INTERNATIONAL TROPICAL TIMBER ORGANIZATION
Project PD 162/91 - Papua New Guinea

Intensification of growth and yield studies in previously logged forest

Data, programs, and models for natural forest growth and yield

A final technical report on project outputs

Denis Alder, Forova Oavika, and Cossey Yosi

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Executive Summary

This report documents the formal outputs from ITTO project PD 162/91 "*Intensification of growth and yield studies in previously logged forest*" as the project enters its final stages. The project has established 72 permanent sample plots of 1-ha, 70 of which have been re-measured. In all there are 210 data files representing plots and re-measurements. The data has been checked and is of good quality.

A set of analysis programs have been written and are documented in the report. These cover stand structure summaries, stand increment and recruitment, vegetation analysis, species growth characteristics, cross-tabulation programs for species increment and mortality with stand density, crown quality, defect, tree size, and so on.

A growth model has been developed called PINFORM which can be used to project the growth of the permanent plots or any forest inventory data from a similar forest type, with simulation of harvesting, and calculation of volume yields. The model has been described in detail in other reports. The present document provides an updated user's guide to the most recent version, PINFORM 1.28.

Appendices describe all the data structures used in the project database, and document the diskettes and files available for the data, the analysis programs, and the growth model.

The project has undertaken various dissemination activities including an international workshop in November 1998, a local workshop in March 1998, various study tours and training fellowships, and extensive *ad hoc* training by consultants. An important output from the project is therefore the various personnel trained in field procedures for permanent plots, in database and computer methods, and in the application of the PINFORM model to forest planning.

The modelling work has shown that, although forest conditions are very variable from place to place, the general prescriptions of the PNG Forest Authority of a 50 cm diameter limit and 35 year felling cycle gives a slightly conservative annual allowable cut. The felling cycle is not a critical factor, but enforcement of the diameter limit and control over felling intensity to respect the maximum annual allowable cut is. Otherwise excessive logging damage occurs which may lead to very slow stand recovery.

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Acknowledgments

The ITTO project has since its inception been directed by Forova Oavika. The database has been managed by Cossey Yosi. Field work on the PSPs has been led by Kunsey Lavong and undertaken by teams comprising Stanley Maine, Matrus Peter, Christopher Raepa, Timothy Urahau, Thomas Bilalu, Tana Keputong, Andrew Pora, and Amos Basenke. Janet Sabub has provided secretarial and data entry services. Formerly, Warea Andasua, Philip Kapi, Evelyn Kunjap and Rose Gaiware have assisted. Klaas Romijn acted as the original consultant on the project and developed the PERSYST data processing system, provided field training, and wrote procedure manuals. The author's present contributions have only been made possible through their efforts.

At the Forest Authority Headquarters, Martin Golman and Vitus Ambia provided briefings on forest planning matters in PNG, especially relating to the FIPS system. The Director of the Forest Research Institute, Terry Warra, provided the facilities and hospitality of the FRI, which enabled the work to proceed.

Disclaimer

This document is solely the responsibility of its author, and does not necessarily represent the views of the International Tropical Timber Organization, the Forest Authority of Papua New Guinea, or its Forest Research Institute.

Abbreviations

AAC.....Maximum annual allowable cut.
AusAID.....Australian Agency for International Development
Dbh.....Diameter at breast height (1.3 m).
Excel .....*Microsoft Excel*. A registered trademark of Microsoft Corporation.
FIPS .....Forest Inventory Programming System
FIMS.....Forest Inventory Mapping System
FMA.....Forest Management Authority
FRI .....Forest Research Institute
ITTO .....International Tropical Timber Organization
PERSYST .....Permanent Plot System
PINFORM.....PNG/ITTO Natural Forest Model
PNG .....Papua New Guinea
PSP .....Permanent sample plot.
TRP .....Timber Rights Purchase
VBA.....Visual Basic for Applications. *Visual Basic* is a registered trademark of Microsoft Corporation.

Typographic and other conventions

Text typed in *Arial 10 point italics* refers to wording on PINFORM menus, dialog forms or outputs. Figures reproduced directly from PINFORM show the PINFORM figure number (1-6) in bold immediately above, as part of the figure. The figure number used in this report is always shown in the left margin as part of the caption. This document is printed using Book Antiqua, Impact and Arial fonts available with Microsoft Windows 95 and is formatted for A4 paper.

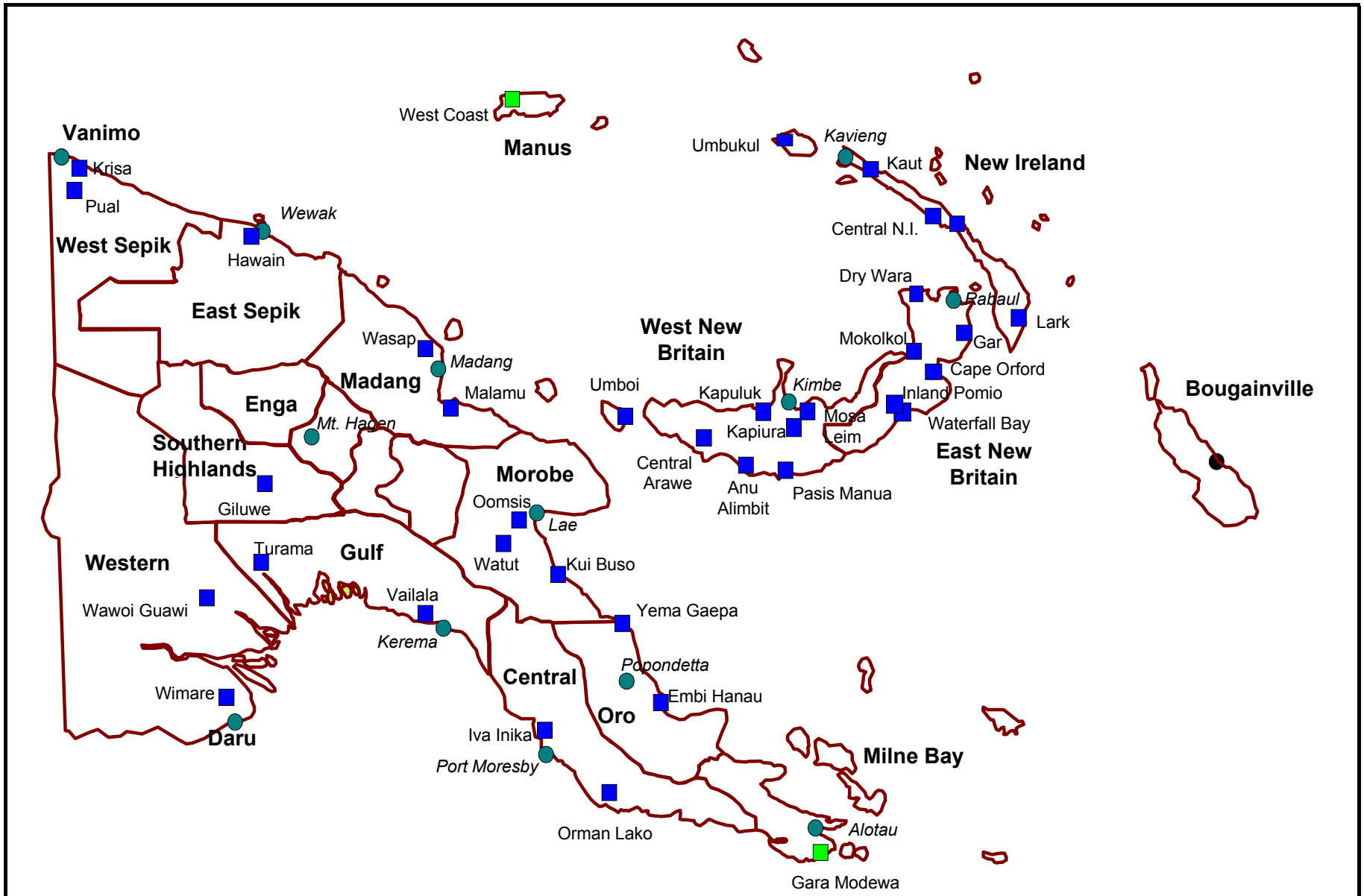


Figure 1 Location of permanent sample plots established under the ITTO project

Province		Locality (TRP)	Code	Plots	'90	'91	'92	'93	'94	'95	'96	'97	'98
Western Province	WEST	*Wawoi Guavi*	WAWOI	2					TT			TT	TT
		Wimare	WIMAR	2					TT			TT	TT
Gulf Province	GULF	*Turama*	TURAM	2					TT			TT	TT
		Vailala	VAILA	2					TT			TT	TT
Central Province	CEN	*Iva Inika*	IVAIN	2							TT	TT	TT
		Ormand Lako	ORLAK	2					TT		TT		
Milne Bay Province	BAY	*Gara Modewa*	GARAM	2					TT		TT		TT
Oro Province		*Embi-Hanau*	EMBIH	4					TTTT		TTTT		TTTT
		Yema Gaepa	YEMA	1							T	T	
Southern Highlands	SH	*Giluwe*	GILUW	2				T	T		TT	TT	TT
West Sepik	SPKW	*Krisa L.A.*	KRISA	2					TT		TT		
		Pual L.A.	PUAL	2					TT		TT		TT
East Sepik	SPKE	*Hawain Lfa*	HAWAN	2					TT		TT		TT
Madang Province	MAD	*Rai Coast*	MALAM	2						TT	TT	TT	TT
		Madang N.Coast	WASAP	2	T			T	T	T	TT	TT	TT
Morobe Province	MOR	*Kui Buso*	KUI	2					TT	TT	TT	TT	
		Oomsis Bl.5 Sl	OOMSI	2				TT	TT	TT	TT	TT	
		Umboi Blk	UMBOI	2					TT	T	T	TT	TT
		Trans Watut	WATUT	2				TT		TT	TT	TT	
West New Britain	WNB	*Anualimbit Lfa*	ANUAL	2						TT		TT	
		Central Arawe	CARAW	2						TT		TT	
		Kapiura	KAPIU	2				TT		TT		TT	
		Kapuluk	KAPUL	2				TT		TT		TT	
		Mosa Leim	MOSAL	2				TT		TT		TT	
		Pasi/manua Lfa	PASMA	2						TT		TT	
East New Britain	ENB	*Cape Orford*	CFORD	2						TT		TT	
		Dry Wara	DWARA	2						TT			
		Gar	GAR	2				TT		TT		TT	
		Inland Pomio	INPOM	1						T		T	
		Mokolkol Sl.	MOKOL	2				TT		TT		TT	
		Waterfall Bay	WFBAY	2				TT		TT		TT	
New Ireland	NI	*Cent.N.Ireland*	CNIRD	2						TT		TT	
		Kaut	KAUT	2				TT		TT		TT	
		Lark	LARK	2						TT		TT	
		Umbukul	UMBUK	2				TT		TT		TT	
Manus Province	MAN	*Manus W.Coast*	WCOST	2						TT		TT	
Total plots measured				72	1			22	30	43	30	56	28

Table 1 Schedule of IITO plots by province, concession, and year of measurement

Introduction

Background

The ITTO project *Intensification of growth and yield studies in previously logged forest* started in 1992 and has resulted in the establishment and re-measurement of 70 permanent sample plots widely distributed throughout Papua New Guinea. The project's broad objectives were to strengthen growth and yield studies in natural forest in PNG, and to develop a growth model to assist planning of forest management options.

The present manual is the concluding technical report from the project. It aims to provide a complete documentation of the PSP database that has been built up, of the analysis programs that can operate on it, of the growth model PINFORM, and of the general management conclusions that can be arrived at from the results. It incorporates material from earlier technical reports on PINFORM and the data analysis methods, notably Alder (1997, 1998a).

The model as a practical tool

The model developed for Papua New Guinea has been called PINFORM, which is an acronym for PNG/ITTO Natural Forest Model. Growth models for natural forest management should not be regarded as ivory-tower projects. They are simply a computational framework for pulling together the complex information on tree growth, recruitment and mortality that is required to correctly describe a natural tropical forest. Forests of this type are too complex for their potential yield to be evaluated by any simple graphical method, such as could be used for plantations. Consequently, a computer model becomes indispensible. PINFORM has been designed to be easy to use, running as a program in Microsoft Windows. It can make projections using summaries from the ITTO sample plots themselves, or from external forest inventory data.

The basic conclusions that arise from the use of the model are discussed at the end of this manual. Several workshops have been held to promote the use of the model by the PNG Forest Authority, and the authors are of the view that it can now be regarded as a substantially useful tool for forest management.

Location of PSPs

The approximate locations of the permanent sample plots are shown in Figure 1. Table 1 shows the number of plots at each locality, and the dates of re-measurement. Each tick represents one re-measurement of one plot in the indicated year. In all a total of 72 plots were established, and 70 have been re-measured at least once. All provinces except the highlands provinces of Simbu, Enga, Central and Eastern Highlands are represented, usually by four or more plots. Bougainville was also excluded due to the disturbances on that island. The plots were established in pairs, typically within 1 km of each other, at precise locations selected using random co-ordinates on a grid (Oavika, 1993). All the plots, with one or two exceptions, have been established in the forest shortly after logging, and were specifically intended to monitor forest recovery and re-growth.

Establishment and measurement dates

Most of the plots were established during 1993 and 1994, as shown in Table 1. Plots at Iva Inika and Yema Gaepa were established later, in 1996. One plot, at Wasap in Madang, was inherited from the older FRI plots, with re-measurement data from 1990 being incorporated into the ITTO data set. For the most part the plots have been re-measured biannually, but some of the more accessible sites (Oomsis, Kui, Wasap, Umboi) have been measured annually. In all there are 210 plot measurements, with 70 plots re-measured twice, 50 plots re-measured three times, and 14 plots re-measured four or more times as shown in Table 2.

Table 2 Number of enumerations for PSPs

Enumeration	**1**	**2**	**3**	**4**	**5**	**6**
Plots measured	72	70	50	14	3	1

The design and measurement procedures for the sample plots are described in detail in Romijn (1994a). They follow widely accepted international standards described in, for example, Vanclay (1992) and Alder & Synnott (1992).

Sample plot design

The plots are square, 100 by 100 m, with an area of 1 ha. They are subdivided into 25 quadrats each of 20 x 20 m. At each measurement, the species is checked and diameter measured. Crown position and crown quality are coded subjectively, and various coded notes recorded regarding the trees status, damage, and health. At the initial establishment, tree positions, merchantable height and crown diameters are recorded. All trees above 10 cm diameter are measured. At re-measurement,

tree positions, merchantable height and crown diameters are also recorded for ingrowth trees[1], but not for those previously measured.

Data entry and editing via PERSYST

A computer program called PERSYST was written to facilitate entry and editing of plot data. This program is fully documented in Romijn (1994b). The program runs under FoxPro 2.5 for Windows, and uses the DBF file standard to store all data. PERSYST allows the following operations:

- Creation of files for new plots
- Editing of plot data
- Generation of measurement forms, including data from last measurement
- Control on the progress of data entry
- Plot summary statistics for a single plot
- Editing of plot list and species list files
- Reports on work progress
- Printed species lists

Under PERSYST, each plot and measurement is stored in a separate file, whose name is based on the locality code from Table 1, to which are appended the plot number and enumeration number. The locality codes are always padded with _ (underscore) if there are less than 5 characters. Thus the first enumeration of plot 1 at Kui is stored in the file KUI__011.DBF.

Additionally, there is a species list file called SPECLIST.DBF, which contains the species code, botanical and local name, the growth model group and other information.

A file called PSP_LIST contains location details for each plot, including province, district, timber resource permit (TRP), UTM co-ordinates, and dates for measurement, data entry, and final editing.

For complete documentation of the file structures used in PERSYST, see Romijn (1994b). The various coding systems used for tree variables are explained in Romijn (1994a).

[1] Ingrowth trees are those observed for the first time above 10 cm diameter.

The analysis modules

The data analysis package for the ITTO plots was developed in order to summarise the large mass of tree and plot data in the individual files for further analysis. At the same time, dynamic parameters (recruitment, mortality, increment) are calculated by most of the programs and used as variables in the summarisation process. Each program was designed to explore a particular aspect of stand dynamics.

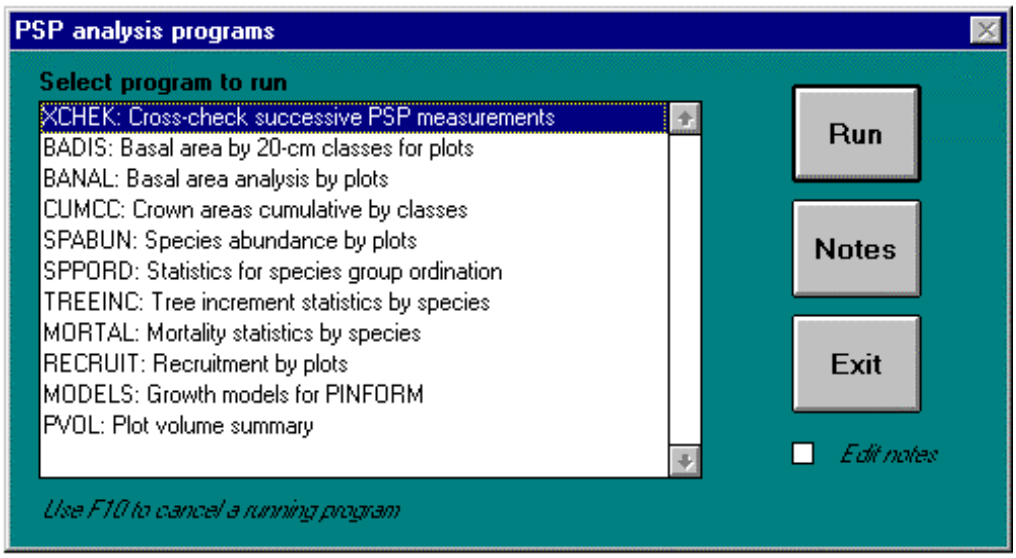
The programs do not provide complete simple solutions. The summary output files must be further studied and explored using statistical methods and trial simulation models to arrive at suitable growth functions. They therefore provide substantial assistance to the research worker, but do not replace the need for a specialised knowledge.

The modules are stand-alone FoxPro programs that work automatically and directly on the PERSYST sample plot database. A program organiser called ANALYSIS can be used to select the programs. This can be started from the PERSYST program by clicking on the button labelled *data analysis*. It can also be started directly from the FoxPro command window by typing:

DO ANALYSIS

When started by either method, the front-end displays the screen shown in Figure 2.

Figure 2 Selection screen for data analysis programs



Each program generates an output file in a standard format as a DBF table. Appendix A lists the output file formats. Most of the programs run through the 210 plot measurements currently existing in some 60-90 seconds.

XCHEK cross-checking program

The cross-checking program is designed bring together the various measurement files for a PSP and check them for consistency. The program is also designed to facilitate error correction, which is rather slow and difficult using PERSYST.

When the program starts, four options can be set before running the check:

- *The plots to be processed* may be entered as a complete plot code (*eg*. OOMSI01) or as a wild-card designation, such as OOMSI*. In the latter form, all plot codes which match the wild card will be included in the output report.
- *The species to be included* can be entered as a wild card designation. By default this is *, indicating any species code will be included. For example, ANI* would include ANI, ANI THU, ANI CHI, ANI POL, etc.
- *The output file name can be specified*. By default this is called ~MERGE.
- *If the re-process option box is marked*, then the existing merge file will be activated without carrying out any processing.

The **Run** button re-builds the merge file from the original PSP data files, carrying out checks on successive measurements. If the *re-process* option has been selected, the existing merge file is activated directly. It is then possible to view or print all or selected portions of the merge file, together with any associated error messages. The selection screen allows plots and quadrats to be selected using wildcard characters. By default, all quadrats are selected (using *), with the same plot designator as was used to create the ~MERGE file.

The **view** button displays the printed report using the FoxPro report viewer. The **print** button will send the report directly to the printer. Note that the printed reports can be very long. Even a single plot may require 30-50 pages. All data for all measurements of a plot are listed, with the successive measurements for each tree shown adjacent, and observations or error messages in the right hand column. It is therefore recommended when printing a plot that it is limited to a particular quadrat that needs detailed examination. Most checks and error correction can be done on screen without printing.

The **edit** button provides the most useful facility for routine corrections. The data is displayed as a FoxPro *browse* screen, with the successive measurements for each tree in sequence, and error messages in the right-hand column. Corrections made to this screen will be posted back to the original PSP data files if the following 2-step sequence is followed to exit the screen:

- Use **ctrl-W** to exit. If **esc** is used, any updates will not be saved to the original files, although they will be retained in the ~MERGE file and can be saved later.

- When the program prompts *Update the original PSP files with corrections?*, press **Y**.

Corrections which involve the addition or deletion of tree records at particular measurements cannot be done directly from XCHEK, but must be done from PERSYST.

The **summary** button gives a quick summary showing the types of errors and the numbers of trees affected. This is useful for a quick check on the data from a plot.

BADIS stand structure tables

The BADIS program tabulates basal area and tree numbers by 20-cm diameter classes for each measurement of all PSPs. The data are arranged with the successive measurements for each plot adjacent. A report format prints this out directly in a neat and intelligible format. The output file, called ~BADIS, can also be imported into Excel or other packages to produce graphs. The file structure is shown in Appendix A.

The program requires no inputs from the user. On execution it prompts *~BADIS file exists. Re-build?* Pressing **Y** causes the plot data files to be re-processed. Otherwise the existing output file from a previous run of the program is opened directly for browsing or printing in report format.

BANAL stand dynamic analysis

The BANAL program provides information about total and dominant basal area and tree numbers at the initial measurement. It shows changes over time in basal area and numbers due to growth, recruitment, and losses. It also gives the percentage error in basal area increment due to odd measurements[1]. It operates in the same way as BADIS, in that it requires no user parameters except a confirmation of whether or not to re-build the output file ~BANAL if it already exists. The file structure is shown in Appendix A.

CUMCC crown area analysis

CUMCC works in a similar fashion to BANAL and BADIS in that no user inputs are required other than to confirm over-writing of the output file. The program was designed to explore the relationship between the total crown projection area and the dominance or crown position of trees. It produces an output file, ~CUMCC, whose structure is shown in Appendix A. There is one record for each plot, which summarises the crown projection areas, in m^2/ha by cumulative classes of dominance. The first column includes only emergents (crown class 5). The second includes dominants and emergents (class 4-5). The third includes classes 3-5, and so on.

SPABUN species abundance by plots

The SPABUN program is designed to provide outputs that can be used for ordination or cluster analysis of the PSPs according to species abundance. There are several options which appear

[1]These include recruit trees over 30 cm and trees shrinking more than 1 cm or growing over 5 cm per year.

when the program starts up (see Figure 3). Under method, one of three alternatives can be selected:

1. *List the most common species.* This format is the only one which can be output in a report. A selected number of the most common species are listed for each plot, with N/ha, the selected abundance index, cumulative abundance, species name and family. The data structure is shown in Appendix A as ~SPABUN1.

2. *List abundances by plots and species groups.* This produces a rectangular matrix with plots as rows, and species groups as columns. Each element contains the group abundance. This type of data is suitable for plot ordination using the species groups. The data structure of the output file is similar to ~SPABUN2 in Appendix A.

3. *List abundances by plots for an indicator species list.* A list of species can be set up which are considered to be indicative of forest types. This option will produce a rectangular matrix of abundances by plots (rows) and indicator species (columns). The data structure is shown in Appendix A as ~SPABUN2.

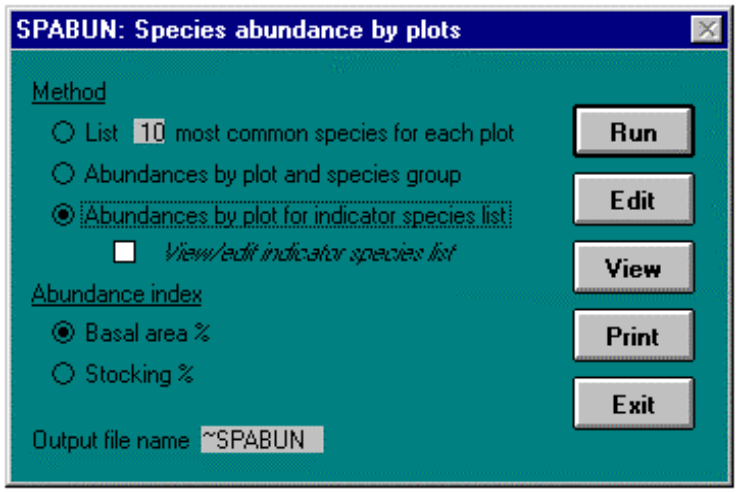


Figure 3 Options screen for the SPABUN program

The indicator species list can be edited by clicking the box labelled *View/edit indicator species list.* This is a browse table to which new rows can be added with the ctrl-N key. Existing rows can be deleted with the mouse by clicking the left-hand edge of the row. When a species code is entered in the list, the corresponding name will be looked up automatically. An error message is given if the code does not correspond to a species.

Neither of the two rectangular matrix formats (options 2 or 3) can be printed as a report; both are designed to be imported into a statistical package with ordination or cluster analysis facilities.

The abundance index can be selected as either tree numbers as a percent of the total stocking, or basal area %.

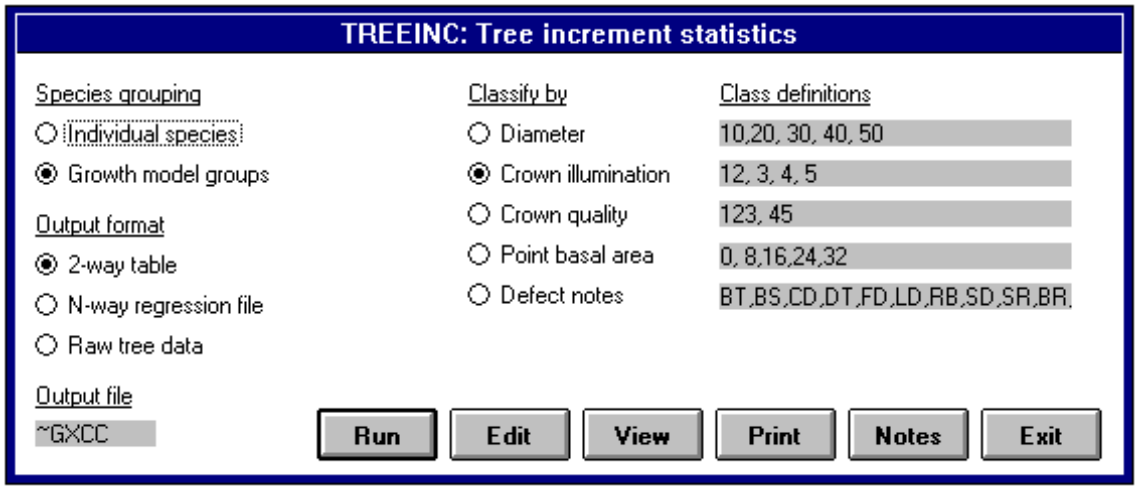
SPPORD species statistics for grouping

The SPPORD program is designed to provide a list of all species which occur on the plots together with key statistics that can be used to form species groups. The species codes, economic group, botanical and family name are given. The total number of trees, tree numbers by 20 cm diameter classes, and the number of plots on which the species is present are calculated. Mean increment with standard error are shown, and the 90% quantile of the diameter distribution (D_{90}).
The output file is called ~SPPORD. If it exists when the program is run, the user will be asked if it is to be re-built. Press **Y** to reconstruct the file from the current PSP data and species list file SPECLIST.DBF.

The program provides for a printed report which lists species and their summary statistics. This can be sorted according to three options: By species code, by economic value, or by frequency of occurrence.

Figure 4 Options screen for TREEINC program

The principle analysis undertaken with this file is via the Excel workbook SPPORD.XLS. This provides the facilities for creating or modifying the species groups.



TREEINC diameter increment analysis

The TREEINC program provides facilities for calculating diameter increments and forming classified summaries against different variables. When the program is started, an option screen appears as shown in Figure 4.

Under Species Grouping it is possible to select either individual species summaries, or summaries by the growth model groups[1].

[1]The model groups are determined by the MODEL field in the SPECLIST.DBF file that will be found in the PERSYST directory (normally C:\PSPS).

Three output formats can be selected:

- *2-way table*. This provides a printable report which summarises species or species groups classified by one of the selected factors under the Classify by list. Tables with upto 5 classes can be printed as FoxPro reports. The output file has the format shown as *TREEINC two-way tables* in Appendix A. Unless the output is to be printed directly as a report, the user needs to make a note of the factor and class limits used in the table, as these are not indicated in the field names.

- *N-way regression file*. For each species or species groups, mean increment can be summarised for a combination of several of the factors in the Classify by list. This type of output can be viewed as a browse screen with the **Edit** button, but cannot be printed as a report. The main objective of this option is to provide a data file suitable for analysis of factors affecting increment using graphical methods, multiple regression or general linear modelling. When this option is selected, the Classify by list is changed to a series of check boxes, any combination of which can be selected to include the factor in the output. The list is also extended to include stratum code[1] as a possible factor for classification. The output file has the format shown as *TREEINC multi-way tables* in Appendix A.

- *Raw tree data*. This allows individual tree increments to be output, together with a variety of other data for each tree that is useful. This includes tree diameter, crown diameter, crown point and total height, crown position and quality. These output files can be used for allometric studies such as height-diameter, or crown-tree diameter regressions, as well as increment studies. When this option is selected, the right-hand portion of the screen changes as shown in Figure 5. With this, the raw data output can be limited to a species group, a genus code, species code, or data may be output for all species. The latter will generate a large file (currently about 17,000 records). The output file has the format shown as *TREEINC individual tree extracts* in Appendix A.

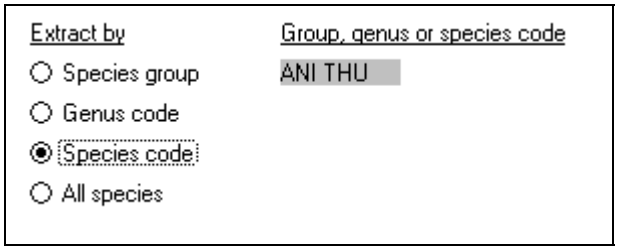


Figure 5 Special options when extracting raw data with TREEINC

[1]Stratum code is determined by the STRATUM field in the file PSP_LIST.DBF, which should be found in the PERSYST directory.

For the *2-way* and *N-way* tables, the classes used are determined by the lists given under Class definitions (see Figure 4). The class definitions are constructed as follows:

- *Diameter and Point basal area:* The entries given are numeric values which determine the lower bound of each class.
- *Crown illumination and quality*: Each class is defined by a list of crown codes.
- *Defect notes*: There are always two classes, *defective* and *non-defective*, indicated by **T**rue or **F**alse in the output data files. The trees to be classified as defective are indicated by a list of codes. If a tree has any of these codes in the TCCODES field of the plot data file at the first measurement, it will be classed as defective.

It should be noted that for *2-way tables*, printed reports can only be produced if there are 5 or fewer classes. If more classes are defined, then the output file will be produced correctly, but it cannot be printed as a report. It must be exported to *Excel* or a similar program for formatting and presentation.

MORTAL mortality rate analysis

The MORTAL program operates in a very similar way to TREEINC, except that there is no concept of raw data output. For classes of diameter, crown position, crown quality, competing basal area or defective/non-defective, the annual mortality rate (AMR) for a species or species group can be produced as a *2-way* or *multi-way* tables. The output formats for these two file types are shown in Appendix A.

RECRUIT recruitment analysis

The RECRUIT program summarises recruitment by plots. The information is similar to that in the ~BANAL output file, by the basal area and number of recruits is divided into non-pioneer and pioneer species. The file structure is shown in Appendix A.

MODELS growth models for PINFORM

The MODELS program provides a single step process to summarise data in the format required by PINFORM. The information produced is identical to that shown in the PINFORM table illustrated on page 11. The file structure is shown in Appendix A.

PVOL plot volume summaries

Plot volume summaries are produced by program PVOL. One record is produced for each plot, showing the initial volumes for trees greater than 10, 30 and 50 cm dbh. Mean periodic increments are shown for the same size classes over the entire measurement period. Net and gross volume increments are given. Gross increment is the actual growth. Net increment is the growth with mortality during the period deducted, and is the actual residual gain in volume.

Table 3 Table of species growth models reproduced from PINFORM

Model	Trees sampled		Diam. incr. (cm/yr)		Annual mortality %		Dmax	Typical species
group	*Sound*	*Defect*	*lower 50%*	*upper 50%*	*Sound*	*Defect*	*99%*	*in order, comprising first 66% of basal area in group*
A	356	19	0.097	0.436	0.71%	0.00%	30	Timonius, Cleistanthus, Mammea veimaurensis
B	2108	109	0.123	0.564	1.25%	4.32%	44	Myristica, Polyalthia, Gonystylus macrophyllus, Medusanthera
C	2146	100	0.139	0.621	1.09%	4.53%	52	Horsfieldia, Garcinia, Chisocheton, Aglaia
D	4027	234	0.154	0.653	1.23%	4.01%	59	Syzygium, Canarium, Planchonella
E	4359	243	0.175	0.809	1.34%	5.11%	68	Ficus, Cryptocarya, Pimeleodendron amboinicum, Calophyllum, Celtis, Litsea
F	2669	155	0.214	1.011	0.80%	2.83%	76	Pometia pinnata, Terminalia, Dillenia, Pterocarpus indicus, Euodia
G	325	30	0.286	1.314	0.76%	0.00%	110	Vitex, Spondias cytherea, Nothofagus
H	162	16	0.052	0.285	0.80%	6.22%	33	Osmoxyllon novoguineensis, Zygogynum, Aralia, Ryparosa javanica
J	144	18	0.047	0.345	2.30%	3.71%	45	Cnesmocarpon discoloroides, Mallotus, Steganthera, Xanthophyllum papuanum, Oreocallis wickhamii
K	850	54	0.088	0.420	0.88%	2.97%	51	Maniltoa, Diospyros, Parastemon versteeghii
L	396	5	0.109	0.513	0.84%	0.00%	71	Vatica rassak, Vitex cofassus, Gmelina moluccana, Ilex
M	53	3	0.096	0.417	0.85%	0.00%	125	Alstonia scholaris, Aglaia sapindina, Alstonia brassii
N	180	5	0.186	0.842	1.69%	0.00%	100	Teijsmanniodendron, Neonauclea, Pterygota horsfieldii, Endospermum meddulosum
P	467	54	0.172	0.716	0.73%	2.99%	41	Gnetum gnemon, Astronia, Dendrocnide, Erythrospermum
Q	608	49	0.196	0.927	3.25%	10.51%	43	Macaranga, Ziziphus, Macaranga aleuritoides
R	655	27	0.170	0.793	2.21%	9.35%	44	Microcos, Prunus
S	245	16	0.302	1.285	1.81%	0.00%	51	Elaeocarpus, Duabanga moluccana, Alphitonia
T	442	33	0.282	0.990	1.33%	2.79%	65	Anisoptera thurifera, Cerbera floribunda, Galbulimima belgraveana, Merrilliodendron
U	278	20	0.315	1.466	0.95%	2.98%	72	Artocarpus, Anthocephalus chinensis, Tristiropsis, Hibiscus
V	68	6	0.332	2.169	2.58%	8.31%	120	Elmerrillia, Hernandia, Ailanthus integrifolia
X	119	5	0.720	2.788	5.10%	29.36%	47	Trichospermum burretii, Trichospermum, Trema
?	1142	81	0.137	0.623	2.92%	10.37%	54	Unknown species
#	21799	1282	0.156	0.769	1.35%	4.67%	66	All species combined

Introduction

PINFORM is a cohort model for the projection of stand growth which has been developed under the ITTO project, based on the ideas of Vanclay (1989, 1994). It allows various management scenarios to be tested out on specific stands, described by forest inventory, to see how they respond and what future commercial harvests may ensue. Its functions are sensitive to species composition, stand density, site index, fire regime, and logging damage.

Aspects of the model have been described in several reports. The growth functions used are discussed in Alder (1997, 1998a, 1998b). A user's guide for version 1.24 is given in Alder (1998a), together with a discussion of the testing of the model and its implications for forest management in PNG. Several workshops have been held to present aspects of the model and to provide practical training in its use to research workers and forest managers within the PNG Forest Authority. This section gives an updated guide to the most recent version, 1.28, which corrects a number of minor problems with the earlier release.

Installation and start up of PINFORM

Appendix B lists the project diskettes and their contents. One of these is designed to install the latest version of PINFORM[1]. The installed program is called PINFORM5.XLS, and is compatible with either Excel 5 or Excel 97. It cannot be run by Excel 4 or earlier editions. It will run under Windows 3.1, 95 or 98. The Visual Basic system of Excel must be correctly installed for the program to run.

Once copied to the hard disk, as described in Appendix B, the program can be started by clicking on the PINFORM5 file name from the Windows Explorer or File Manager. More conveniently if it is to be used frequently, an icon can be set up to start the program. An icon file PINFORM.ICO will be found in the installation directory that can be used for this purpose.

The main menu

As soon as the program starts, the Excel menu will be replaced by the PINFORM menu bar. The complete list of available choices are shown in Figure 6. There are three main headings: *Forest management*, *Model outputs*, and *Control*.

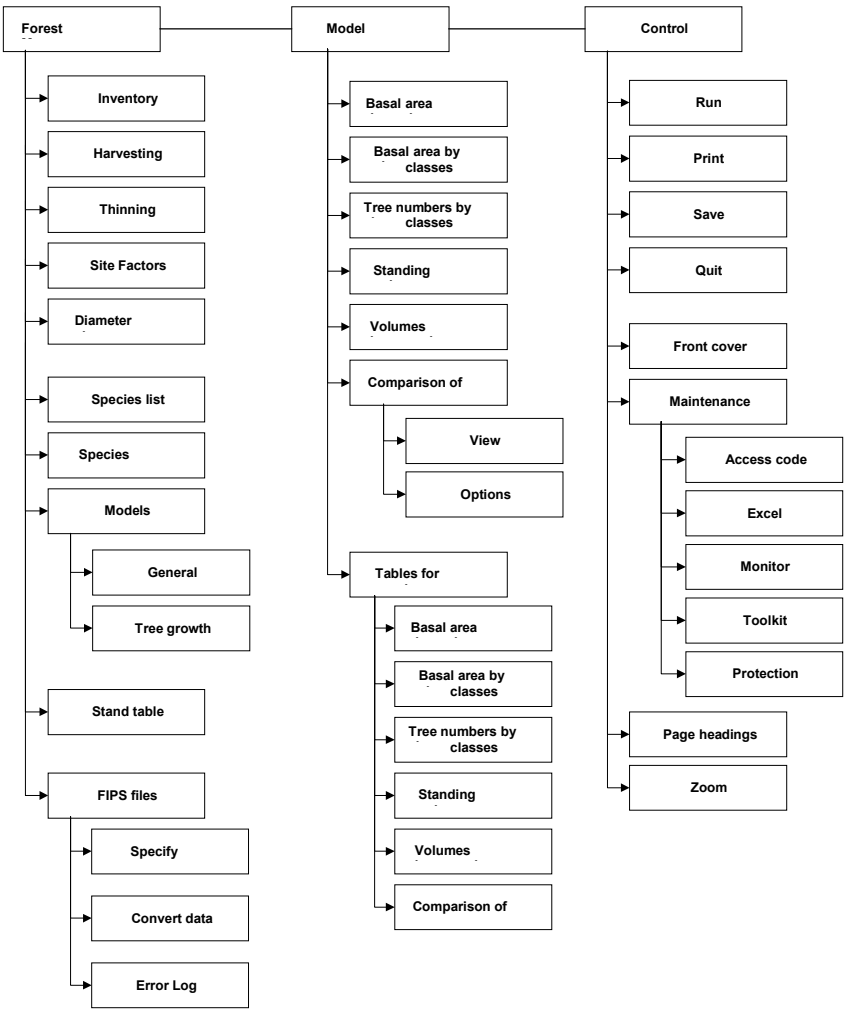
The *Forest management* menu brings up a list of sub-headings as shown in the figure. These are concerned with basic settings for a model run. The *Inventory* option sets the file that is used as the basis for a simulation. The *Harvesting* and *Thinning* menus set forest management options such as felling cycle. The *Site factors* option allows different site quality, fire regime, and logging

[1] At the time of writing, this is version 1.28. See Appendix B for information on updates.

methods to be compared. The *Diameter classes* menu sets class widths and lower bounds used in the various output tables and graphs. The *Species list* and *Species groups* menus allow various aspects of species naming and grouping to be controlled. The *Models* menu sets the underlying coefficients used by the growth model. The *Stand table* menu produces a stand table by species that is directly comparable with FIPS output, to check baseline data being used by the model. The *FIPS files* menu allows for checking and conversion of FIPS inventory data so that it can be used by PINFORM.

The *Model outputs* menu simply displays the various graphs or tables produced during a simulation run. The *Control* menu has options to initiate a simulation run, to print displayed graphs or tables, to save the model with all current settings and data, to exit and return to Windows, to set headings for printed outputs, and to adjust the size of graphics.

Figure 6 The menu system for PINFORM



The menu system works in the same way as all other Windows menus, with selections being made by clicking with the mouse. Hot keys are also designated on the menu by underline characters and can be used in combination with the Alt key to

access the menu. With one or two exceptions, the menu selections either display a dialog box that allows further options to be set and operations to be executed, or they simply display a worksheet or graph with model parameters or results.

Basic use of the model

The basic use of PINFORM requires setting the inventory and harvesting options via the *Inventory* and *Harvest* menus. The model is then run with the *Control/Run* menu, and the various graphs examined to assess:

- Indicators of sustainability
- Average yields
- Composition of outputs

Harvesting options can be modified to improve sustainability or yield.

Setting inventory files

The *Inventory* menu brings up a dialog box which will appear as shown in Figure 7.

Figure 7 Dialog to set an inventory file

The valid PINFORM inventory files will be listed in the central window by their title. When one is selected by clicking it, the file name and title will appear in the bottom part labelled *Selection*. If the directory at the top appears incorrect, it can be changed by clicking the Browse button. A standard Windows file finder box will appear, through which the user can navigate to the disk and directory of choice. Any file in the target directory can be clicked to close the finder dialog box: any valid PINFORM inventory files will then be listed by title.

PINFORM inventory files have an extension PIN and use a special format. The demonstration edition of PINFORM includes as samples the first measurement from the ITTO PSPs converted to PIN format. The PSPs are mostly in pairs, and are grouped within the files by localities.

PINFORM inventory files can also be created from the FIPS data files used by the PNG Forest Authority for its normal inventory operations.

Once a file has been selected, the *OK* button is clicked to return to the PINFORM menu system.

Harvesting options

The *Harvesting* menu allows options such as the felling cycle and diameter limit to be set. The dialog box appears as shown in Figure 8.

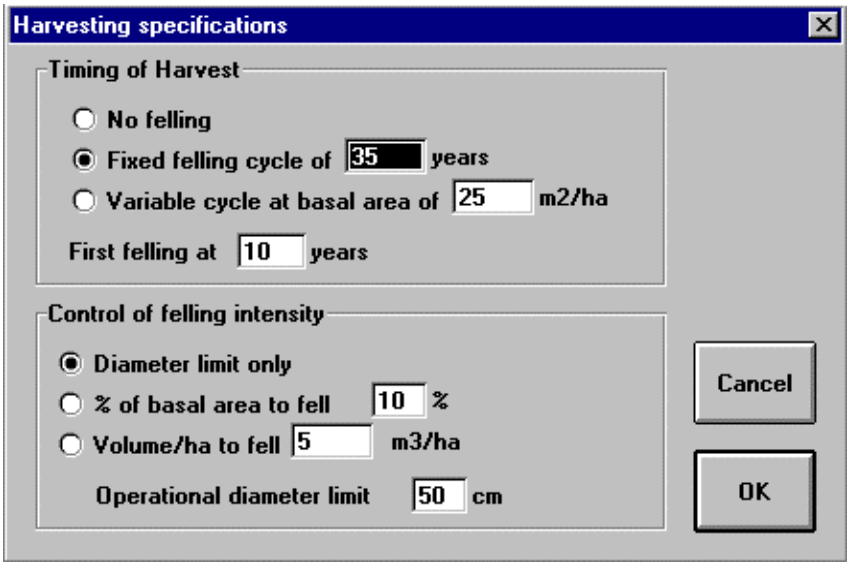


Figure 8 Dialog to set harvesting options

The timing of the harvest can be controlled by three alternatives:

- *No felling*: In this case, the inventory data supplied will be grown by the model without felling. This is useful for comparison purposes, or for analyses related to conservation issues. It also illustrates some basic aspects of forest dynamics.

- *Fixed felling cycle*: This is the conventional option. The felling cycle to be used is entered in the adjacent box.

- *Variable felling cycle*: This allows the stand to be felled when it reaches a certain level of stocking in terms of basal area. It can be used to explore questions of appropriate felling cycles without resorting to extensive trial and error.

The first harvest performed by the model is done in the year set in the box labelled *First felling at .... years*.

The intensity of felling can be controlled by one of three methods:

- *Diameter limit only:* In this case, all commercial trees are felled which are above the diameter specified in the *operational diameter limit* box.
- *Basal area %*: A percentage of the basal area to be removed can be specified. This will still respect the diameter limit and commercial criteria, but not more than the specified percentage will be removed.
- *Volume/ha*: A fixed volume is removed, although again, diameter limits and commercial criteria are respected.

In all cases, only trees belonging to commercial species groups are felled, and then only trees which are non-defective.

When felling is controlled by basal area % or volume, then the specified volume or basal area must be available from the commercial trees before the operation starts. Otherwise it is delayed until the next time period (normally 5 years), and may be delayed further if the volume or basal area still cannot be attained. This is designed to avoid an unrealistic situation where the forest is continually being nibbled for very small volumes.

However, when only the diameter limit control is used, the model will repeatedly carry out very small harvests if the felling cycle allows it.

Running a simulation

The *Run* menu brings up a dialog box as shown in Figure 9. This gives the time limit for the simulation, shown in the example as 100 years, and allows a line on the *comparisons graph* to be selected and labelled. Clicking the *Start* button begins the simulation. Clicking *Cancel* reverts to the menu without running the model.

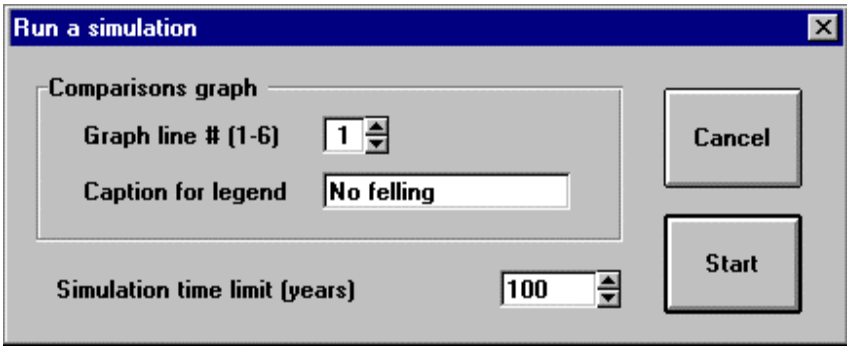


Figure 9 The Run dialog

The graph that is displayed at the time the *Run* option is selected will remain visible during the simulation. If no graph is displayed, then the graph of basal area dynamics is shown by default.

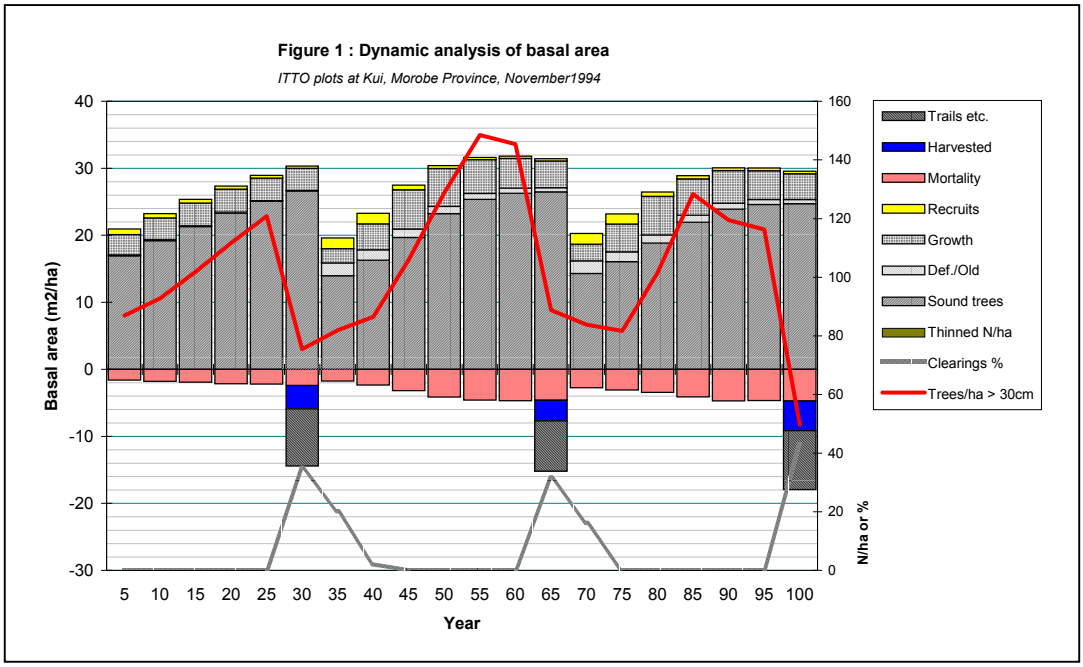
During the simulation run, the current simulated year is shown on the status bar. There is an initialisation phase, usually of about 15 seconds, before the run starts whilst PINFORM reads the inventory data and re-sets graphs and tables from a previous run.

The *Esc* key can be pressed during a simulation run to cancel it and return to the menu.

Model outputs

PINFORM generates six different graphs during a simulation run. Each of these is backed by a corresponding table. Various examples of the graphs are referred to in the explanation below. The graphs are made visible in each case by the menu choice with the corresponding name.

Figure 10 PINFORM graph of basal area dynamics



1. *Basal area dynamics*: This graph shows basal area on the left axis and time as the ordinate (see Figure 10). A bar is shown for standing basal area of sound trees and of defective or damaged trees. Growth and recruitment are shown on top of these. Below the zero axis are shown deductions from basal area: mortality, harvesting, and logging damage. A solid line shows numbers of trees above a user-specified diameter limit. This relates to the right-hand axis. A lighter solid line shows the area of forest which is unstocked (clearings or grass areas) as a percentage, also on the right axis.

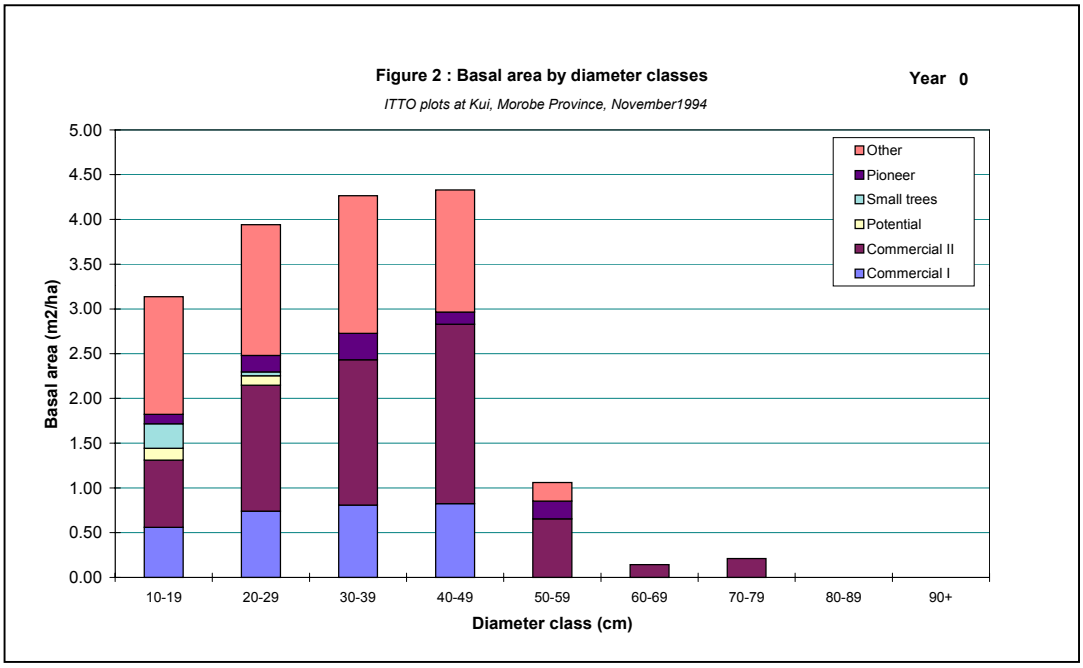
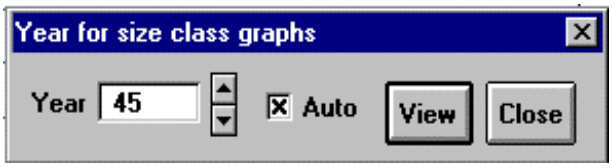


Figure 11 PINFORM stand structure diagram

2. *Basal area by size classes*: This graph shows forest structure during one time period as a diagram of basal area by size class, with the bars sub-divided by species groups (Figure 11).. *Double-clicking on the graph brings up a year selector dialog* as shown in Figure 12, which allows the year in view to be changed.

Figure 12 Year selector dialog



In this dialog, the year to be viewed is entered in the *Year* field, either directly or by clicking the spinner with the mouse. The graph will update to that year when the *View* button is clicked. Checking the Auto box causes the graph to update automatically in 5-year steps as spinner is clicked. This is convenient for stepping through a time sequence, but is very slow when jumping over a large period. In that case the *Auto* box should be cleared and the *View* button used to update the graph.

4. *Tree numbers by size classes*: This shows tree numbers by size classes and species groups for one simulation period. As with the equivalent basal area diagram, double clicking on the graph brings up a year selector dialog as in Figure 12.

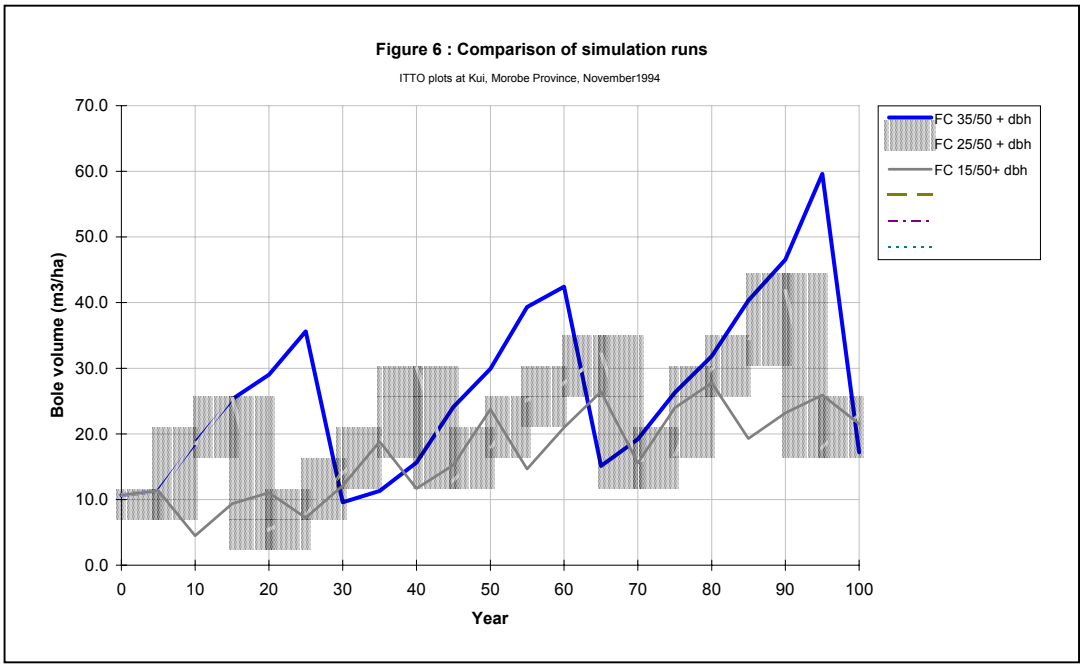
5. *Standing volumes*: Standing volumes are shown over time, sub-divided into species groups. The diameter limit above

which volume is shown is defined by the *Diameter classes* menu.

6. *Volumes harvested*: This graph shows volume yields for each felling, with the species groups and the year. It shows only extracted volume, and therefore necessarily excludes defective trees, non-commercial species, and volume below the operational diameter limit.

7. *Comparison of runs*: This graph shows a single volume line over time for each simulation run. It allows performance under different management regimes to be compared directly. The volume shown can either be total volume above a diameter limit, equivalent to the standing volumes graph; or commercial volume, based on non-defective commercial species above the operational diameter. This latter therefore corresponds to the volumes shown on the *Volumes harvested* graph. The example (Figure 13) compares standing volumes with 3 different felling cycles.

Figure 13 PINFORM graph comparing different simulation runs



The tables which contain the data shown on the graphs can be viewed by using the *Tables for graphs* menu, and selecting the appropriate sub-menu, each with the same name as the graph.

These tables are not elaborately formatted, but if they need to be reproduced, then can easily be exported to another Excel spreadsheet or to a word processor and formatted as required for presentation.

Exporting graphs and tables

Graphs and tables can be exported for publication purposes, or to enable further analysis in another spreadsheet. This can be done using Windows cut and paste technique. For a graph,

select the background, and then use *ctrl+C* to copy it. In the target application, it can usually be pasted in either as an Excel object using *Ctrl+V*, or using the *Paste Special* options as a Windows metafile or picture.

For a table, select the cells required using the mouse, and then copy them with *ctrl+C*. They can be pasted into another Excel spreadsheet using *ctrl+V*. In a word processor, they are usually better pasted in Rich Text Format as a table, using the *Paste Special* option.

Diameter class options

Graphs and tables can be printed in PINFORM using the *Print* menu under *Control*. This prints whatever table or graph is visible on the screen.

The diameter classes used on graphs and tables can be set by the menu choice *Diameter classes*. This dialog also allows the lower diameter limit for volume graphs to be defined, and the lower diameter limit for the tree numbers line that appears on the *Basal area dynamics* figure. The dialog appears as shown in Figure 14.

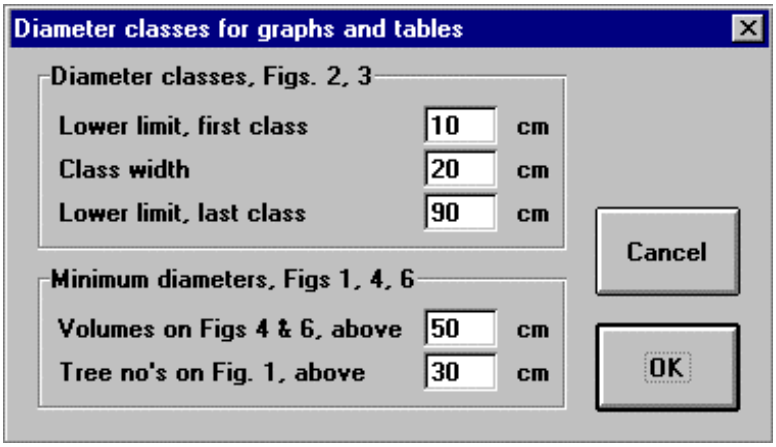


Figure 14 Dialog to set diameter class values for graphs

In the example, diameter classes will be 10-29, 30-49, 50-69, 70-89, and 90+ cm. Volumes are shown above 50 cm, and tree numbers above 30 cm.

Note that changes to these classes do not take effect until the next time a simulation is run. The current graphs and tables will not be immediately updated.

Site factors and sensitivity analysis

Species show a range of growth rates on different plots, which appear to be due to site differences. The *Site factors* menu brings up a dialog that allows the growth index to be adjusted up or down 30% from a standard value of 100%, which represents the average for all sample plots.

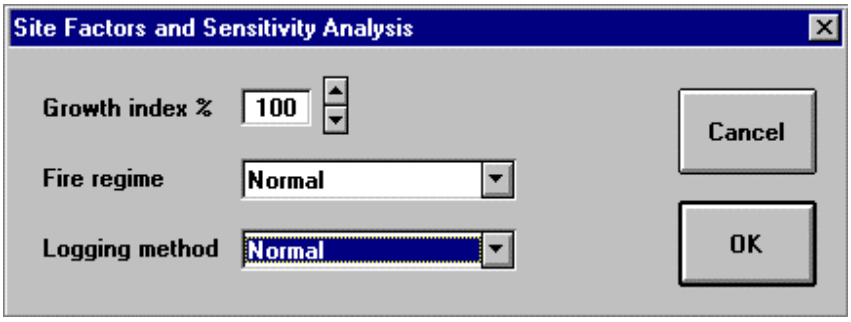


Figure 15 Dialog box for setting site factors

Three severities of fire regime can be compared for sensitivity analysis. They are *Normal*, *Frequent*, and *Severe*. The *Normal* fire regime corresponds to that observed on the plots. The *Frequent* regime assumes higher mortality, especially of small trees, and slower recovery of cleared areas. This would correspond to a situation such as that experienced over an El Niño period within closed forest, with more frequent and severe forest fires than normal. The *Severe* regime is intended to emulate the effects of annual uncontrolled burning, as may occur at the forest margins. In this scenario, mortality is substantially increased, and recruitment very much depressed.

In the same way, three levels of logging impact can be compared. The baseline functions are for *Low Impact* logging. This involves using agricultural tractors with winches, and careful skid trail and felling direction planning in conjunction with stock and topographic maps. The *Normal* regime for PNG, with limited control and the use of heavier tracked vehicles, assumes 50% higher rates of damage than for the baseline function. The *High Impact* option doubles the damage associated with low impact felling, and would correspond to the use of D8 or D9 specification tracked vehicles, and complete indifference by the operators to questions of damage to the residual stand.

These options allow the sensitivity of results to assumptions about site, fire risk, and logging methods to be tested. For standard use of the model, the *Growth Index* should be 100%, and the other options set to *Normal*.

Viewing and modifying the species list

The *Species list* menu option displays the species list used by PINFORM. This gives the mnemonic code for the species, its MEP group, the growth model group, botanical and common names, the FIPS code number, and the user's management group allocated within PINFORM.

This worksheet is normally protected and cannot be edited. However, the *Protection* function under the *Maintenance* menu will switch off this protection temporarily, allowing any column to be edited. This facility requires password access, as changes to the species list will affect the way the model works.

The most common changes that may need to be made are to the *Group* number in the right hand column. This number is between 1 and 6, and corresponds to one of the management groups listed on the *Species groups* dialog discussed below. It can be modifed to assign species to a different group.

The species list can be printed using the *Print* menu function. It can also be copied in whole or part be selecting cells with the mouse or *Shift+arrow* keys, and then using *ctrl+C* to copy the selection to the Windows clipboard.

Species groups

The *Species groups* menu allows the names of species groups to be edited, their commercial priority to be changed, and the set of commercial groups to be defined. The dialog box appears as shown below.

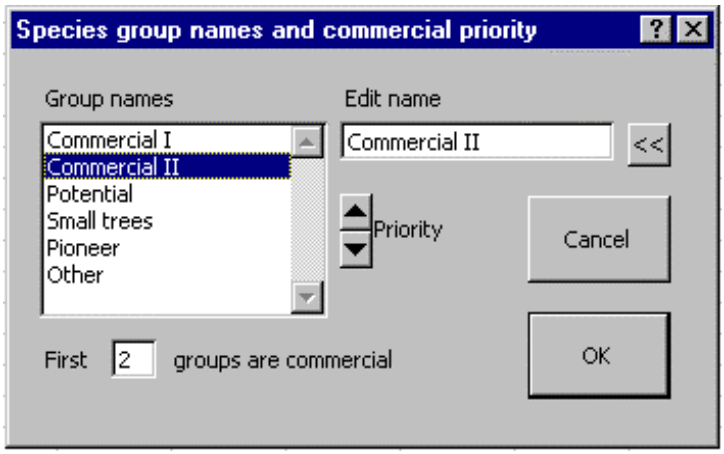


Figure 16 Dialog to modify species groups

In this dialog, six group names will be shown, which correspond to the group codes one to six in the last column of the species list. The selected name will appear in the *Edit name* box. It can be edited or overtyped with a new name. When the << button is clicked, the list will be updated to reflect the name change. If no item in the group list has been selected, the *Edit name* box will remain blank. If the selected item in the list is changed before pressing <<, then the contents of the *Edit name* box are overwritten with the new list selection.

The order of groups from top down reflects their commercial priority. The spinner labelled *Priority* can be clicked to move a selected group up or down. This changes its commercial importance. The priorities influence how felling is performed, as the logging always takes all the higher priority species before the lower ones. If there are limits on volume or basal area to be harvested, then lower priority species, although commercial, may not be harvested. This is designed to reflect the realities of timber operations, in which higher valued species will normally be felled before the lower valued ones.

When priorities are changed, the groups in the species list will actually be renumbered automatically to reflect the new order.

Not all the groups are commercial. The box at the bottom designates which are considered commercial groups. Not more than 5 commercial groups can be specified; at least the last group must always be treated as non-commercial. Only commercial species will be harvested.

When a species occurs in the data which is not in the species list, it will always be treated as belonging to the sixth group.

Displaying the growth model coefficients

Coefficients from the growth models can be displayed via the *General* and *Tree Growth* sub-menus of the *Models* menu bar. For a discussion of the general models, which include stand density, logging damage, and recruitment levels, refer to Alder (1998a). The tree growth models appear as shown in Table 3 on page viii.

Compiling an initial stand table

The menu selection *Stand table* displays a table for the current inventory data file, showing tree numbers, basal area and volumes by species. The species are listed in order of their volume above 50 cm dbh. The highest volume species are listed first. The right hand column shows the percentage of volume above 50 cm dbh accounted for by the species. Two size classes are shown: Trees 20-50 cm, and trees above 50 cm. All species are listed individually until a limit of 95% of the cumulative volume is reached. A summary line is given at the bottom for all species.

The format of this table is practically identical to the stand table produced by FIPS, and it can be directly compared. However, it should be noted that the volume equation used by PINFORM is the single-entry, diameter only, equation given Alder(1998a) on page 13, whereas FIPS uses both diameter and height. Furthermore, when FIPS data is converted to a PIN file, as discussed below, there will be small changes in the tree number and basal area figures as the individual tree measurements are merged into 1-cm classes. Hence the figures from FIPS and PINFORM, although very similar, will not be identical to the last decimal place.

The stand table is usually updated when a new file is assigned via the *Inventory* menu. In this case, when the stand table is viewed, a message appears requesting that the table should be updated. Clicking the *OK* button will allow this to be done.

If the inventory file has not apparently changed, then the stand table is not updated when it is viewed. However, the updating can be forced by double-clicking on the sheet with the mouse.

Converting FIPS data

The forest inventory system used by the Forest Authority at present is called FIPS. PINFORM has the facility to read and convert FIPS data files. There are three sub menus relating to this, found under the *FIPS files* menu. They are as follows:

Specification	Sets the file names and locations for the input and output files, and some parameters relating to the inventory plots.
Convert data	Starts the data conversion process.
Check data	Flags diameters that seem excessively large in the input data file and allows the file to be corrected and saved from Excel.

The *Specify* menu produces the dialog form shown in Figure 17. The input file name can be selected using a typical Windows file open dialog by pressing the *Browse* button, or it can be typed directly into the *Input path and file* field. The FIPS file names will be .DBF files with a name starting FD, and with digits representing province, project and block numbers.

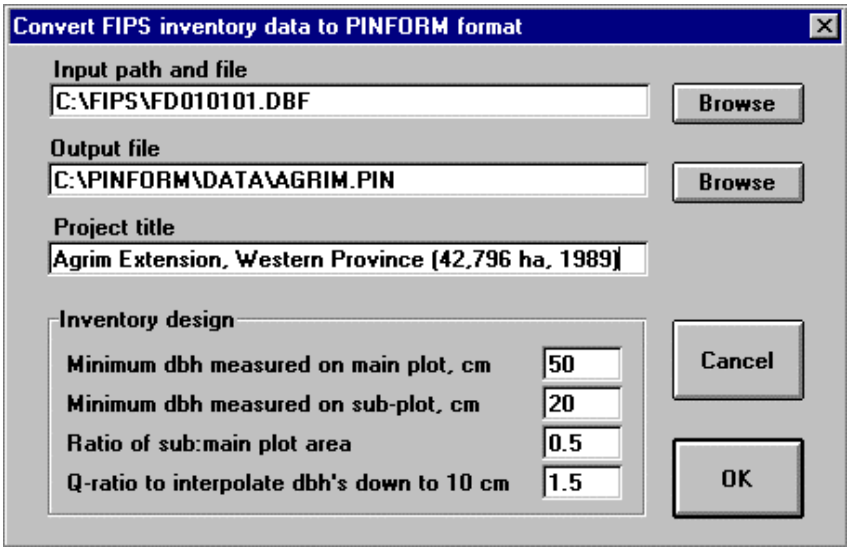


Figure 17 Specification dialog for FIPS data conversion

The output file name can be selected from the corresponding *Browse* button, which gives a typical Windows *Save As* dialog to set the disk, directory, and allow a file name to be selected or typed in. Alternatively, the full output file name and path can be typed in directly to the box. This is a file with a .PIN extension.

The project title must be typed in. This is saved as the first line of the .PIN file.

The inventory design for linear strip sampling with FIPS is standard, and the settings shown need not normally be changed unless circular plots or some other variant design have been used. The first box shows the smallest diameter measured on the main sample. The second shows the smallest diameter on

the sub-sample. The third gives the ratio of sub-sample area over main-sample area.

For example, the normal FIPS system is to use a 20 m wide strip to measure all trees over 50 cm, and an inner strip of 10 m to measure all trees over 20 cm.

The final box with the Q-ratio for interpolation is designed to allow PINFORM to fill in the missing data that it needs between 20 and 10 cm. FIPS inventories normally only measure down to 20 cm. The interpolation is made by taking each tree occurring in the range 20-30 cm, deducting 10 cm from its diameter, multiplying its assumed stocking by the Q ratio given (eg. 1.5), and adding it to the output file. This gives trees in the 10-20 cm class whose species composition exactly reflects the 20-30 cm class, but which are 1.5 times more numerous.

The longer term projections of PINFORM are quite sensitive to the stocking in the 10-20 cm class. A Q-ratio of 1.5 seems appropriate.

The FIPS conversion process has been tested with strip sample data as described above. It has not been tested with the circular plot design that has been used from time to time.

After the specification has been set and the dialog closed, the *Convert data* operation can be run. The output file specified is created with an extension .PIN. The conversion process can take one or two minutes, and progress is shown at the bottom left of the screen. After conversion, it is necessary to go back to the *Inventory* menu and select the file that has been created. The *Project title* given in the *Specify* screen should be seen in the list of available PINFORM files. If it is not, check that the correct directory names have been used for both sets of files.

Errors occurring during the file conversion process are logged on a worksheet that can be viewed with the *Error log* menu function. This shows the record number and field in the original DBF file where the error was detected, the value of the variable in error, and a message indicating the nature of the problem. These errors should be edited using FoxPro or the FIPS system to correct them. However, a small number of errors in a large file will not usually materially affect results, and can be ignored. The file conversion process will halt if more than 5% of the records in the file contain errors. This is probably a sign that the wrong type of file is being converted.

Program control functions

The *Control* menu gives access to a number of functions controlling program operation. These are as follows:

Run This executes a simulation, as described on page 16.

Print This allows whatever is currently displayed to be printed. A standard Windows printer control dialog appears, allowing various settings to be changed, including the printer itself. For tables, selected cells can be printed on their own, without printing all the data.

Save This allows the current state of PINFORM to be saved either with the original name (PINFORM.XLT) or under a new name, with a default .XLS extension.

Quit Closes the program and returns control to Windows.

Front Cover Displays the PINFORM front cover. The button marked » at the top left restarts the programme. This can be useful to clear some types of error.

Maintenance These functions are inaccessible unless an *Access code* is entered. They allow for various operations of interest to the programmer.

Page headings This shows a dialog box that allows the top left, centre and bottom left headings to be set for all printed outputs. When executed, this function may take 30-60 seconds to update all worksheets in the model.

Zoom This sizes graphics so that they properly fill the screen.

Errors and problems

Version 1.28 of PINFORM is substantially more trouble-free than the last general release, version 1.24. It is important to note the version number when starting the program, to avoid confusion with earlier versions.

When running under Windows 95 or 98, do not close the program using the X box at the top right of the screen. Close with the *Quit* bar under the *Control* menu. If the Window close button is used accidentally, PINFORM will disappear, but the menu will remain[1], and it will still be necessary to use Quit to close properly. This bug will be fixed in a later edition.

If the program is not responding at all, use *Ctrl+Alt+Del* to force the program to shut down.

[1] Like the Cheshire cat's smile in *Alice in Wonderland*.

If troubled by persistent errors or operating problems, contact the author at D-ALDER@EUROBELL.CO.UK with as much detail as possible about the circumstances.

Implications for forest management

The PINFORM model provides a method of extrapolating measurements made on plots over a 5-year period to suggest probable yields over 35 years, and recovery and sustained yields over 100 years or more. This is achieved by a dynamic analysis of the components of stand growth, but remains nonetheless an extrapolation process, which must therefore be regarded as provisional.

The model shows that there is great variability in potential yield from plot to plot, and forest management in natural selection forest can be most successfully achieved by considering each planning area individually. Blanket prescriptions applied at a national level may produce odd results in specific situations. However, generally the model confirms the PNG Forest Authority's standard assumptions of a 35 year felling cycle, a 50 cm minimum diameter limit, and a typical commercial yield at the end of the felling cycle of 25 m3/ha. These figures suggest a commercial mean annual increment of 0.71 m3/ha/yr.

Test runs with the model using various plots and different felling cycles show typical figures within this range, and generally slightly higher (up to 0.8-1 m3/ha/yr in some instances). The yields are not very sensitive to felling cycle. They are sensitive to over-logging which can occur on highly stocked stands at the first felling. A concept that emerges from the model *is the need to limit felling to the mean annual increment*, which should be taken as the *maximum annual allowable cut (AAC).*

PINFORM provides a means for calculating AAC on a project-by-project basis, using forest inventory data, and establishing guidelines that can be used for monitoring volume removal to ensure that the forest is not over-cut. In conjunction with the application of the *PNGFA Logging Code of Practice*, this will ensure a good standard of sustainable forest management.

Fire, logging damage, and site factors : A proposed follow-up project

PNGs lowland forests are exposed to significant fire risk, as the recent El Niño year has shown. *Imperatum* grass also, in conjunction with fire, can invade forest areas and convert them to savannah. These environmental factors, combined with other sources of site variation, and the effects of logging damage, have a very strong effect on forest recovery and growth. PINFORM models these factors using assumed functions that give outcomes conforming to common experience. However, a more complete and scientific study is required if the model is to be used with full confidence.

A Project Idea has been submitted and reviewed by the ITTO Committee on Reforestation and Forest Manangement entitled

Fire, logging and site interactions in the management of lowland tropical forests. A full project proposal will be formulated and submitted to ITTO. If approved and funded, this project will allow the existing base of plots to be maintained and re-measured for a further 5 years. It will also allow PINFORM to be revised to incorporate fire and grassland interactions more correctly. A logging damage study may be incorporated as part of the project, which would allow the present functions (based on international experience) to more accurately reflect local conditions.

Conclusion

This report documents the outputs from ITTO project PD162/91. The project has achieved all its original goals, and at its conclusion leaves as outputs:

- A network of 72 1-ha permanents sample plots re-measured over 3-5 years established in lowland tropical forest in PNG, mapped and well-demarcated on the ground.
- A clean, documented and accessible database of measurements from these plots.
- A suite of analysis programs to facilitate the use of the data for growth and yield studies.
- A substantive cadre of better trained and informed personnel, as a result of various study tours, workshops, fellowships, field training and technical training by consultants, combined with work experience over the duration of the project.
- A growth model, PINFORM, which has been installed in the PNG Forest Authority and widely demonstrated, which can inform and improve forest management decision making.
- Several project manuals, documenting all aspects of procedures employed in the field, the database system, the analysis program, and the growth model.

Alder, D (1997) The ITTO permanent sample plots in Papua New Guinea : Progress in growth model development 1997. ITTO project PD 162/91 Internal Report, November 1997. 23 pp.

Alder, D (1998a). PINFORM : A growth model for lowland tropical forest in Papua New Guinea. ITTO project PD 162/91 Internal Report, April 1998, 54 pp.

Alder, D (1998b). The ITTO permanent sample plots in Papua New Guinea : Some results of analysis. Paper to ITTO Workshop on *Permanent sample plots and growth models for natural forest management in Papua New Guinea*, held at Forest Research Institute, Lae, 10-13 November 1998.

Alder, D & Synnott, TJ (1992) Manual of permanent sample plot procedures for mixed tropical forest. Oxford Forestry Institute, University of Oxford, Tropical Forestry Paper 25.

Romijn, K (1994a) PSP standards and procedures, parts A-D. ITTO Project PD 162/91 Internal Report.

Romijn, K (1994b) PERSYST: A data management system for permanent sample plots in natural forest. ITTO Project PD 162/91 Internal Report.

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

Vanclay, JK (1992) Data requirements for developing growth models for tropical moist forests. *Commonwealth Forestry Review* 70(4)248-271.

Vanclay, JK (1994) Modelling forest growth and yield: Applications to mixed tropical forests. CAB International, Wallingford, UK. 280 pp.

Oavika, F (1993) Procedures for the establishment of permanent sample plots. Forest Research Institute, Lae 25 pp + app.

PSP data *PERSYST files in PLOTDATA directory, containing tree measurements. There is one record for each tree.*

Field	Type	Description
PLOTID	C7	*Plot identification, linked to table PSP_LIST*
DATE	D8	*Date of measurement*
QUADRAT	C2	*Quadrat number*
TREENO	C2	*Tree number*
SPECIES	C7	*Species code, linked to table SPECLIST*
SF	C1	*Species identification flag*
EASTING	N4.1	*East co-ordinate within quadrat, m*
NORTHING	N4.1	*North co-ordinate within quadrat, m*
POM	N4.1	*Height of diameter point of measurement, m*
DIAM	N5.1	*Diameter, cm*
DIAM2	N5.1	*Alternate diameter, cm, when POM is changed*
DF	C1	*Diameter measurement flag (blank for good quality measurements)*
STATUS	C2	*Tree status (live, dead, missing, etc.)*
STEMFORM	C1	*Stem form code (straightness, A-F)*
CRPOS	C1	*Crown position according to Dawkins 5 point scale*
CRQUAL	C1	*Crown quality according to Dawkins 5 point scale*
CRDIAM1	N4.1	*Crown diameter, m*
CRDIAM2	N4.1	*Crown diameter, second measurement at right angles to first, m*
HDIST	N4.1	*Horizontal distance, m, for height measurement*
HBASE	N3	*Angle to base of bole, %*
HMERCH	N3	*Hypsometer angle to top of commercial bole, %*
HCRBASE	N3	*Hypsometer angle to first major branch of crown (crown base), %*
HTOTAL	N3	*Hypsometer angle to top of tree, %*
BACOUNT	N2	*Point basal area by 1 m2/ha prism*
TCCODES	C14	*Coded notes - list of 2 letters codes*
CHECKSUM	N4	*Sum of numerical values across the record used as check on data quality*

SPECLIST *PERSYST file containing the species list used by the ITTO project. There is one record for each species.*

Field	Type	Description
SPECIES	C7	*Species code, linked to table SPECLIST*
MEP	C2	*Forest Authority price code (Minimum Export Price)*
MODEL	C1	*Growth model group (A-Z)*
SPEC_NAME	C28	*Botanical name*
TRADENAME	C18	*Local name*
FAMILY	C18	*Family*
SPOLD	C10	*Old species code if renamed*
SYNONYMS	C28	*Old botanical name, if changed*
CODE	C3	*Forest Authority inventory code*
GCC	C1	*not presently used*
SG	C1	*do.*
STC	C1	*do.*
SNO	N3	*do.*

PSP_LIST *PERSYST file containing plot location information and measurement dates. There is one record for each plot.*

Field	Type	Description
PLOTID	C7	*Plot identification, linked to table PSP_LIST*
PLOTTYPE	C4	*Type of plot*
QN	N1	*Quadrat numbering method*
STRATUM	C5	*Stratum code*
LOGGED	N4	*Not presently used.*
PROVNUM	C2	*Province code number*
PROVINCE	C18	*Province name*
LOCATION	C14	*Descriptive location (nearest village, district, etc.)*
TRPNAME	C14	*Name of Timber Resource Permit (concession)*
MAPREF	C9	*Map reference*
LON	C9	*Longitude*
LAT	C9	*Latitude*
GRIDZONE	N2	*UTM zone*
UTMEAST	N6	*UTM east coordinate*
UTMNORTH	N7	*UTM north coordinate*
ESTDATE	D8	*Date plot established and first measured*
DATEDE1	D8	*Date of data entry, 1st measurement*
DATEDV1	D8	*Date of data verification, 1st measurement*
……		*these are repeated until the 7th measurement with the same field names…*
DATEM7	D8	*Date of 7th measurement*
DATEDE7	D8	*Date of data entry, 7th measurement*
DATEDV7	D8	*Date of data verification, 7th measurement*

~BADIS *Summary file produced by BADIS analysis program. There is one record per plot and enumeration.*

PLOTID	C7	*Plot identification, linked to table PSP_LIST*
STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
ENDATE	D8	*Enumeration date*
ENUM	C1	*Enumeration number*
BA20	N6.2	*Basal area of trees 10-29 cm (m2/ha)*
BA40	N6.2	*Basal area of trees 30-49 cm (m2/ha)*
BA60	N6.2	*Basal area of trees 50-69 cm (m2/ha)*
BA80	N6.2	*Basal area of trees 70-89 cm (m2/ha)*
BA100	N6.2	*Basal area of trees 90 cm or more (m2/ha)*
NHA20	N6	*Number of trees 10-29 cm (n/ha)*
NHA40	N6	*Number of trees 30-49 cm (n/ha)*
NHA60	N6	*Number of trees 50-69 cm (n/ha)*
NHA80	N6	*Number of trees 70-89 cm (n/ha)*
NHA100	N6	*Number of trees 90 cm or more (n/ha)*

~BANAL *Summary file produced by BANAL analysis program. There is one record per plot.*

PLOTID	C7	*Plot identification, linked to table PSP_LIST*
STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
ESTDATE	D8	*Plot establishment date*
YINT	N5.2	*Total measurement period (first to last measurement)*
SBAT	N6.2	*Standing basal area (m2/ha)*
NHA	N7.1	*Number of trees (n/ha)*
BADOM	N6.2	*Basal area of dominants (crown classes 4-5) (m2/ha)*
NDOM	N7.1	*Number of dominants per ha.*
HTDOM	N6.1	*Mean total height of dominants*
HCDOM	N6.1	*Mean crown base height of dominants*
LBA	N6.2	*Losses, basal area (m2/ha)*
LNHA	N7.1	*Losses, trees/ha*
RBA	N6.2	*Recruits, basal area (m2/ha)*
RNHA	N7.1	*Recruits, trees/ha*
BAIT	N6.3	*Basal area increment (m2/ha/yr)*
BAIDOM	N6.3	*Basal area increment of dominants (m2/ha/yr)*
QBAI	N6.3	*Queries (possible errors) in tree increments, summed as m2/ha/yr*
QRBA	N6.3	*Queries (possible errors) in recruitment, summed as m2/ha/yr*

~CUMCC *Cumulative crown areas by dominance classes. There is one record per plot.*

Field	Type	Description
PLOTID	C7	*Plot identification, linked to table PSP_LIST*
STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
SBA	N6.2	*Standing basal area (m2/ha)*
NHA	N5	*Number of trees (n/ha)*
CA5	N6	*Sum of crown projection areas, m2/ha for crown class 5*
CA54	N6	*Cumulative sum of crown projection areas including classes 4 and 5*
CA543	N6	*Cumulative sum of crown projection areas including classes 3 to 5*
CA5432	N6	*Cumulative sum of crown projection areas including classes 2 to 5*
CATOT	N6	*Cumulative sum of crown projection areas including classes 1 to 5*

~SPABUN1 *Most common species for each plot at first measurement. There is one record per species and plot.*

PLOTID	C7	*Plot identification, linked to table PSP_LIST*
NHA	N6	*Number of trees for this species (n/ha)*
AB	N6.1	*Abundance for species. Depending on program option, may be basal area% or N/ha.*
SPP	C7	*Species code, linked to field SPECIES in table SPECLIST*
SPEC_NAME	C30	*Species botanical name, as extracted from SPECLIST.*
FAMILY	C15	*Species family, as extracted from SPECLIST.*

~SPABUN2 *Abundances of indicator species as file designed for cluster or association analysis. There is one record per plot.*

PLOTID	C7	*Plot identification, linked to table PSP_LIST*
ENUM	C1	*Enumeration number (usually the last for the plot to give most reliable species codes).*
.....	N5.3	*Variable number of fields with names corresponding to species or genus codes.*
.....	N5.3	*Each of these fields contains abundance for that species and plot. The field names*
.....	N5.3	*included correspond to the species listed in the ~COMSPL file.*
OTHERSP	N5.3	*Abundance of all species not explicitly included in preceding fields.*

~COMSPL *List of indicator species. File generated and maintained by SPABUN. One record per species.*

SPECIES	C7	*Species code, linked to field SPECIES in table SPECLIST*
SPEC_NAME	C30	*Species botanical name, as extracted from SPECLIST.*
FAMILY	C20	*Species family, as extracted from SPECLIST.*

~SPPORD *Species increment and size distribution for grouping. There is one record per species.*

SPP	C7	*Species code, linked to field SPECIES in table SPECLIST*
SPNAME	C30	*Species botanical name, as extracted from SPECLIST.*
FAMILY	C20	*Species family, as extracted from SPECLIST.*
MEP	C2	*Forest Authority price code (Minimum Export Price)*
MODEL	C1	*Growth model group (A-Z)*
NPLOT	N3	*Number of plots on which the species occurs*
DINC	N7.2	*Mean diameter increment of species. Unreliable measurements are excluded.*
DISE	N8.3	*Standard error of diameter increment.*
NIT	N6	*Number of trees included in the increment statistics.*
D20	N6	*Frequency % in size class 10-29 cm diameter*
D40	N6	*Frequency % in size class 30-49 cm diameter*
D60	N6	*Frequency % in size class 50-69 cm diameter*
D80	N6	*Frequency % in size class 70+ cm diameter*
CDF90	N6.1	*Diameter of 90% point on cumulative frequency curve.*

TREEINC two-way tables *One record per species or species group, depending on program option*

SPP	C7	*Species code, linked to field SPECIES in table SPECLIST*
DINC1	N8.3	*Mean increment of reliably measured trees in first tabulated class, cm/yr*
DISE1	N8.3	*Standard error of mean*
NIT1	N8	*Number of increment trees in class*
.....		*} These fields are repeated for any number of classes. The user must note down the*
DINCn	N8.3	*} basis of classification and the values used when running SPABUN. For example, the*
DISEn	N8.3	*} classes could be diameter classes 10-50, 50-70, 70+, or crown classes 1-3 and*
NITn	N8	*} 3-5. Tables with upto 5 classes can be processed as printed reports by SPABUN.*

TREEINC multi-way tables *One record per species or group and per factor and class in the general linear model*

Field	Type	Description
SPP	C7	*Species code or growth model group code, depending on user option selected.*
STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
DIAM	C6	*Tree diameter class as text, eg 10-30 (implying 10-29.99 cm)*
CPOS	C4	*Crown position class as text. Eg 123 means crown classes 1-3*
CQUAL	C4	*Crown quality class as text. Eg 123 means crown classes 1-3*
PNTBA	C6	*Point basal area class as text. Eg 0-10 mean 0-10 m2/ha.*
DFCT	C1	*Defect class, T or F (true or false) dependning on whether or not selected coded notes apply.*
DINC	N7.2	*Mean diameter increment for the class, cm/yr excluding unreliable measurements.*
DISE	N7.3	*Standard error of mean increment.*
NT	N6	*Number of increment trees in the class.*

TREEINC individual tree extracts *There is one record per tree.*

STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
MODEL	C1	*Growth model group (A-Z), cross-linked to SPECLIST*
PLOTID	C7	*Plot identification, linked to table PSP_LIST*
TREEID	C5	*Quadrat and tree number combined. Eg 01-07 is tree 7 in quadrat 01.*
SPP	C7	*Species code, linked to field SPECIES in table SPECLIST*
DIAM	N6.1	*Tree diameter at the start of measurement, cm.*
CPOS	N1	*Crown position 1-5*
CQUAL	N1	*Crown quality 1-5*
PNTBA	N2	*Point basal area by 1 m2/ha prism*
DFCT	L1	*TRUE if one or more of the coded notes listed by the user is present for the tree*
DINC	N7.2	*Tree increment averaged over total measurement period, cm/yr*
CRDIAM	N6.1	*Mean crown diameter, m.*
HCRBASE	N6.1	*Bole height to crown base, m., from ground level*
HMERCH	N6.1	*Merchantable bole height, m.*
HTOTAL	N6.1	*Total tree height, m.*

MORTAL two-way table *There is one record per species or species group*

SPP	C7	*Species code or growth model group code, depending on user option selected.*
NT1	N6	*Number of trees in class (eg diameter class or group of crown classes).*
AMR1	N6.4	*Annual mortality rate, %, in the class.*
.....		*} These fields can be repeated for several classes of the same factor.*
NTn	N6	*} MORTAL can print tabulated outputs for up to 5 classes.*
AMRn	N6.4	*} The factor used as a basis for classification must be noted by the user.*

MORTAL multi-way table *One record per species or group and per factor and class in the general linear model*

SPP	C7	*Species code or growth model group code, depending on user option selected.*
STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
DIAM	C6	*Tree diameter class as text, eg 10-30 (implying 10-29.99 cm)*
CPOS	C4	*Crown position class as text. Eg 123 means crown classes 1-3*
CQUAL	C4	*Crown quality class as text. Eg 123 means crown classes 1-3*
PNTBA	C6	*Point basal area class as text. Eg 0-10 mean 0-10 m2/ha.*
DFCT	C1	*Defect class, T or F (true or false) dependning on whether or not selected coded notes apply.*
NT	N6	*Number of trees in class.*
AMR	N6.4	*Annual mortality rate, %, in the class.*

~RECRUIT *Recruitment by ecological class. One record per plot.*

Field	Type	Description
PLOTID	C7	*Plot identification, linked to table PSP_LIST*
STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
YINT	N5.2	*Total measurement period (first to last measurement)*
SBA	N5.2	*Standing basal area (m2/ha) at start of period.*
NHA	N6	*Number of trees (n/ha) at start of period.*
RBA1	N5.2	*Total recruitment (m2/ha) over the measurement period, non-pioneer growth model groups.*
RNHA1	N6	*Total recruitment (n/ha) over the measurement period, non-pioneer growth model groups.*
RBA2	N5.2	*Total recruitment (m2/ha) over the measurement period, pioneer growth model groups.*
RNHA2	N6	*Total recruitment (n/ha) over the measurement period, pioneer growth model groups.*

MODELS *Growth and mortality rates in format used directly by PINFORM. One record per model group.*

MODEL	C1	*Growth model (A-Z)*
NT1	N7	*Number of trees above median diameter increment*
NT2	N7	*Number of trees below median diameter increment*
DINC1	N6.3	*Mean increment of trees with increments below median*
DINC2	N6.3	*Mean increment of trees with increments above median*
AMR1	N6.4	*Annual mortality % of sound trees*
AMR2	N6.4	*Annual mortality % of trees classified as defective*
DMAX	N6.1	*Diameter of 99% point on cumulative frequency distribution.*
NERR	N7	*Number of measurement errors (gross + or - increments, unmeasured trees, etc.)*
SPLIST	C200	*Names of species comprising top 66% of BA in the group.*

PVOL *Summaries of plot volume increment. One record per plot.*

PLOTID	C7	*Plot identification, linked to table PSP_LIST*
STRATUM	C5	*Stratum code, cross-linked to PSP_LIST*
ESTDATE	D8	*Plot establishment date*
YINT	N5.2	*Total measurement period (first to last measurement)*
SBAT	N7.2	*Standing basal area (m2/ha)*
VOL10	N7.2	*Bole volume, all species, 10 cm dbh+ (m3/ha)*
VOL30	N7.2	*Bole volume, all species, 30 cm dbh+ (m3/ha)*
VOL50	N7.2	*Bole volume, all species, 50 cm dbh+ (m3/ha)*
PAIV10G	N6.3	*Mean periodic increment, including recruits, excluding losses, 10 cm+, m3/ha/yr.*
PAIV30G	N6.3	*Mean periodic increment, including recruits, excluding losses, 30 cm+, m3/ha/yr.*
PAIV50G	N6.3	*Mean periodic increment, including recruits, excluding losses, 50 cm+, m3/ha/yr.*
PAIV10N	N6.3	*Net periodic increment (with mortality deducted from growth), 10 cm+, m3/ha/yr.*
PAIV30N	N6.3	*Net periodic increment (with mortality deducted from growth), 30 cm+, m3/ha/yr.*
PAIV50N	N6.3	*Net periodic increment (with mortality deducted from growth), 50 cm+, m3/ha/yr.*

Appendix B : Diskettes and installation files

The table below shows diskette labels for the standard archive diskettes for the project. These archive files can be supplied by e-mail. For further information contact *itto@global.net.pg* or *d-alder@eurobell.co.uk*. All the files on the diskettes are self-extracting archives.

Diskette labels	
ITTO Project PD 162/91 – Archive disk 1 Contains compressed ITTO PSP data, plots A-M. To install enter DOS mode or use Windows Run command and type: **A:ITTOPSP1 -D -O -Spw C:** *Substitute another drive letter if hard disk is not C:* **Warning: This will overwrite any files of the same name on your system. Any edits to those files will be lost!** *The information on this disk is the property of the PNG Forest Authority and may not be used without authorization.* *The password **pw** ca be obtained from* <itto@global.net.pg> Revision date: 14 January 1999	**ITTO Project PD 162/91 – Archive disk 2** Contains compressed ITTO PSP data, plots O-Z. To install enter DOS mode or use Windows Run command and type: **A:ITTOPSP2 -D -O -S*pw* C:** *Substitute another drive letter if hard disk is not C:* **Warning: This will overwrite any files of the same name on your system. Any edits to those files will be lost!** *The information on this disk is the property of the PNG Forest Authority and may not be used without authorization.* *The password **pw** ca be obtained from* <itto@global.net.pg> Revision date: 14 January 1999
ITTO Project PD 162/91 – Archive disk 3 Contains compressed data analysis programs. To install enter DOS mode or use Windows Run command and type: **A:ITTOPROG -D -O C:** *Substitute another drive letter if hard disk is not C:* **Warning: This will overwrite any files of the same name on your system. Any edits to those files will be lost!** *For assistance using these programs contact <d-alder@eurobell.co.uk>.* Revision date: 14 January 1999	**ITTO Project PD 162/91 – Archive disk 4** Contains compressed copy of PINFORM 1.28 with demo data files. To install enter DOS mode or use Windows Run command and type: **A:PINF128 -D -O C:** *Substitute another drive letter if hard disk is not C:* **Warning: This will overwrite any files of the same name on your system. Any edits to those files will be lost!** *For assistance using these programs contact <d-alder@eurobell.co.uk>.* Revision date: 14 January 1999
ITTO Project PD 162/91 – Archive disk 5 Contains compressed report of Nov'98. To install enter DOS mode or use Windows Run command and type: **A:ITTOREP1 -D -O C:** *Substitute another drive letter if hard disk is not C:* **Warning: This will overwrite any files of the same name on your system. Any edits to those files will be lost!** Revision date: 14 January 1999	**ITTO Project PD 162/91 – Archive disk 6** Contains compressed report of Dec'97 and ITTO workshop paper of Nov'98. To install enter DOS mode or use Windows Run command and type: **A:ITTOREP2 -D -O C:** *Substitute another drive letter if hard disk is not C:* **Warning: This will overwrite any files of the same name on your system. Any edits to those files will be lost!** Revision date: 14 January 1999
ITTO Project PD 162/91 – Archive disk 7 Contains compressed report of Mar'98 on PINFORM version 1.24. To install enter DOS mode or use Windows Run command and type: **A:ITTOREP3 -D -O C:** *Substitute another drive letter if hard disk is not C:* **Warning: This will overwrite any files of the same name on your system. Any edits to those files will be lost!** Revision date: 14 January 1999	