GEMFORM also includes a cohort-based growth model specifically designed for stand projections from the types of data available from commercial inventories and stock surveys. This are characterised by high minimum diameter limits and partial measurement of species, factors which restrict the use of more detailed and sophisticated models.

Input data can be accepted in a variety of formats. Various dialog screens allow data tables for blocks (strata), plots, trees, and species to be configured with different field names or as columns on Excel sheets. Plot size may vary and have one or two levels of sub-sampling. Point sample (angle count) plots can be accepted. Pre- and post stratified designs, simple random sampling, or stock surveys can be processed as data sources.

GEMFORM operates as an Excel add-in. When installed, its own toolbar is attached to the standard Excel display, with controls for sampling design, stand table layout, growth projection, process execution, and help. The package can be downloaded from the internet at www.bio-met.co.uk/gemform, and includes a detailed help file to assist in installation and operation.

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Acknowledgements

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List of abbreviations

API ..... Aerial photo interpretation
CIDA ..... Candadian International Development Agency
DFID ..... Department for International Development of the United Kingdom
GEMFORM ..... Guyana Empirical Model for Forest Management
GFC ..... Guyana Forestry Commission
IFP ..... Interim Forestry Project
SQL ..... Structure Query Language
TREMA ..... Tree Recording and Mapping (a software package)

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Where this report refers to Excel, Access, FoxPro, Visual Basic, Office as proper nouns, then it is referring to the software products of those names produced by Microsoft Corporation. It acknowledges Microsoft's proprietary rights with respect to these names.

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Introduction

Scope of report

This report describes some enhancements that have been made to the computer program GEMFORM, which was developed to provide for stand tables and growth projections from a variety of data sources in Guyana. In previous work (Alder, 2001), the design and development of GEMFORM were described, and its operation documented. That version lacked the facility to read forest inventory data files, and was restricted to processing stock survey data.

This version (GEMFORM 1.10) has been extended to read inventory data files in a variety of formats representing some variation around the basic theme of stratified random sampling. The stand table module has been extended to produce sampling errors and reliable minimum estimates. Growth projections are possible from the forest inventory data as well as from stock surveys.

This report supplements the Help file that accompanies the Gemform package by highlighting some of the operational features and enhancements. It does not however aim to give detailed instructions in the use of the program. For this, the user is referred to the Help system.

Downloadable resources

The following files have been placed at WWW.BIO-MET.CO.UK/GEMFORM

Description *and unzipped filename*	**File name**	**Contents type**	**File size** *zipped*
GEMFORM program, version 1.10 *GEMFORM.XLA*	GFXLA.ZIP	Excel 2000 add-in	295kb
GEMFORM Help *GEMFORM.HLP*	GFHLP.ZIP	Windows Help	175kb
Growth model parameters for Guyana *Growth Models Database.mdb*	GFGM.ZIP	Access 2000 database	777kb
Reformatted Guyana IFP data *IFP data.mdb*	GFDAT.ZIP	Access 2000 database	12kb

The downloaded files are all WinZip compatible, and expand to the file types indicated above. They should be downloaded and expanded in a suitable directory, *e.g.* C:\GEMFORM. Opening the Help file by clicking on it will give several initial topics. Select the Help icon (see right), and then click on the underlined Install link for installation instructions.

Data sources for GEMFORM

Types of data file

GEMFORM works with stock survey and forest inventory data files. Stock survey files can be in Excel worksheets or Access tables. Forest inventory data must be in Access files. Forest inventory data in DBF files can be processed with GEMFORM by linking them through an Access file.

The layout of the files can be quite flexible, and is specified in the dialog forms described in the GEMFORM help. The following discussion is a classification of some of the possibilities. The most complex case is illustrated by the IFP data file provided as a download with GEMFORM.

A simple stock survey

The simplest file type comprises stock survey data in an Excel spreadsheet, with no separate species list. There are several files of this type in GFC's archives. GEMFORM can produce flexible stand tables for these files, but *cannot do growth modelling or summaries by species groups* unless a separate list is generated for the file, and linked using the species names.

In this type of file, GEMFORM requires the species name and dbh field. It can also use a log length parameter if a volume equation is based on form factor, rather than form height.

The stock survey area is referred to as a block. The block area must be given, but this can be done in several ways:

- A fixed block area can be specified for all data sets (*eg.* 100 ha).
- The block area can be given on the sheet header for workbook data
- A separate table or worksheet can list blocks and their areas.

Stock surveys with species list

Stock survey data with a separate species list can be used as the source data for GEMFORM. An example of this type of data is the GFC Silvicultural Survey data (Alder, 2000). The data structure for this is reproduced in Figure 1 overleaf.

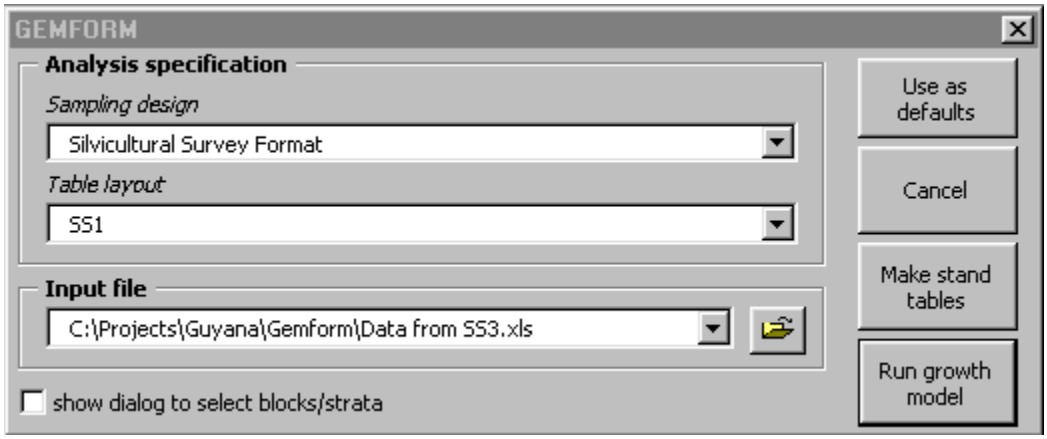
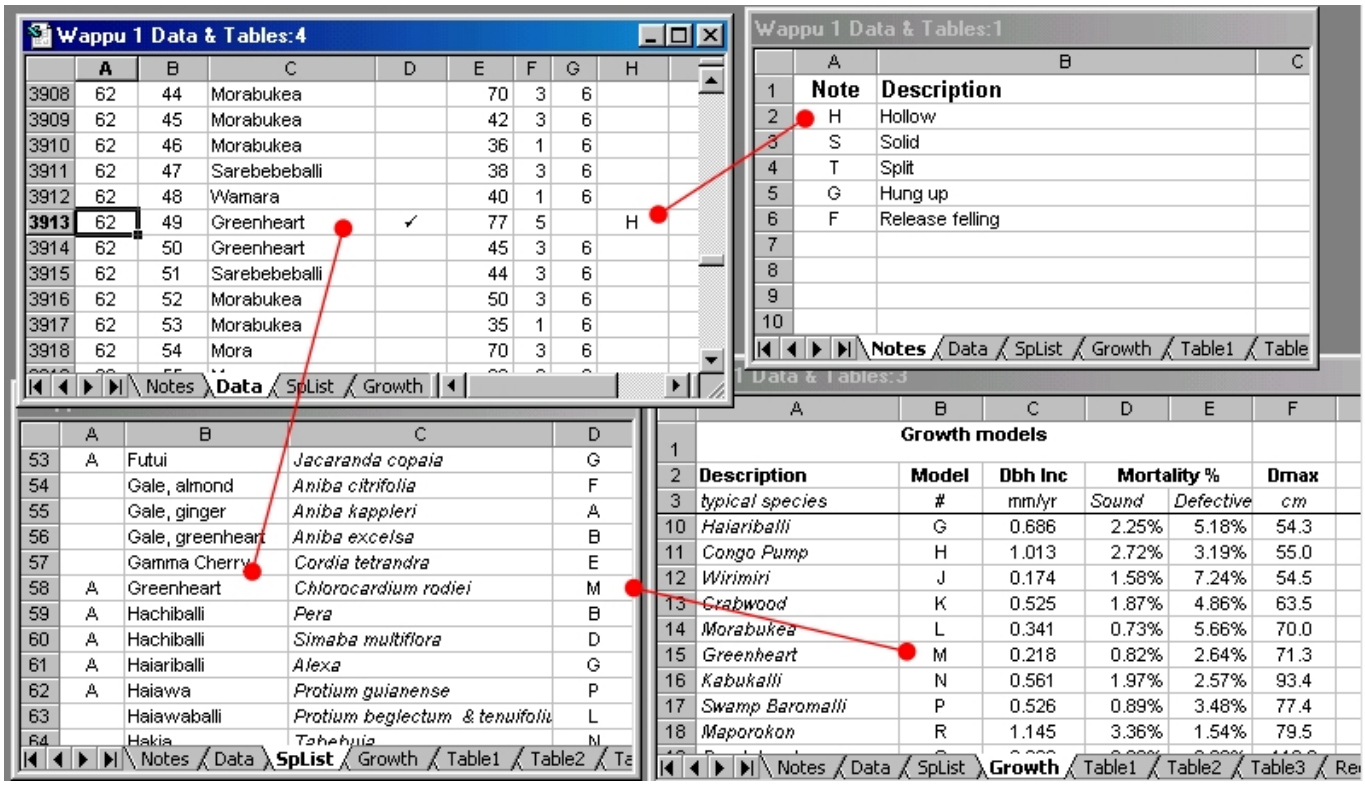


Figure 1 Worksheets and data linkages in the GFC Silvicultural Survey format



The distributed version of GEMFORM already contains a configuration to process this type of data. On the Run form, the Sampling Design should be set to Silvicultural Survey Format, and the Table Layout to SS1. A suitable silvicultural survey file should be picked, as shown above.

Forest inventory data

Forest inventories differ from stock surveys in that they are sample-plot based, and it is critical to accurate data processing that sample plot size and layout are correctly specified. This is done in GEMFORM via the Table form.

Forest inventory data in GEMFORM must always be in an Access database. Other file types, such as Excel, DBF or other database sources can be either imported into Access, or linked to Access as linked tables. The latter is efficient for older types of DBF files (*eg.* those from TREMA), and avoids having to convert the files.

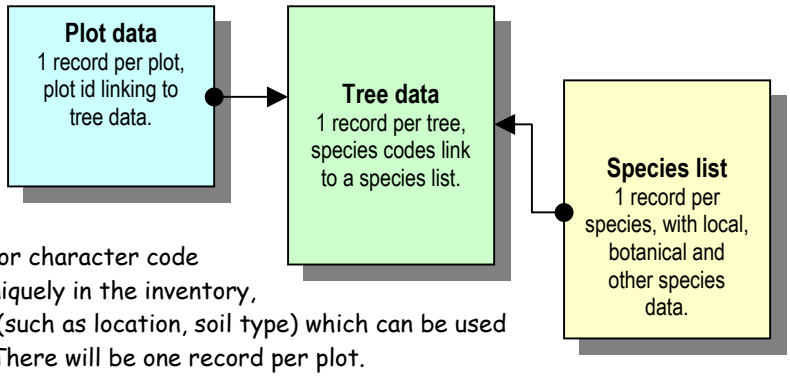
No special arrangements for indexing are required, as GEMFORM sets up any needed queries and indexes as it processes the data. It will be found that GEMFORM will create several queries preceded by ~ when it runs. These are temporary and can be deleted if inconvenient. The Access database does not need to be open when GEMFORM runs, but it must not be locked for updating[1].

[1] This can occur on a network with certain operations, notably database compaction and repair, editing of relationships or table or query design changes, if these operations are being carried out by another user while GEMFORM is running.

Post-stratified inventories

There are two basic inventory design concepts which GEMFORM can process, which are referred to as post-stratified and pre-stratified inventories. In the post-stratified inventory, plots are stratified by some characteristic after sampling has been completed. This may often be an observed attribute on the plot, such as forest type, or soil type; it may also be a locational attribute. The key feature of this situation in GEMFORM is that there is no data table for the strata or blocks, and the stratum areas are not known.

The typical data organisation appears as shown.



There will be three data tables: Plots, Trees, and a Species List. In the *Plot* table there will be as minimal information, a Plot ID field, giving a numeric or character code designating the plot uniquely in the inventory, and an attribute field (such as location, soil type) which can be used to stratify the data. There will be one record per plot.

In the *Trees* table, there will be one record per tree measured on the ground. All the data for all plots must be in a single table. Each record must have a *Plot ID* that links to the *Plot ID* in the *Plots* table. As minimal additional data, there must be a Dbh and Species code field. There may also be stem quality and bole length fields which can be used in processing; however, these are not obligatory.

The *Species List* table must have a species code field that matches the *species code* field in the *Trees* table. It will also normally have fields for Common name, and botanical name. To enable all the features in GEMFORM it should also have a species group and growth model code field for each species.

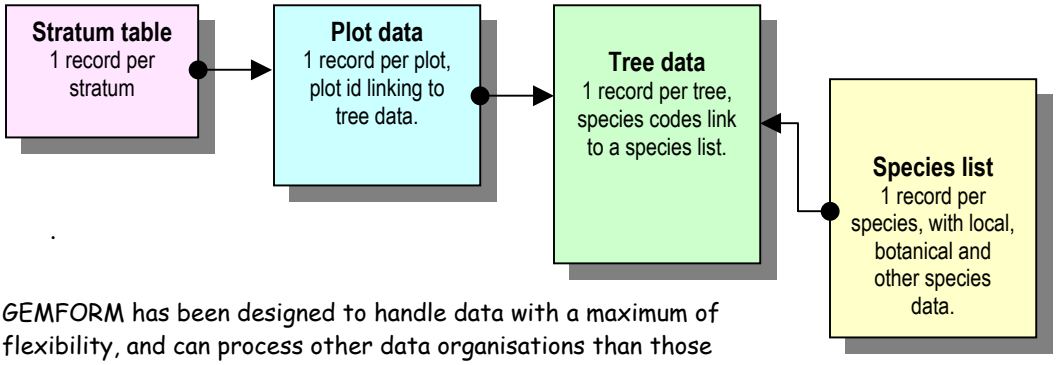
Pre-stratified inventories

Pre-stratified inventories should be regarded as the normal situation for well-planned inventory operations. The key feature is that physical strata or sampling blocks are identified and mapped before sampling commences on the ground, and the stratum areas are known from remote sensing or aerial photo interpretation (API).

The data structure for this type of inventory will be identical to that noted above except that there will be an additional table for stratum or block areas and titles. These must have a block id field that links to a *block id* field on the plot table. In addition to the *Blocks* table must have an area field, giving forested area in ha, and a title field that appears in output tables.

The term Block is used in GEMFORM, but should not be necessarily taken as being identical to the 1 km^2 management blocks used in many areas in Guyana. A block in the GEMFORM usage is a sampling unit, and is identical in concept to a statistical stratum. It may be based on any suitable mappable attribute.

The diagram below illustrates that data tables and their linkages required for this type of inventory.



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Other inventory data arrangements

GEMFORM has been designed to handle data with a maximum of flexibility, and can process other data organisations than those described above. These are not recommended for use, but may occur with some historical data sets.

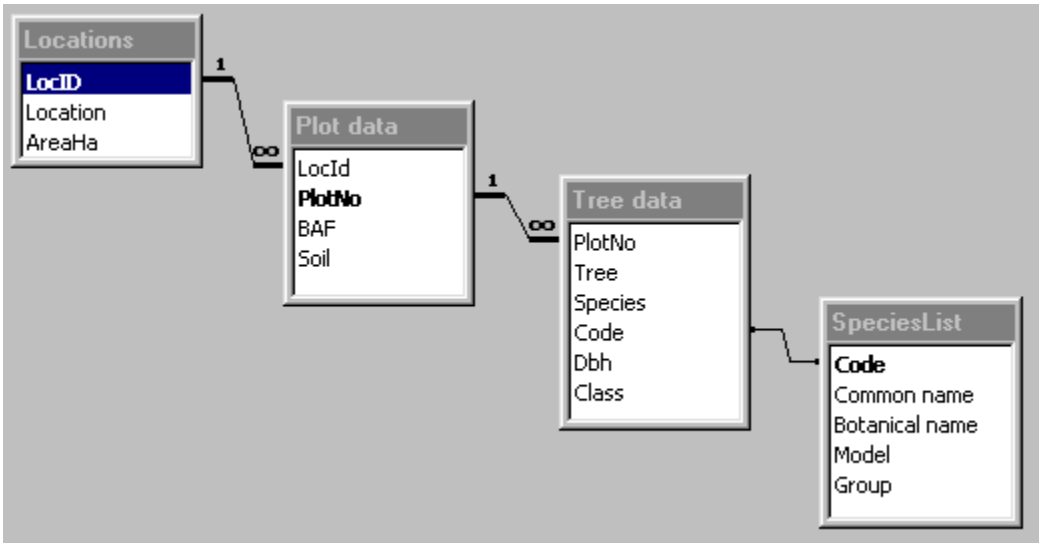
It can generally process data in which there is no species list, but only a species name embedded in the tree data table. It can also process the case in which the plot header table is absent, and plots are identified only be a plot id field in the tree data table. Both these cases limit the program features that area available to simple stand tables. No growth modelling is possible, and without a species list, no species group summaries can be given.

Sample plot layouts

GEMFORM can process several sample plot arrangements. These include fixed area or point sampling. For fixed area plots, one or two levels of sub-sampling are possible. With either fixed or point sampling, the plot size or basal area factor can vary from plot to plot if it is specified as a field in the plot header table. The method of specifying the design is described in the Help system under the *Design* icon (left), *Plots* tab.

IFP data example

The Guyana IFP data, derived from the CIDA-supported 1990-93 inventories, has been cleaned up and prepared as a demonstration data set for GEMFORM in the file *IFP data.mdb* (see page 1). This has the data tables, fields and linkages shown below.



The block or stratum table is called [*Locations*] and has three fields. The block ID is called [*LocID*]. The block title is [*Location*], and the block area is [*AreaHa*][2].

The plot header table is called [*Plot data*] and has four fields. The [*LocID*] field links to the block table. The [*PlotNo*] field uniquely identifies the plot. The [*BAF*] field contains the prism factor, in m2/ha, as these data are from point sampling plots. The [*Soil*] field contains a soil type code that can be used for post-stratifying the data.

The tree data table is called [*Tree data*], and contains six fields. The [*PlotNo*] field links to the plot header file. The [*Tree*] field contains the tree number, and is not needed by GEMFORM. The [*Species*] field contains species name. This is not necessary for GEMFORM, but can be used to test the options with no species list table. The [*Code*] field is the species code; this links to the [*Code*] field in the [*SpeciesList*] table. The [*Dbh*] field contrains tree diameter in cm. The [*Class*] field contains a numerical stem quality class.

The species list table is called [*SpeciesList*], and contains 5 fields. The [*Code*] field links to the tree data, and is the species code. The [*Common name*] and [*Botanical name*] fields are self-explanatory. The [*Model*] field contains a growth model code for the species, derived from Alder (2000). The [*Group*] field can have arbitrary species group codes edited-in to give different sub-totalling in stand tables, and commercial groups for stand projection.

It will be noted that:

- Field and table names can contain spaces, but must then be specified with a […] around the name. Generally, field names are not case sensitive, but linking codes are. A code of *a101* would not match *A101* for example.
- Field and table names can be as required, and are specified on the *Design* form according to their function.
- All measurements must be metric. Areas are in hectares, diameters in cm, lengths or heights in metres, basal area factors in m^2/ha, and volumes in m^3/ha.
- Field data types for measurements must be numeric, preferably Double in Access. Codes and ID fields can be Integer, Text or other numeric types, but must match up between linked tables or an error will result. In other words, the PlotNo field in the above example could not be an Integer type in one table, and a Text type in another; they might look the same, but the program would fail.

To review the settings for the IFP data file as downloaded, set the sampling design to *IFP Inventory* on the pull down list, as shown. The alternative of *IFP Inventory (no block header)* can be used to test the program in post-stratified mode, using soil type to stratify blocks.

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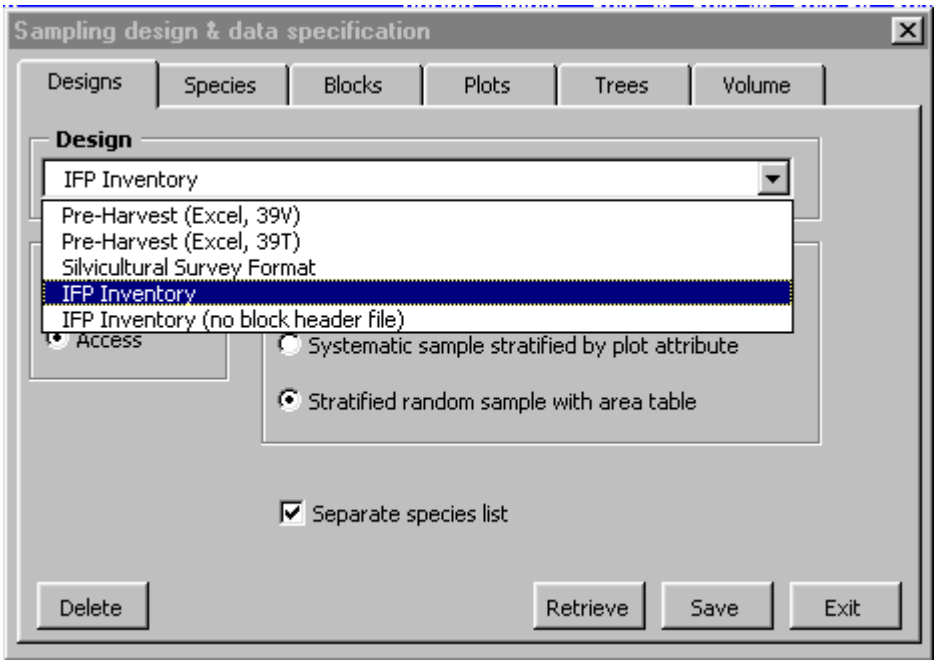
[2] Note that the area data was not in fact known to the author, and the figures entered in this table are fictitious, not actual areas from the IFP Inventory. They should be edited to correct values before using this data except for demonstration/training purposes.


Sampling design & data specification
Designs
Species
Blocks
Plots
Trees
Volume
Design
IFP Inventory
Pre-Harvest (Excel, 39V)
Pre-Harvest (Excel, 39T)
Silvicultural Survey Format
IFP Inventory
IFP Inventory (no block header file)
Access
Systematic sample stratified by plot attribute
Stratified random sample with area table
Separate species list
Delete
Retrieve
Save
Exit

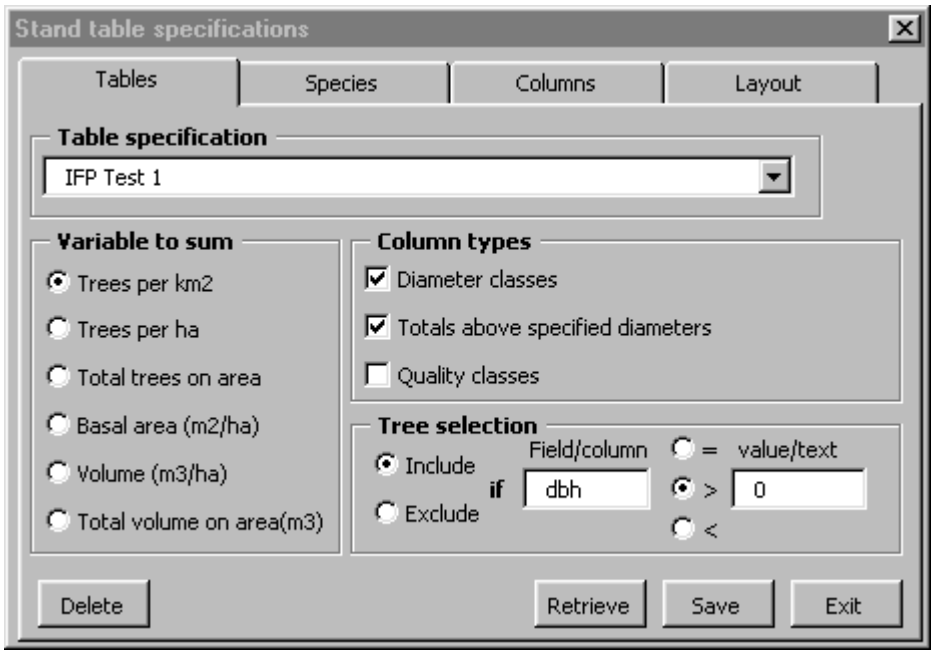
Stand table options

Stand tables are generated as Excel worksheets by GEMFORM, from any of the possible data sources described in the previous section. The rows in the table comprise species entries or species group subtotals. The columns can be diameter classes, totals above minimum diameters, or totals classified by stem quality. The layout of the stand table is set by the Table form, whose icon is shown at the left.

Stand table specifications can be saved under different names, so that the column configuration can be recalled and run without needing to re-enter all the settings.

With inventory data, sampling error and confidence limits can be calculated for totals columns. The confidence limits can be to specified probability levels.

The image below shows the appearance of the Stand table layout form. Invoking this screen from GEMFORM, and then pressing F1, will bring up the Help file which gives further information on the function of each tab and detailed information on the parameter settings. Overleaf is shown the typical appearance of a stand table.



Stand tables are generated from the Run dialog (see page 2) by pressing on the *Make stand tables* button. The selected *sampling design*, *table layout* and *input file* must be compatible with each other.

Appearance of a stand table output by GEMFORM.

The number of columns is determined by user settings for diameter classes, totals above diameter limits, and quality classes. Summary rows for species groups are use definable. Tree numbers, basal area or volume can be summarised. With inventory data sampling statistics can be displayed for sub-total rows or for totals above diameter columns.

Stand table of Total stocking for Silvicultural survey 3 (100 ha)

Species		Diameter class (cm)					Quality	
Common name	*Botanical name*	*30-50*	*50-70*	*70-90*	*90+*	*50+*	*Good*	*Defect*
Morabukea	*Mora gongrijpii*	889	326	46	8	380	441	828
Greenheart	*Chlorocardium rodiei*	369	213	41	9	263	150	482
Silverballi, Kereti	*Ocotea puberula*	779	92	5	1	98	268	609
Wamara	*Swartzia leiocalycina*	320	57	1	2	60	118	262
Bulletwood	*Manilkara bidentata*	28	31	30	15	76	51	53
Sub-total (P)		**2,385**	**719**	**123**	**35**	**877**	**1,028**	**2,234**
Soft Wallaba	*Eperua falcata*	96	50	12	3	65	42	119
Kabukalli	*Goupia glabra*	249	15		1	16	45	220
Huruasa	*Aberema jupunba*	45	35	16	1	52	15	82
Kaditiri	*Sclerolobium guianense*	58	48	4		52	3	107
Maporokon	*Inga alba*	77	33	4		37	24	90
Fukadi	*Terminalia amazonia*	60	22	9	2	33	24	69
Itikiboroballi	*Swartzia benthamiana*	48	26	6	1	33	18	63
Shibadan	*Aspidosperma cruentum & album*	61	14	7		21	46	36
Burada	*Parinari campestris*	39	17	8	2	27	36	30
Futui	*Jacaranda copaia*	94	12			12	22	84
Baromalli	*Catostemma commune*	77	14	1		15	42	50
Maho	*Sterculia pruriens & rugosa*	60	12	2		14	31	43
Dukali	*Parahancornia fasciculata*	27	11	3		14	30	11
Simarupa	*Simarouba amara*	14	10	2	1	13	5	22
Silverballi, sawari skin	*Ocotea canaliculata*	12	12	1		13	14	11
Karohoro	*Schlefflera morototoni*	23	9			9	4	28
Silverballi, Kereti poor		34	3			3	3	34
Manni	*Symphonia globulifera*	17	4	1		5	9	13
Ulu	*Trattinickia demerarae & rhoifolia*	18	2	1	1	4	13	9
Kurokai	*Protium decandrum*	35					11	24
Dalli	*Virola surinamensis & sebifera*	25	2			2	12	15
Purpleheart	*Peltogyne*	14		2		2	7	9
Suya	*Pouteria speciosa*	6	5	1		6	7	5
Wadara	*Couratari guianensis*	1	1	4		5	1	5
Silverballi, yellow	*Aniba hypoglauca*	4			1	1		5
Tatabu	*Diplotropis purpurea*	10		1		1	4	7
Silverballi, brown	*Licaria cannella*	13	1			1	8	6
Silverballi, Wabima		3			1	1	1	3
Silverballi, pear leaf	*Ocotea acutangula*	8	1			1		9
Hububalli	*Loxopterygium sagottii*	2	3			3		5
Barakaro	*Ormosia coccinea*	4	1			1	1	4
Hachiballi	*Pera*	2		1		1	2	1
Silverballi, Gale		5					2	3
Dukalli		1	1			1	2	
Baromalli, sand	*Catostemma fragrans*	2						2
Tonka Bean	*Dipteryx odorata*		1			1		1
Sarebebeballi	*Vouacapoua macropetala*	1						1
Haiawa	*Protium guianense*	1						1
Sub-total (A)		**1,246**	**365**	**86**	**14**	**465**	**484**	**1,227**
Yaruru	*Aspidosperma excelsum*		19	26	3	48		48
Kakaralli, Black			35	8		43	12	31
Monkey Pot	*Lecythis davisii & zabucajo*		11	12	3	26	3	23
Kakaralli werimeri			17	6		23	11	12
Manarieballi, Red			7	5		12	2	10
Duka	*Tapirira marchandii & obtusa*		5	6		11	3	8
Aruadan	*Couepia exflexa*		3	2	2	7		7
[Unknown]			6	2		8		8
Asepoko	*Pouteria guianensis*		2	2	1	5		5
Devildoor	*Glycydendron amazonicum*			2	1	3	1	2
Kokoritiballi	*Pouteria reticulata*		3	2		5		5
Uya	*Parkia ulei*		2	2		4		4
Paripiballi	*Chrysophyllum pomiferum*		1	3		4		4
Kakaralli	*Eschweilera spp.*		2	2		4		4
Koraroballi	*Hymenolobium sp.*			1	1	2		2
Warakaioro	*Laetia procera*		2	1		3	1	2
Kamahora	*Pouteria*		2	1		3		3
White Cedar	*Tabebuia insignis*		3			3		3
Konoko	*Licania sp.*		1	1		2		2
Manariballi , like	*Pseudopiptadenia suavolens*				1	1	1	
Bauawa			2			2	1	1
Apakaito			2			2		2
Kakaralli, fine-leaf				1		1		1
Dukuria	*Sacoglottis guianensis*			1		1	1	
Trysil	*Pentaclethra odorata & macroloba*			1		1		1
Black Heart			1			1		1
Imiriaballi			1			1		1
Corkwood, Hill			1			1		1
Kamakuti			1			1		1
Manobodin	*Emmotum fagifolium*		1			1		1
Duru	*Apeiba echinata & petoumo*		1			1		1
Kautaballi	*Licania alba & majuscula*		1			1		1
Imoradan			1			1	1	
Marishiballi	*Licania canescens & micrantha*		1			1	1	
Manaribalii	*Pithecellobium pedicellare*		1			1	1	
Canawaballi			1			1		1
Barabara	*Diospyros*		1			1		1
Sub-total (B)			**137**	**87**	**13**	**237**	**39**	**198**
Unknown		221	11	6		17	61	177
Sub-total (U)		**221**	**11**	**6**		**17**	**61**	**177**
TOTAL (all species)		**3,852**	**1,232**	**302**	**62**	**1,596**	**1,612**	**3,836**

Background

The estimation of sustainable yields is of great importance in sound forest management, and is the *raison d'etre* for GEMFORM. The growth model incorporated was developed in October 2000 for processing the silvicultural survey data (Alder, 2000), and has been generalised in this version to operate with any data set.

The actual models used for Guyana are incorporated in the download file *Growth Models Database* (see page 1). They are taken directly from Alder (2000).

The descriptive material that follows in this section will also be found in the GEMFORM help file.

Stand Projection outputs

The typical appearance of the stand projection output is shown below. One table is produced for each stratum or block, with the block title and area shown in yellow.

	A	B	C	D	E	F	G	H	I
1	**GEMFORM stand projection**			**Period**	**Initial**	**Year 20**	**Year 40**	**Year 60**	**Year 80**
2	*Forest block/stratum*	*Area (ha)*	*Size*	*Stand component*	*Trees (n/km2) by felling cycle*				
3	**47 Mile**	**303**	50+	*Harvest*	-	99	118	170	144
4			50+	*Harvestable, retained*	216	72	-	53	109
5			30-49	*Advance growth, sound*	186	361	639	331	280
6			30+	*Defective, damaged*	340	576	1,288	1,083	1,046
7			30+	*Non-commercial species*	8,933	7,234	7,556	6,646	6,504
8					*Volume (m3/ha) by felling cycle*				
9			50+	*Harvest*		3.9	3.8	3.9	3.9
10			50+	*Harvestable, retained*	7.7	2.8		1.2	2.9

There is one column for each felling cycle, plus the initial condition in year zero. The stand statistics represent the status immediately after harvesting, except for the initial column, which shows the stand as it is at the time of measurement. The number of columns will depend on the number of felling cycles being simulated, but is limited to a maximum 255 by Excel.

The rows in the table are as follows:

(1) Harvest This gives the number of trees per km^2 of commercial species, defect and damage-free, that can be harvested at each felling cycle. The classification of commercial species, and the criteria for defect and damage, are set on the growth models form. The numbers of trees felled depends on the yield regulation option on that form.

(2) Harvestable, retained This gives the number of trees above the minimum felling diameter that are retained due to the yield regulation criteria. These are sound, defect and damage-free commercial species.

(3) Advance growth, sound This gives the number of trees at each felling cycle (after felling, and allowing for damage losses) which are in the size class below the commercial diameter limit. These are potential crop trees, sound, defect-free and of commercial species. The size class that defines advance growth is set on the growth models form.

(4) Defective, damaged This gives the number of commercial trees that are unusable due to either form defect, decay or damage, above the advance growth diameter limit.

(5) Non-commercial species This gives the number of trees of non-commercial status, irrespective of their stem quality, above the advance growth diameter.

(6) Harvest by volume This gives data in terms of m3/ha for the same trees as included in row (1). It shows the actual harvest extracted at each felling cycle.

(7) Harvestable, retained by volume This gives data in terms of m3/ha for the same trees as included in row (2).

Growth model data layout

Growth model data can be stored in either an Excel or Access file. The image below shows a typical Excel table layout.

	A	B	C	D	E	F
1	**Growth models**					
2	**Description**	**Model**	**Dbh Inc**	**Mortality %**		**Dmax**
3	*typical species*	#	mm/yr	*Sound*	*Defective*	*cm*
4	*Small understorey trees*	A	0.116	1.58%	12.28%	32.9
5	*Marishiballi*	B	0.213	2.03%	7.09%	35.9
6	*Swizzle stick*	C	0.357	2.99%	6.14%	30.9
7	*Sand Baromalli*	D	0.222	1.94%	8.77%	43.5
8	*Kakaralli, default/unknown*	E	0.362	0.89%	2.95%	50.4
9	*Trysil*	F	0.512	2.05%	3.97%	42.4
10	*Haiariballi*	G	0.686	2.25%	5.18%	54.3
11	*Congo Pump*	H	1.013	2.72%	3.19%	55.0
12	*Wirimiri*	J	0.174	1.58%	7.24%	54.5
13	*Crabwood*	K	0.525	1.87%	4.86%	63.5
14	*Morabukea*	L	0.341	0.73%	5.66%	70.0
15	*Greenheart*	M	0.218	0.82%	2.64%	71.3
16	*Kabukalli*	N	0.561	1.97%	2.57%	93.4
17	*Swamp Baromalli*	P	0.526	0.89%	3.48%	77.4
18	*Maporokon*	R	1.145	3.36%	1.54%	79.5
19	*Purpleheart*	S	0.629	2.62%	3.98%	112.6

Five parameters are needed for each row in the data table. These items are:

Model ID This must be a single capital letter, from A-Z, allowing for 26 possible models. In the species list there must be a corresponding column or field giving the model ID for each species. It is not necessary to use all the letters, or to use them in any sequence. There is no implicit meaning in the letters - they are simply for identification.

Dinc Mean diameter increment, in cm/year.

AMR(s) Annual Mortality Rate for sound, healthy trees free of damage or decay.

AMR(d) Annual Mortality Rate for trees with indications of damage or decay.

Dmax — A typical size for mature individuals of the species, represented by the 95% point on the cumulative diameter distribution. This is not a critical parameter in the model, and needs only be given approximately.

Technical description of the model

The growth model works in the following stages:

(1) Individual tree data are grouped into cohorts with the same growth model ID, utilization status, form and defect status, and diameter. Utilization status is classified as commercial/non-commercial. Form status is classified as acceptable/rejected from a utilization perspective. Defect status from damage or decay is classified as present/absent. Each cohort is identified by the above characteristics, assigned its initial diameter, and has a culculated stocking in N/km^2.

(2) Over a felling cycle, the growth of the cohort is based on the mean diameter increment for the respective Model ID, multiplied by the length of the cycle in years. This growth is added to the initial diameter.

(3) Mortality is calculated over the length of the felling cycle using a compound interest formula. The mortality rate is taken from the growth models table according to the Model ID, and whether decay/damage is present or absent.

(4) Over the felling cycle, the number of trees lost from mortality is accounted for year by year. These are replaced by new cohorts with an initial diameter specified by the baseline diameter parameter. Recruits maintain the same proportion of species, form defect and decay defect as in the original stand.

(5) Harvesting is calculated up to the limit of the specified regulated yield, and the numbers of trees in affected cohorts adjusted for removals. Only trees which are of commercial species, not defective, damaged or of reject form status can be harvested. Others are always left. The criteria for defect and damage depend on the tree quality grading system and the criteria expressions on the growth models form.

(6) The regulated yield is set as a fixed limit, by volume, tree numbers, or percentage of stock, as indicated on the Growth models form. It can also be calculated automatically to ensure that sustained yield, in terms of volume, is constant over the number of felling cycles being simulated. This latter process repeats the entire simulation using a search algorithm that starts by felling all commercial timber, and successively reduces its estimates until sustainability is achieved.

(7) The model repeats for the specified number of felling cycles, using the cohorts left after felling as the starting point for the next cycle.

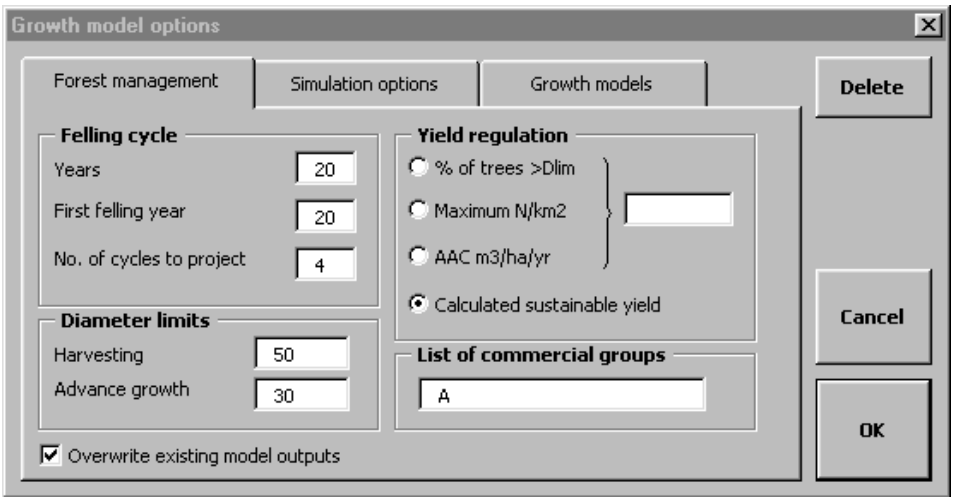
(8) Recruitment is simulated for harvested trees in the same way as for natural mortality. If 100 trees are felled, then 100 recruits of the baseline diameter size will replace them, of the same quality and species. The timing is spread equally through the felling cycle to give a range of size classes at the next cycle.

(9) Trees which grow above the specified *Dmax* are assumed to have reached a degree of senescence, and the mortality function for damaged/decayed trees is applied. This curtails the size distribution and avoids excessively large trees occurring. However, such trees are not marked as defective, and remain utilizable if they were so originally.

The model is a simple and robust one, and is designed for crude data sources such as stock surveys and commercial inventories, where the stand may be only partially enumerated in terms of size classes and species. Commercial inventories and stock surveys are characterised by high minimum measurement diameters (30 cm dbh or more) which create serious problems for more refined models. The recruitment method in GEMFORM has been specifically adapted to this situation, although longer term projections will be more reliable if smaller diameter measurements (preferably down to 10 cm) are available.

Forest management options

The growth model options form sets up the stand projection system used by GEMFORM. The forest management tab gives details of the felling cycle, diameter limits, yield regulation method, and defines which species groups are considered to be commercial.



The Simulation options tab controls how the species list links to the growth models table, the logging damage coefficient applied, the defect criteria used, and how recruitment is modelled.

The Growth models tab defines the structure and file type and location of the growth model information.

The OK button saves the current model settings *in association with the file name containing the growth model*. The Cancel button closes the form without saving changes. The Delete button will remove settings associated with an unwanted growth models file. Selecting a different growth model file will re-invoke the settings for that file, especially field names, but also other settings.

On the Forest management tab, the felling cycle options include:

- *The length of each felling cycle*. This may be anything from 1 year upwards.
- *The year of the first projected felling* after the start of the simulation
- *The number of felling cycles* to project.

The diameter limits control harvesting and the displayed data for advance growth. The harvesting limit must be greater than the advance growth limit. Trees above the harvesting limit of commercial species are available for felling. Advance growth numbers are shown for commercial trees, both sound and defective, and non-commercial trees.

Yield regulation controls the intensity of harvesting at each cycle. Four options are shown. Three of these involve a fixed target value, which should be entered in the box indicated on the form. The fourth is an optimising method with no fixed target. The options are:

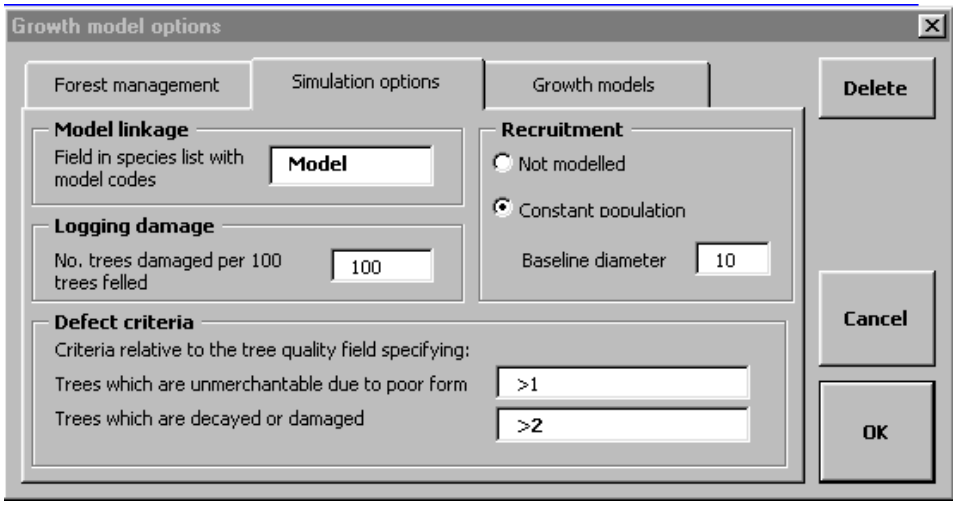
- *% of trees above the minimum diameter*. This percentage will be felled at each cycle if available. The total stock is taken as including defective or malformed commercial trees, but only sound trees may be harvested, so the actual harvest will probably be less than the calculated percentage.
- *Maximum number of trees per km^2 to fell*.
- *An annual allowable cut* (AAC), in terms of m3/ha/yr. This is multiplied by the length of the felling cycle to give the allowable harvest at each cycle.
- *A calculated sustainable yield* in terms of volume. This is done iteratively, so the simulation may re-run several times with this option. The calculation finds the largest volume yield that can be cut equally over the number of felling cycles specified.

The first three methods are similar to common legal requirements for yield regulation in different countries. The fourth is most likely to satisfy certification requirements for sustainable forest management.

The list of commercial groups should give the codes for species groups that are commercial. If nothing is listed, no trees will be harvested. A species group field must be defined for the growth model to be useable.

Simulation options

The *Simulation options* tab of the growth models form, as shown below, contains a number of technical items required by the model.



The model linkage gives the field name or column letter (for Access or Excel data) in the species list that gives the growth model code for each species.

The logging damage multiplier is used to estimate logging damage in the model. This is the number of trees in the residual stand significantly damaged per each 100 trees removed. As a rule of thumb, a value of 100 is appropriate for natural forest logging with reasonable care. Note that the damaged trees are taken from the whole stand, including non-commercial trees and commercial trees that may be already damaged or malformed. Hence the actual effect of logging damage on future harvests will be found to be small.

The defect criteria define how the data identifies trees of poor form, and those which are damaged or defective. The criteria are applied to the stem quality field in the tree data, which must therefore be specified if the growth model is to run. The criteria can take the form of a relational operator such as >, >=, <, <=, # (not equals), or =, followed by a value. If the criteria is true for a particular tree, then it is classified accordingly.

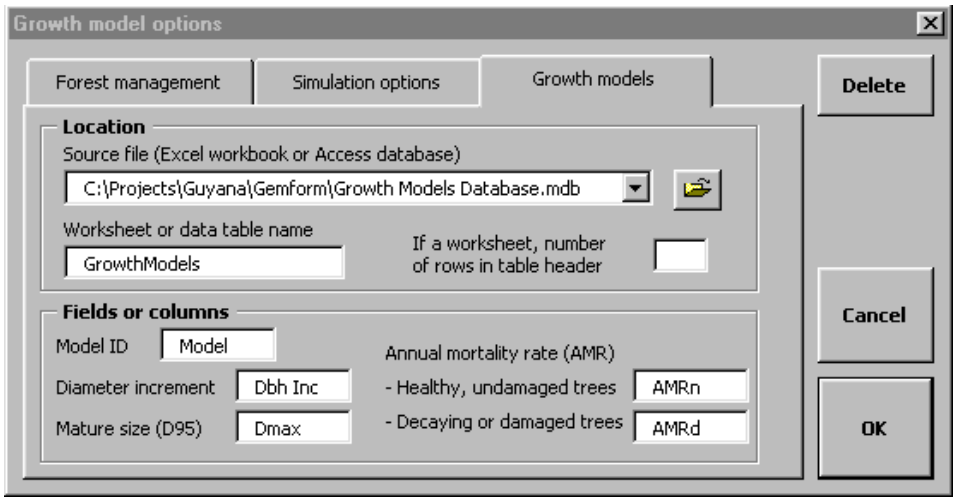
Damage/decay defect and form defect should be distinguished in the data because the standard models apply different and higher mortality rates to trees with damage or decay, but not to those which are healthy but of poor form.

Recruitment can either not be modelled, which will always lead to declining yields with long-term projections, or modelled on a constant population assumption. The baseline diameter for recruitment *must be the smallest size class measured* in the inventory or stock survey. If it is set to a higher value, the amount of recruitment will be excessive.

Specifying the growth model parameters table

The Growth models tab gives the location and field names for the growth model parameters, as noted on page 11 . In the Location box, the filename pull-down lists growth model files that have been used. A new set of models can be allocated by clicking the Open button. The file can be either an Access database or an Excel workbook, but need not be the same as the data file given on the *Run* form. The worksheet or data table name must be given where indicated. If the file is an Excel workbook, then the starting row for the table in the worksheet should be given, excluding any headings or titles.

In the fields or columns box, the five required components of the growth model must be set. If it is an Access file, field names should be given. These should be enclosed in square brackets [...] if they contain embedded spaces. If the data is in an Excel worksheet, then column letters must be used.



When the OK button is clicked, all settings on all the tabs of the form will be saved in association with the current growth model file name. If a different filename is selected that has previously been used, its parameter settings will be recalled. If the pull down file list because burdened with redundant entries, they can be deleted by selecting them and using the Delete button.

Conclusions

GEMFORM should prove to be a useful package, and has been written based on the author's experience of needs in a number of tropical countries, as well as the basic requirements of the Guyana Forestry Commission. The data input options, and stand table layouts are flexible enough to meet most requirements. The growth modelling method, although quite simple, is enough to give a realistic idea of the types of yields that can be obtained from natural stands, and thence to avoid the over-cutting and forest degradation that tends to be so prevalent in the tropics.

The author is committed to supporting this model, and users who have any difficulty either in setting up data, or in running the program, should contact him via email at denis@bio-met.co.uk for advice and assistance.

Denis Alder
Oxford
12th March 2002

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Alder, D (2000) *Development of growth models for applications in Guyana*. Technical report for the Guayana/DFID Forestry Commission Support Project. 41 pp.

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