

# Training and methodology development in forest biometrics for the management of natural forests in Uganda

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*A technical report submitted to the EDF/Uganda Forest Department Forest Resources Management and Conservation Programme, September 2002.*

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## Summary

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This report describes a consultancy from 23 August to 20th September 2002 to further develop software and procedures, and provide training, relative to exploratory forest inventory (EI), integrated stock survey and management inventory (ISSMI), permanent sample plots (PSPs) and tree volume studies for sustainable management of natural forest in Uganda. The visit extended work that has been developed over 5 preceding visits in 1998, 1999 and 2000. The main focus was on developing a data processing capacity for EI.

For the EI, there are now 4,449 plots of 500 m<sup>2</sup> covering about 32,000 ha over 5 forest reserves. This data was reformatted by the consultant into a single database, and the data entry form revised into an application called EiSys. A mapping program was written to generate ArcView shape files of inventory blocks, transects and plots, and enable their locations to be checked and included in maps and reports. An existing general purpose inventory program (GEMFORM) was modified to a local version (EiPac). This program produces stand tables with flexible column specifications, species grouping and sorting, sampling error and reliable minimum estimate rows or columns, as required, and analysis of stem quality. It also includes a growth model, although full calibration of this was outside the terms of reference and available time. Training in the office was given on the setting up and use of these programs. A workshop was also given which covered briefly the model calibration process, the use and interpretation of stand tables, and field demonstration of inventory procedures. The consultant suggests that it is important now that the EI data collected so far be used in the development of concise management plans (CMP) for the forest reserves, covering especially allocation of felling series to compartments, estimation of allowable cuts of common commercial species, strategy for commercialisation of less-desirable common species, and ameliorative measures for degraded areas.

For ISSMI, minor improvements were made to existing software. Some problems had arisen in converting existing mapping programs for ISSMI to Windows 2000 and MS Office 2000. These were fixed. Further training in the application of ISSMI was given at a workshop in Masindi, in two field visits (Budongo and Mabira) and by in-service training in the office. It was suggested that like the EI, it was important to apply the ISSMI data and computer outputs to detailed compartment management. ISSMI blocks of 4-ha need to be assigned to sawmillers and controlled on the ground. Several suggestions were made relative to this. A compartment sequenced for felling by the CMP should be surveyed by ISSMI. A wall-map should be generated for the DFO's office, with ¼ of blocks allocated for harvesting (the 25% ratio is premised on a 15-year ISSMI cycle and 60-year felling cycle). Felling licenses should be restricted to these designated blocks. Block maps should be produced to guide and control felling on the ground, for monitoring and supervision. Whilst improvements to the ISSMI software could streamline these operations, existing facilities are sufficiently capable for this process to be started. Use of the method would justify suggested improvements.

For PSPs, the data entry software was improved in minor respects, being split into the Front-end/Back-end database model most suited to network operation, upgraded to Office 2000, and improved ergonomically. There are some 52 PSPs in the database, of which 22 are due for re-measurement in 2003. The consultant noted that it is critical to time further work on data systems development and field procedures training just as these re-measurements are scheduled to begin. Otherwise there will be a considerable accretion of errors in the data that will be hard to resolve and may render the PSPs useless.

The volume sampling has had low priority but remains very critical. It was recommended that it be prioritised, with a team assigned with chainsaw and vehicle to acquire measurements from 700 trees over the next six months. This exercise underlies all volume estimates for planning and revenue estimates, as existing equations are biased too low.

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## **Disclaimer**

This report describes the author's own work, and any errors or omissions are his sole responsibility. It does not necessarily reflect the views or policies of the management of the EDF/Uganda Forest Resources Management and Conservation Programme.

## **List of abbreviations**

CFI.....	Continuous Forest Inventory
DFID.....	Department for International Development of the UK
EC.....	European Community
EDF.....	European Development Fund
EI.....	Exploratory Inventory
EPHRU .....	Editing of PSPs from the High forest Region of Uganda
FR .....	Forest Reserve
FRMCP.....	Forest Resources Management and Conservation Programme
FRP .....	Forest Rehabilitation Project
GEMFORM .....	Guyana Empirical Forest Model
ISSMI.....	Integrated Stock Survey and Management Inventory
ITTO .....	International Tropical Timber Organisation
LAN.....	Local Area Network
MYRLIN .....	Methods of Yield Regulation with Limited Information
NFMCP .....	Natural Forest Management and Conservation Project
PSP .....	Permanent Sample Plot
RME.....	Reliable Minimum Estimate
SFM .....	Sustainable Forest Management
SQL.....	Structured Query Language
TOR .....	Terms of Reference
TSS.....	Technical Services Section
UFD .....	Uganda Forestry Department
UTM.....	Universal Transverse Mercator

## Background

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This report continues work that has been undertaken the author during five short consultancy visits since September 1998, totalling in all about 5 months work. These missions were to the preceding EDF-funded forest management project in Uganda, the *Natural Forest Management and Conservation Project* (NFMCP), which terminated in March 2002. The objectives and outputs from those visits are described in Alder (1998, 1999a, 1999b, 1999c, 2000)<sup>1</sup>.

These various visits focussed on four main areas relating to the biometry of the natural high forest in Uganda:

- Efficient methods of stock survey and management inventory, including both the training of staff in ground operations specified by the consultant, design of field forms, and development of a data processing system. This integrated stock survey and management inventory system is called ISSMI. Stock survey and management inventory are fundamental to effective control of selection forest management on the ground.
- Appropriate techniques and procedures for a new series of permanent sample plots (PSPs) in the high forest zone of Uganda. This again included both the specification of field operations, design of field forms, and development of a data entry and editing system called EPHRU (Editing of PSPs from the High forest Region of Uganda). PSPs are required in order to develop projection models of forest growth rates, and hence estimate sustainable yields and allowable cuts for sustainable forest management (SFM).
- Acquisition of new tree volume data based on destructive sampling, with the felling and scaling (ie detailed measurement and quality assessment) of a sample of 2000 trees, according to size and species criteria given in the June 1999 report (Alder, 1999c). The consultant designed field forms and detailed instructions, and provided training on the ground, but suggested that the data entry and editing system should be within the capacity of the project. This was intended to address the known deficiencies in the tree volume equations then available, which were based on Relascope sampling during the Budongo Forest Inventory of 1990-1 (see below). These equations were described in Alder (1999a, pp 5-6).
- The design of a new form of exploratory inventory (EI). EI has been carried out by the Uganda Forestry Department (UFD) using procedures recommended by Slavicky (1990). The present author developed the data processing system and undertook early analysis of that work (Alder, 1991). The data processing system was used as the basis for several further EI studies<sup>2</sup>, some undertaken during the NFMCP era. However there were three problems with this earlier form of EI which indicated the need for a new system: (i) The sampling used radial lines, and had therefore a heterogeneous sampling intensity relative to each plot, (ii) the ½-ha sample unit was difficult to lay out and not efficient either statistically or in practice, and (iii) the DOS-based programs and outputs were incompatible with modern Windows-based report writing, analysis and database methods.

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<sup>1</sup> These reports are stored as Word documents on the project's TSS Server computer under

D:\BIOMETRICS\DOCUMENTS\REPORTS\, with file names SEP98, FEB99, MAY99, JUN99, DEC00 respectively.

<sup>2</sup> These have been led by David Elungat, the FD Biometrician, who was the author's counterpart during the World Bank Forestry Rehabilitation Project, 1989-91.

The terms of reference for the present mission are quoted verbatim below from the contract document<sup>3</sup>.

## **Terms of reference**

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### **“2. OBJECTIVES OF THE CONSULTANCY**

*During a period of one month, the consultant will:*

- a. *Develop the office practices to a level where all basic stock survey and inventory data processing can be carried out routinely by Project staff.*
- b. *Review the application of information generated in the office and make recommendations on how it can be applied meaningfully and easily by field staff at FMU level.*
- c. *Integrate the recommendations of other studies on ISSMI and EI into the ordinary natural forest management practices of the FD.*
- d. *Conduct hands-on training for relevant staff of the FD, Nyabyeya Forestry College and Makerere University, Faculty of Forestry and Nature Conservation to a level where they will be able to use these practices in normal management of natural forests.*
- e. *Conduct training in MYRLIN, a computer package that can be used to calculate yield for forests with minimal data.*

### **3. AREAS OF EMPHASIS**

*The specific areas where emphasis will be placed are:*

- a. *Integrated stock surveys and management inventory (ISSMI)*
- b. *Exploratory Inventory (EI)*
- c. *Permanent Sample Plots (PSP)*
- d. *Tree Volume Measurement (depending on available data)*
- e. *Yield Regulation*

### **4. OUTPUTS OF THE CONSULTANCY**

- a. *A general report (which can be published) on improvements made in the areas outlined in (3) above.*
- b. *Operating manuals for office and field practices*
- c. *User-friendly computer applications developed and training given”*

The consultant interpreted these TORs in terms of what was practicable within the 25-day contractual period of the mission, and has focussed on developing software for the Exploratory Inventory, which was almost completely lacking (12 days), some improvements to the ISSMI software (4 days), preparation for and delivery of field training visits and workshops as stipulated in the above TORs (8 days), report writing and general presentations (12 days), some minor improvements to the EPHRU software for PSPs (1 day). This totals 34 days, with 9 days extra-contractual services being provided by the consultant.

## **Outputs**

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The key outputs from the present visit are listed below and described in detail in this report:

- EI software, comprising a program (EIPAC) to produce stand tables in a flexible way from a wide range of inventory designs and data sources in natural forest; and a program (EIMAP) to generate ArcView GIS map layers for inventory blocks, transects and plots using the georeference information in the database. This latter includes also Help system documentation.
- A revised EI database (EI DATA2) and data input program (EiSYS), which unites the two differently formatted datasets and restructures them to minimize errors in georeferencing of blocks, plots and transects. This process also involved significant work in cleaning up

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<sup>3</sup> Contract SC/14/2002 of Programme 8-ACP-UG-030, EDF-Uganda Forest Resources Management and Conservation Programme.

the referencing of the data, especially for Mabira forest, where duplicate block numbers had been used.

- ❑ A revised version of ISSMI (version 2.11) which has been updated to and tested with Windows 2000 and Office 2000. The central ISSMI database was updated to Office 2000 versions. Changes were made to the tree selection input form. A new form was added to assist in block level forest management. The mapping program was updated to version 2.04d to eliminate crashes when some block coordinate fields were blank, and the Installer for the mapping program was updated for compatibility with Windows 2000.
- ❑ A revised version of the EPHRU program for PSP data entry. This was updated to Office 2000, and split into the Front-end/Back-end database model, so that a database now exists called PSP data which is distinct from the data entry application EPHRU2. The layout of the data entry screen was modified for improved clarity.
- ❑ A workshop and field training exercise was provided from 10-12th September 2002 in Masindi and Budongo Forest. The Powerpoint slides from this workshop are available on the TSS Server computer under *D:\Biometrics\Documents\Ppresentations*. This included teaching and a paper exercise relative to MYRLIN, in fulfilment of item 2(e) of the TORs. It also covered the application of the EI and ISSMI systems in forest management, with both paper and field exercises.
- ❑ Two half-day general presentations were provided to invited project and Forestry Department personnel. The first on 28th August briefed the project about the past development of EI, ISSMI, volume studies and PSP work, and the current status as evaluated by the consultant during the first 2-3 days of his visit. The second on 19th September was a final briefing to the same group, essentially presenting the findings of this report. The Powerpoint slides from both these presentations are deposited on the TSS Server computer under *D:\Biometrics\Documents\Ppresentations*.
- ❑ This report constitutes an output that gives technical information about the new software developed and the changes made to existing programs, and also provides further recommendations.

# Exploratory inventory software

## Exploratory Inventory objectives, origins and design

The Exploratory Inventory (EI) procedure has been used since 1990. It is a low-intensity sampling intended to provide initial information about the species and stocking on natural forest areas for preliminary planning purposes. Until 2000, the EI work was done using a design based on random radial lines located at convenient starting points, with ½-ha plots (100 x 50 m). Data processing was done using DOS-based software by the Forestry Department Biometrics Section. The original design and software were developed during the World Bank Forestry Rehabilitation Project of 1989-91 (Slavicky, 1990; Alder, 1991), and the main coverage was done during those years. Since about 1995, the software was found to be increasingly difficult to use because of the problem of integrating the DOS-based outputs (which are printer/text files) with MS Office software for document preparation and analysis. The system also used binary files for storing data, rather than any known database format; the data could not therefore be re-analysed or reviewed with any other package.

In 2000, the author therefore proposed a new design that would improve efficiency and statistical validity on the ground, and be associated with a new generation of software (Alder, 2000)<sup>4</sup>. Work started on the ground using the new procedure almost immediately, and a data entry procedure was designed in Access that has been used to input much of the data<sup>5</sup>. This database evolved through two versions. The first, which used for data from Mabira, Budongo and Kalinzu, encouraged data errors in georeferencing plots, as coordinates had to be calculated manually and entered for every plot. The second, used for the Sango Bay group of reserves, calculated plot coordinates from block coordinates, and was less error prone, but used a different data structure.

By the time of the authors arrival in August 2001, there were 4449 plots in the two databases (Sango Bay and others), as shown in the table opposite. However, there was no method of analysing or using these data.

Reserve	Plots	Blocks	Plots/Block
Budongo	510	26 (ea. 1km <sup>2</sup> )	19.6
Kalinzu	1187	70	17.0
Mabira	1677	79	21.2
Sango Bay	1075	39 (ea. 4 km <sup>2</sup> )	27.6
Total	4449	212 (329 km <sup>2</sup> )	

The design adopted by the EI has been described in earlier reports, but is presented here for reference. The design is a stratified, partially-randomised sample. Stratification is by square blocks, each normally of 1 km<sup>2</sup> (see Figure 1), oriented in a NS-EW direction. Within the block, two transects are laid at random in an EW direction. This randomisation is constrained to values that are integer multiples of 200 m in a NS direction (ie 200,400,600,800 or 1000 m for 1 km<sup>2</sup> blocks). The location of transects is usually determined in the field using a dice: Values 1-5 give possible transect positions, 6 is re-thrown.

Along the transect, plots are established at 100 m intervals, starting 50 m in from the beginning of the transect. Each plot is circular, of 500 m<sup>2</sup>, having a radius of 12.6 m. Within the plot, all trees down to 20 cm dbh are included. A subplot is established within the NE quadrant of the plot on which trees down to 10 cm are measured (Figure 2).

<sup>4</sup> It should be emphasised though that the earlier software was capable of processing many kinds of design, including the new type of EI described here. The main issue was its lack of Windows and modern database compatibility.

<sup>5</sup> This was done by Paolo Viskanic, a GIS consultant to the project.



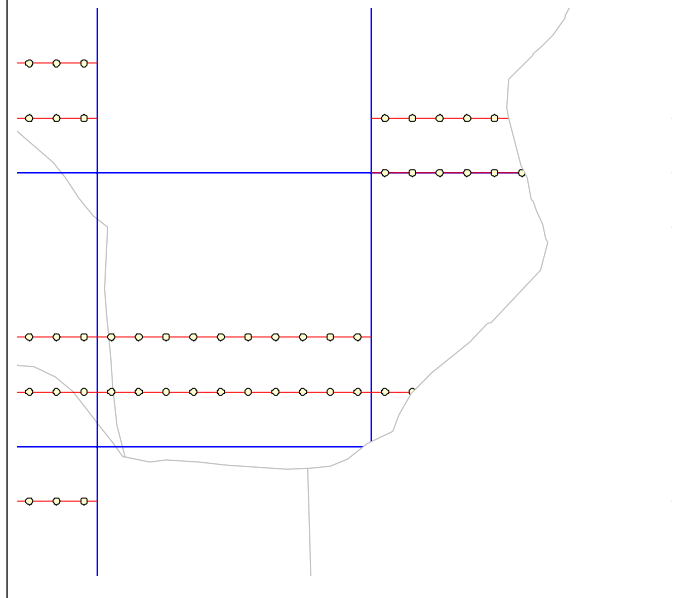
This design gives 20 plots of 0.05 ha on a block of 100 ha, or a sampling intensity of 1%. For Sango Bay, the design was modified to use a 2 x 2 km grid, with 20 plots on each transect, giving a sample intensity of 0.5% (20 ha sampled per 4 km<sup>2</sup> block).

To assist georeferencing of plots, transects and plots are numbered in a standard way. The transects are numbered according to their position. The first possible position (200 m north of the block baseline) is 1, the second possible position (400 m) is 2, and so on. The plots are always numbered from one upwards from East to West, regardless of the actual direction in which plots are established.

In the field it is normal to have separate teams cutting lines and enumerating plots. Line cutting proceeds at about 800 m per day, whilst plots are measured at a rate of about 10 per day<sup>6</sup>.

**Figure 1: EI sampling design, shown arrangement of blocks, transects, and circular plots.**

*Block lines are in blue, transects in red, plots in black/yellow, and forest zoning and compartment boundaries in grey.*

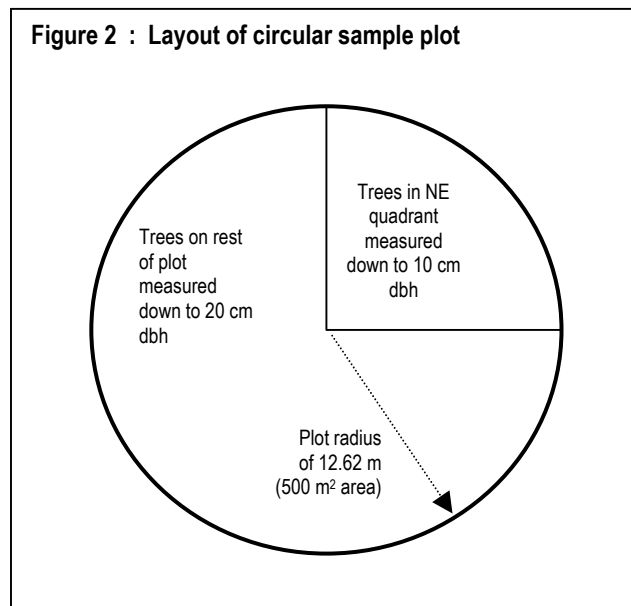


### EI database design

The EI data was, at the consultant's arrival, stored in two different databases, using one format for the Sango Bay data, and another for the other areas<sup>7</sup>. Both of these were in MS Access.

These were converted into a single database, whose tables, fields and relationships are illustrated in Figure 3. This database has the name EI DATA2.MDB. The conversion sought both to unify the datasets, and to retain only the essential information. Entries such as Officer in charge, sheet numbering, and the calculated positions of plots were omitted. For the non-Sango Bay data, the simple plot file had to be 'normalised' (in database terminology) to create separate block and plot files. During this process it emerged that in Mabira, the same sequence of blocks numbers (1,2,3,... etc) had been used in three different parts of the reserve. These were converted by adding 200 and 300 respectively to the duplicate block sequence numbers. It was also found that the Sango Bay UTM coordinates were based on a different UTM zone or system, being south of the equator. They were

**Figure 2 : Layout of circular sample plot**

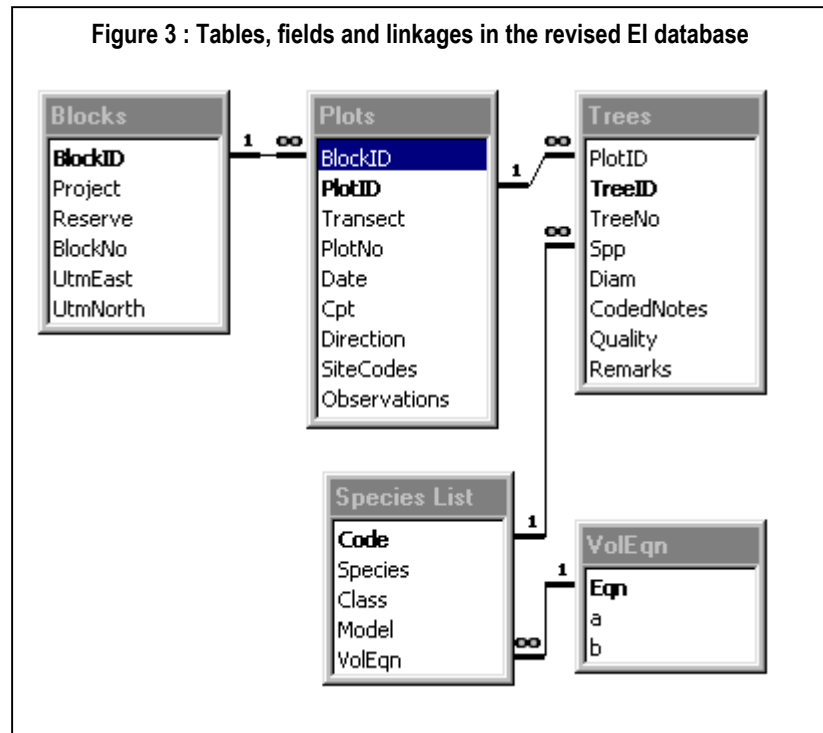


<sup>6</sup> Personnel communication, George Tumusigwe.

<sup>7</sup> These databases were designed for the project by Paolo Viskanic.

converted for compatibility with the other Reserve coordinates by subtracting 9,800,000 from the North coordinate.

There are three main tables in the database, called *Blocks*, *Plots* and *Trees*. The *Blocks* table contains only block-level information. These include the project name, reserve name, block sequence number (*BlockNo*), unique Block ID, and the UTM North and East coordinates. The project name is useful for grouping several small reserves (such as the Sango Bay area), but in most cases will be the same as the reserve name. However, the block sequence numbers should be unique within a project area (in other words, a project should constitute a single sampling frame, with each block having its own number).



Another issue regarding project names is that the name should not contain spaces. For example, Sango Bay is entered in the system as SangoBay. This is because, in the EiMap application discussed later, the project name is used as part of the name for ArcView shape files that may be generated. ArcView (at least to version 3.2) cannot open files whose names contain spaces<sup>8</sup>.

The coordinates for a block must always refer to the SE corner. The *BlockID* field is generated by the system as the data is entered and is unique for all blocks in the database. It is used to link data in the *Plots* table to the correct *Blocks* record.

The *Plots* table contains for each plot, the transect number, plot number, measurement data, compartment, direction in which transect was measured, site codes, and a memo field (of unlimited length) for any other remarks or observations. Plots are linked to *Blocks* by the *BlockID* field. Each plot has its own unique generated *PlotID*, which is used to link each plot to the relevant tree data entries.

The *Trees* table contains tree number, species code, diameter (stored as a real number, and accepting decimal data, unlike the predecessor databases), coded notes, a tree quality code, and a *Remarks* field as a memo of unlimited length. Each tree entry is assigned a unique *TreeID* by the system, and links to the *PlotID* for the plot on which it occurs; this is done automatically by the system as data is entered.

The species list contains species codes and names. In addition, three other fields are present to facilitate grouping of species, growth projections, and volume calculation. The *Class* field is a user-defined group code, which can be given arbitrarily to any set of species to group them

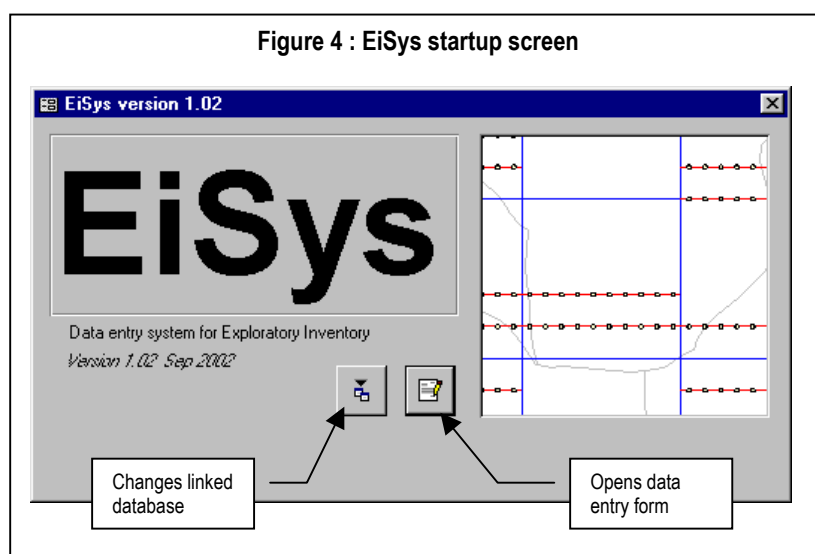
<sup>8</sup> With a little more time, the author would have modified the program code to 'squeeze out' spaces from generated file names, to avoid any possible problems with ArcView and relax the stipulation about not including them in Project names. This will probably be done in a future revision cycle.

for the EiPac program for stand table production and stand projection. The *Model* code is a letter (A-Z) defining a growth model for the species. It is defined in relation to the EiPac program, and is discussed in detail there. The *VolEqn* field is also a letter code, defining a volume equation for the species from the linked *VolEqn* table. These are again discussed in detail in relation to EiPac.

### EiSys : The EI data entry application

Data entry to the EI DATA2 database is done using an Access application called EiSys. This has been created during this consultancy to accommodate changes in the database structure, and provide a more efficient data

entry format. The application has two screens. When EiSys.mdb is opened (for example by clicking on it, or via a shortcut that has been set up on the Windows program menu or desktop), it will show the 'splash screen' in Figure 4. This has two buttons, as indicated. The left button allows the linked database to be changed, via a standard 'Open file' dialog. This is useful when setting up EiSys to work on a new network workstation. It can be copied to the workstation, and then via this button, linked to the EI data2 database on the server. If file locations are re-organised on the server, this also allows the database links to be adjusted easily.

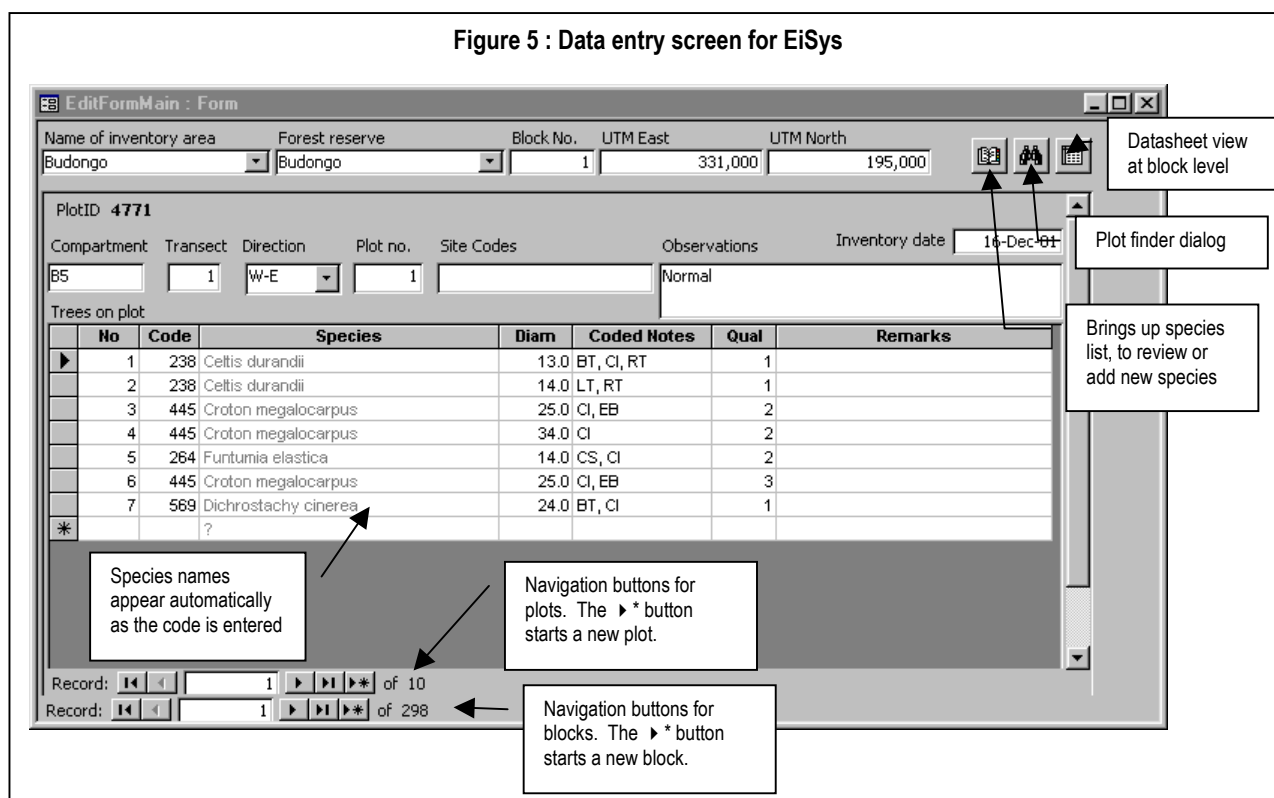


The second button opens the data entry screen, which is illustrated overleaf (Figure 5). This operates conventionally. The main differences from the earlier version is that species names now appear automatically as soon as the species code is entered, and there are separate navigation buttons for plots and blocks. Coordinates only have to be entered when a new block is started.

A plot finder button (binocular symbol) speeds up location of a specific plot, which is referenced by the forest reserve name, block number, transect number and plot number. A datasheet view button lists all the blocks and allows rapid navigation to a specific block or plot. Switching back to form view via the Access menu will then allow editing to continue from the screen in Figure 5.

EiSys is purely a data entry system at this stage, and does not include any reports or analyses. For these, the separate EiPac and EiMap applications are used.

Figure 5 : Data entry screen for EiSys



### EiMap inventory mapping program

EiMap is a program written by the consultant in Visual Basic. Its purpose is twofold: (1) To display graphically the location of blocks, transects and plots to assist in managing inventory progress, and identify any errors in coordinates of numbering that affect georeferencing, and (2) to generate ArcView shape files of blocks, transects and plots that can then be published in maps and reports using the GIS system.

Prior to EiMap, it was very difficult and error prone to extract maps of block, transect or plot positions, and this hindered aspects of control and error checking. The procedure is now direct and easy, with maps being available as soon as the field data is entered.

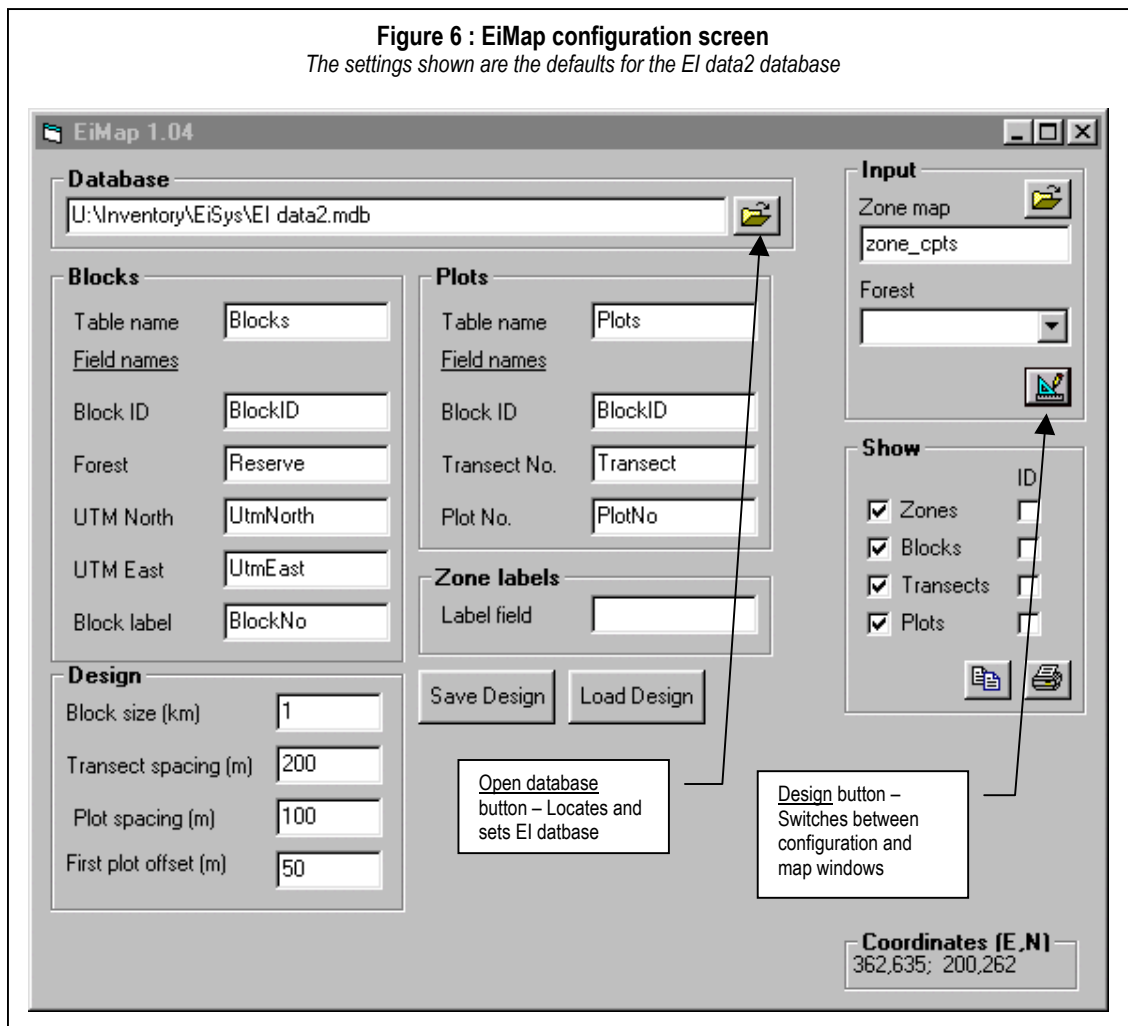
EiMap has its own Windows Help system, which is accessed via the F1 key when the program starts. The information in this report is a summary of the fuller explanations that are given in that Help.

### Installation

EiMap has been left as a reference copy on the TSS Server, at \\SERVER\D\BIOMETRICS\EIMAP. In that directory, three files will be found that comprise the installation kit. These are SETUP.EXE, SETUP.LST, and EIMAP.CAB. To install the program on another computer, create a directory called, for example, C:\EIMAP, with a sub-directory C:\EIMAP\INSTALL. Then copy the installation kit into the C:\EIMAP\INSTALL sub-directory. Click on the SETUP.EXE file to start the installation process. At the second screen, change the installation directory from the default (C:\PROGRAM FILES\EIMAP)<sup>9</sup> to the directory you have created (eg.. C:\EIMAP), then proceed using default options. On completion, the C:\EIMAP directory will contain a number

<sup>9</sup> On Windows 98 systems, it is possible to install entirely using defaults. However, this does not seem to work on Windows 2000.

**Figure 6 : EiMap configuration screen**  
*The settings shown are the defaults for the EI data2 database*



of files including EIMAP.EXE and EIMAP.HLP. Clicking on EiMAP.EXE will start the program, while clicking on EIMAP.HLP will bring up the Help file. The installer will also create a shortcut to EiMap on the Windows Start menu, under Programs, that can be used to start the program.

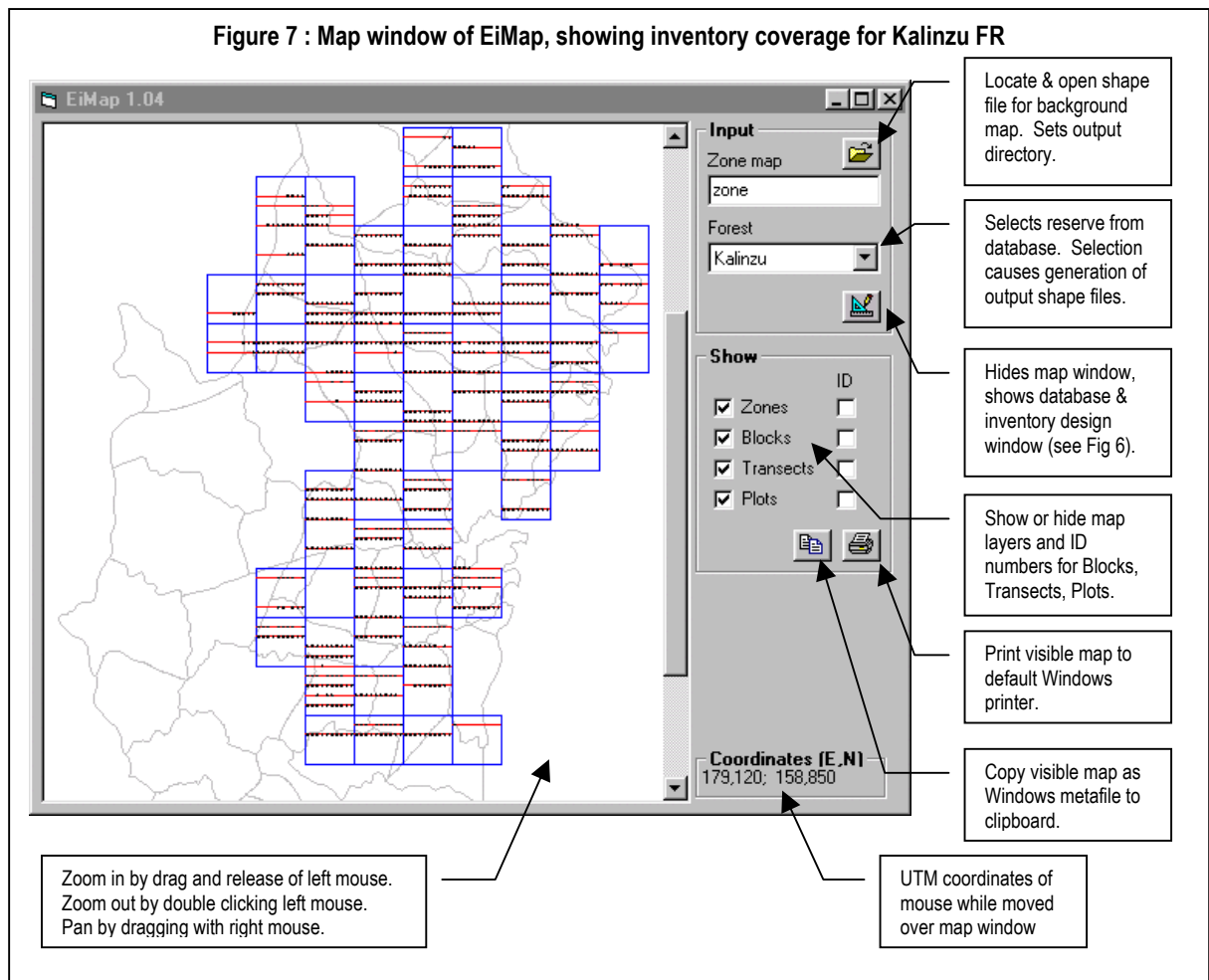
When the program is started for the first time, the location of the EI DATA2 database must be set before information can be displayed. Figure 6 shows how this is done. The Design button, when clicked, reveals the parameter settings for the program. By default, the installer will configure these for the EI DATA2 database and the 1 km<sup>2</sup> inventory layout. The correct database is set by clicking the Open database button, and navigating to the EI data2 database.

If the form boxes are blank, rather than displaying the values shown in Figure 6, then the file EIMAP.IEI has not been installed properly. This can be copied manually from the reference copy of the software at \\SERVER\D\BIOMETRICS\EIMAP to the Windows directory. On Windows 2000, this is called C:\WINNT. On earlier versions of Windows, it is C:\WINDOWS.

Once the database has been set, the Design button can be clicked again. The configuration fields will be replaced by the map window, as shown in Figure 7.

### Using EiMap

Once the database has been set, a forest reserve can be selected using the names in the pull-down list. At the time of writing, data for five reserves is in the system: Budongo, Kalinzu, Mabira, Kaiso and Malabigambo. Kaiso and Malabigambo are in the Sango Bay group, and use a different design configuration. Their mapping is discussed in the next section. The



default configuration (as shown in Figure 6) assumes a 1 km<sup>2</sup> block, with 200 m between possible transect positions, and 100 m between plots.

The example in Figure 7 shows Kalinzu FR. The background map is selected from the Zone Map open file button, and can be any ArcView shape file, but should preferably be a forest or forest compartment outline. Once the forest is selected from the Forest pull down menu, the shape files are generated for blocks, plots and transects. These will be placed in the same directory as the background map used, and will have the general names:

~Ei*forest*BLOCKS.SHP, .SHX, .DBF  
 ~Ei*forest*TRANS.SHP, .SHX, .DBF  
 ~Ei*forest*PLOTS.SHP, .SHX, .DBF

Here, *forest* will be substituted by the name from the pull-down, eg.. Kalinzu. Each ArcView shape file consists of three Windows files<sup>10</sup>, with the extensions .shp, .shx, and .dbf indicated above. The Block and Transect files have line topology, whilst the Plots file has polygon topology (each plot being mapped as a 12.6 m circle).

The ~ is used to indicate that these files are temporary. That is, they may be overwritten whenever EiMap is run. Consequently, any changes made to these files, for example from within ArcView, could be lost. It is important therefore that if the files are to be edited within ArcView, they should be renamed first, and the editing done on the renamed versions.

<sup>10</sup> ArcView or other ESRI applications may also generate .sbn and .sbx files as they create spatial indices. This is however not done by EiMap.

The map can be zoomed and panned using the mouse buttons. Dragging with the left mouse button on the map will create a tracking rectangle. When the button is released, the window will zoom to this rectangle. Dragging with the right mouse button will pan the map. Double clicking will revert to the last zoomed window.

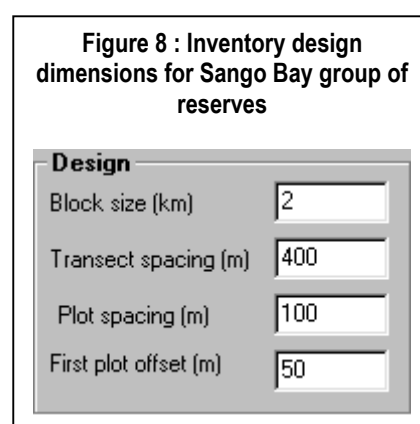
The various checkboxes in the Show frame allow the map layers to be hidden or revealed for greater clarity. If the right checkboxes are ticked, then the numbers for Blocks, Transects or Plots can be seen. This is useful for identifying positional errors.

The buttons at the bottom of the Show frame allow copying to the Windows clipboard, or printing to the default Windows printer. Copying is done as a Windows metafile, which imports well into MS Word, for example. It is always the visible extent of the map window that is copied or printed.

### Changing design settings

The default specifications for the inventory design are for a 1 x 1 km block with 5 possible transects located at multiples of 200 m. There are 10 plots per transect, spaced at 100 m intervals. This design applies to Mabira, Budongo, and Kalinzu amongst the current data set, and is the consultant's recommended design (see Alder , 2000).

A lower intensity design was applied to the Sango Bay group of reserves. This used 2 x 2 km grid, 400 m multiples for transect spacing, and 20 plots per transect (giving also 100 m spacing per plot). To map the data correctly for this area, the settings in the Design frame (see Figure 6) must be changed to these values, as shown in Figure 8 at the right.



Settings for different inventories and database fields can be saved and reloaded using the Save Design and Load Design buttons shown on Figure 6. The designs are saved as text files with extension \*.iei. The standard settings for the EI DATA2 database and the 1 km<sup>2</sup> and 2 km<sup>2</sup> layouts will be found in the files EiSYS1KM2.IEI and EiSYS2KM2.IEI in the directory \\SERVER\D\BIOMETRICS\EIMAP.

### EiPac inventory data analysis program

EiPac is a program written in Visual Basic and packaged as an Excel file which provides general purpose facilities for analysing natural forest inventories and making stand projections. The name is an acronym for Exploratory Inventory and Projection of Allowable Cut. The program was adapted during the present consultancy visit from one developed for Guyana called GEMFORM (Alder, 2001, 2002a, 2002b).

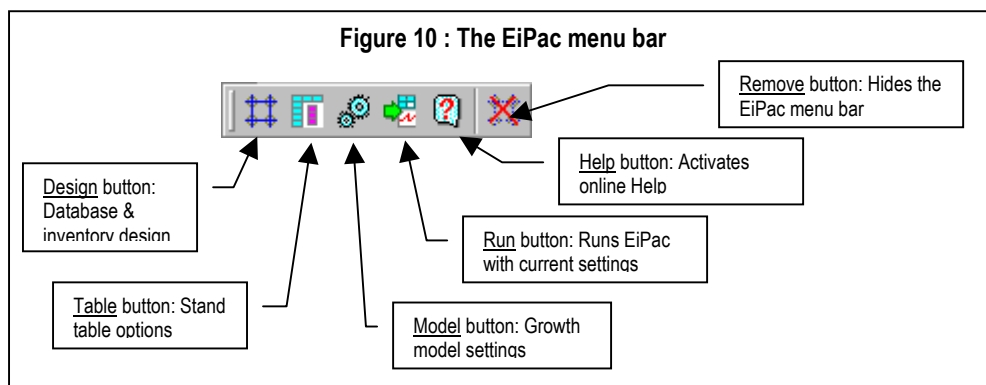
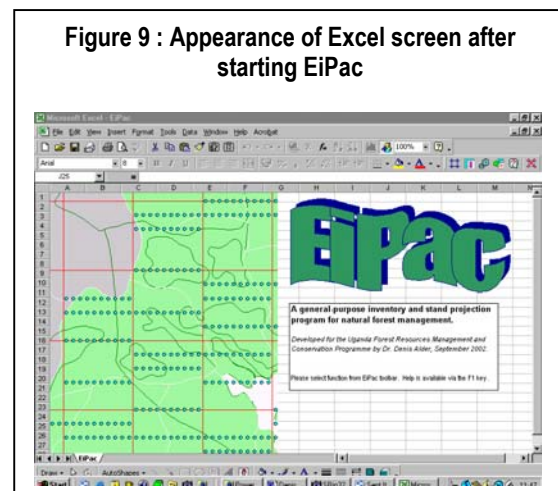
EiPac is installed simply by copying the file EIPAC.XLS from \\SERVER\D\BIOMETRICS\EIPAC to the local directory on the workstation. No other installation is required. However, the workstation must have Excel from MS Office 2000 or higher installed. Clicking on EIPAC.XLS from the Windows Explorer or opening it from within Excel will start the program.



### The EiPac menu bar

When EiPac starts, a single worksheet will be seen as shown in Figure 9 which is designed to identify the program. Most of the operational components of the program are hidden as Visual Basic code and hidden worksheets. However, these components are not proprietary and can be easily accessed through Excel menus if changes need to be made.

While EiPac is active, a menu bar will appear in the Excel window. This allows access to the various EiPac modules. This menu bar will disappear when EiPac is closed.



The Design button activates a tabbed dialog that allows all aspects of the inventory design to be specified, including the database tables and field names to be used. The Table button activates a dialog to specify the columns in the stand table to be generated, how species are to be shown, sampling error rows or columns, and general layout features. The Model button specifies settings and options for the growth model. The Run button opens specified input and output files and runs the program to generate outputs. The Help button can activate online help, and the Remove button will remove the EiPac menu bar if it is not desired.

The Design, Table and Run buttons are described in detail in the following sections. This consultancy has not concerned itself with growth modelling, so although the facility exists within EiPac, it has not been calibrated for Uganda and the use of the Model features are not described in this report.

### Setting up an intermediate database for use with EiPac

EiPac is a general-purpose inventory program that is not closely locked in to the structure of the EI DATA2 database (Figure 3). To work effectively, it is necessary to link EiPac to EI DATA2 through an intermediate database. This can be demonstrated by an example for analysing Budongo Forest data. Proceed through the following steps:

- ❑ *Create an empty Access database, called, for example BudEI. This should be done in the same directory as the working copy of EiPac on your workstation.*
- ❑ *Import as linked tables all the tables in EI data2. The Access menus File ► Get external data ► Link tables are used for this purpose.*



- ❑ Create a make-make table query to extract Budongo plots. This can be done using the query designer by joining the *Blocks* and *Plots* tables, selecting all fields from *Plots*, and the *Reserve* field from *Blocks*. The selection criteria is set to “Budongo”. This is converted to a make-table query after testing it as a select query, to produce a table called *BudPlots*. The SQL format for this query may look like this:

```
SELECT Blocks.Reserve, Plots.BlockID, Plots.PlotID, Plots.Transect,
Plots.PlotNo, Plots.Date, Plots.Cpt, Plots.Direction, Plots.SiteCodes,
Plots.Observations
INTO BudPlots
FROM Blocks INNER JOIN Plots ON Blocks.BlockID = Plots.BlockID
WHERE Blocks.Reserve ="Budongo";
```

- ❑ Create a compartment area table for Budongo. This can be done by locating the .DBF file for an ArcView shape file representing compartments, and opening it from Excel. A column called AREA will give compartment areas in m<sup>2</sup>. Using Excel worksheet functions, create a new column headed *AreaHa* and calculate in it the areas in ha. Rename the column representing compartment IDs (eg. COMP\_) as *Cpt*. Copy the two columns *Cpt* and *AreaHa* to a fresh sheet named *Areas*, and save the resulting file as an Excel Workbook. Then, from Access, import the sheet *Areas* as a linked table into the intermediate database *BudEI*.
- ❑ Finally, remove any compartments not referenced in the inventory from the *Areas* table that has been imported. This can be done using a query on the *Areas* table that checks that the *Cpt* value is in the *BudPlots* table, as shown in the SQL query below:

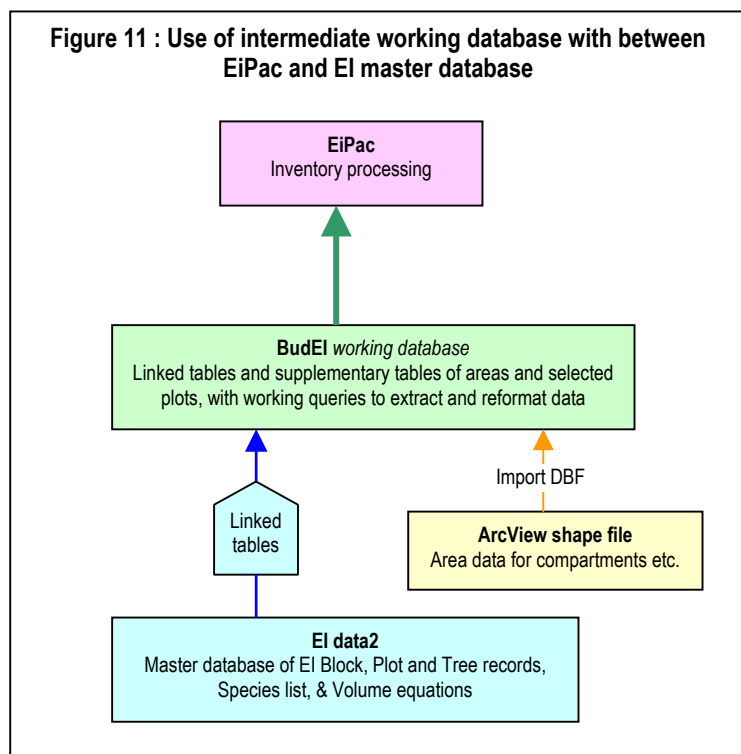
```
SELECT Areas.Cpt, Areas.AreaHa
INTO BudAreas
FROM Areas
WHERE Areas.Cpt IN (SELECT BudPlots.Cpt FROM BudPlots);
```

EiPac will then be used with the *BudEI* database, as shown in the diagram in Figure 11. The above manipulations may appear complex to the average reader, but were the subject of specific in-office training during this consultancy mission for the TSS staff, to develop proficiency and fluency in the use of Access queries to manipulate data.

The key points of the intermediate database for use with EiPac are:

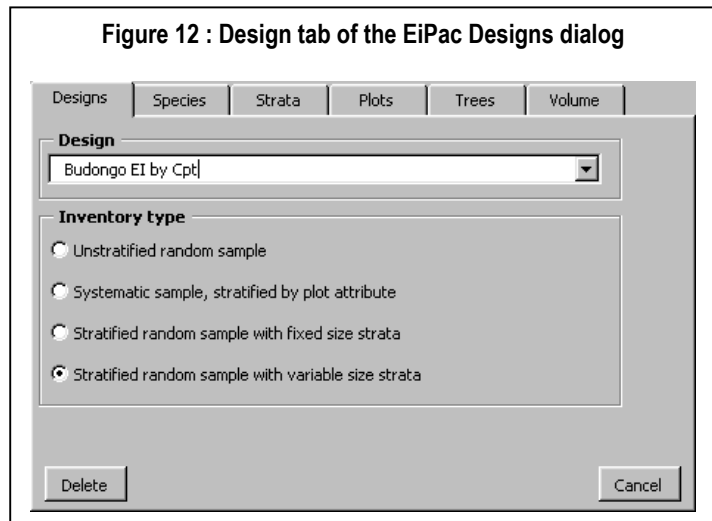
- ❑ It links directly to all tables in the master EI database (EI DATA2).
- ❑ Plots for a specific inventory are extracted.
- ❑ Area data is imported from ArcView files, and linked via a field such as compartment number (*Cpt*) to the extracted plot list.
- ❑ Temporary queries generated by EiPac will be placed in the working database (*BudEI*) rather than the master database.

#### Inventory design features of EiPac



When the EiPac Design button is clicked, the tabbed dialog box shown in Figure 12 appears. The Designs tab, as illustrated, allows the selection of four possible inventory designs. Each of these is compatible with the EI database, but apply different statistical models to analysing the data. The options are:

- ❑ *Unstratified random sample.* With this option, block level information and plot attributes are ignored. The entire set of plots from the table specified by the Plots tab (Fig.14) are taken as an unstratified sample. The total area of the forest sampled must be set on the Strata tab (Fig.13). This option is designed primarily for cases where an unstratified random sample has been performed on the ground, and is not an efficient way of using the EI data; it could however be used to illustrate the effect of stratification on sampling error.
- ❑ *Systematic sample, stratified by plot attribute.* This option requires that the Plot attribute field on the Plots tab contains a field with a post-stratification parameter. This could be a site code, or a location code such as compartment number, but must be a field on the plot header file. The statistical model assumes that each plot represents an equal area sampled (as in a systematic design), and the area weight of each stratum can be validly estimated from the number of plots within it. This is not strictly true for the EI, but is more correct for sampling on a systematic grid. Hence, if applied to the EI data, the sampling errors should be regarded as only approximate with this option. It is however useful as a way of easily extracting stand tables for different site types according to plot coded notes.
- ❑ *Stratified random sample with fixed size strata.* This is the basic method of the EI, using the blocks as strata. For correct calculation, the Block areas (100 ha, or 400 ha for Sango Bay) must be entered under the Strata tab (Fig. 13).
- ❑ *Stratified random sample with variable size strata.* This option would apply, for example, to stratification of the EI data by compartments. To use this option, a table of stratum areas must be provided, with particulars given under the Strata tab.



The pull-down list labelled Design on this form (see Figure 12) can be used to save or recall design specifications by name. When the dialog window is closed (other than by using the *Esc* key), all the details that have been set are saved under the name displayed in this text area. Typing in a new name will save a new design. When an existing design is selected from the list, all the settings for that design will be recalled.

### Stratification methods and table linkages

The *Strata* tab of the Design dialog can take different appearances, depending on the sampling design option selected. With any of the options except the last (see Figure 12), it will appear as shown in Figure 13(a). For *unrestricted random sampling*, the area entered should be the area of the whole forest sampled. If this is not correct, then area totals will be wrong, and the wrong area will be shown on table headings. However, per ha or per km<sup>2</sup> summaries will still be correct. For the design option *Systematic sample, stratified by plot attribute*, the area entered should also be the whole area sampled, otherwise areas shown on table headings will

be wrong. However, per ha or per km<sup>2</sup> figures in the tables will still be correct, whatever the area given.

For the third design option, *Stratified random sample with fixed size strata*, the area entered should be the block size. For reserves except Sango Bay, it would therefore be 100 ha, whilst for the Sango Bay area, it should be 400 ha.

When *Stratified random sample with variable size strata* is specified as the design, then the entries under this tab will change to the format shown in Figure 13(b).

The table name given here corresponds to the example discussed on page 12 ff. The field name given as *Stratum ID* is a field that links to the Plots table. The stratum *Title* field is however used on stand table headings, and could be different. The *Area* field must specify the stratum area in ha. If either the *Stratum ID* or *Area* fields contain null values (empty records) then errors are likely to occur while processing the data.

**Plot design and record specification**

The Plots tab specifies the table source and record structure for the plot data. It also specifies the plot size and sub-sampling

**Figure 13 : Strata tab of Designs form**  
 (a) With fixed area blocks, stratification by attribute, or unstratified plots. The area entered should be whole forest area except for stratification by blocks, in which case it should be the block area (as shown in the example).

(b) With variable area strata. In this case, stratum areas are given in a data table whose name and fields are specified on the form.

specifications. It is shown in Figure 14. The table containing plot header data will normally be a subset of the EI master database *Plots* table, extracted as described on page 12 ff. The *Plot ID* field will be the key field that is unique in the table, and which links tree records to the plot record (see Figure 3). The *Stratum ID* is used with inventory designs

**Figure 14 : Plots tab of the Designs form**

Tier	% Area	Diam <
1	25	20
2		

corresponding to options 3 and 4 on the Design tab. For Option 3, *Stratified random sample with fixed size strata* (see Fig.12), the Stratum ID should be given as *BlockID* (see Fig. 3). For

Option 4, *Stratified random sample with variable size strata*, the Stratum ID should be the field that links to the areas table, which in the example discussed from page 12, will be Cpt (compartment ID).

The Plot attribute field is used with Option 2, *Systematic sample, stratified by plot attribute*, and should be a suitable attribute, such as a site code. This field can be left blank for the other options (any entry will be ignored). For option 1, *Unrestricted random sample*, neither the Stratum ID of Plot attribute fields are used. Any entries in the fields in this case would be ignored.

There are various plot size and sub-sampling possibilities, but the settings shown are those appropriate for the EI, with a fixed size plot of 500 m<sup>2</sup>, of which 25% is a sub-sample including trees below 20 cm.

### Tree, species and volume equation specifications

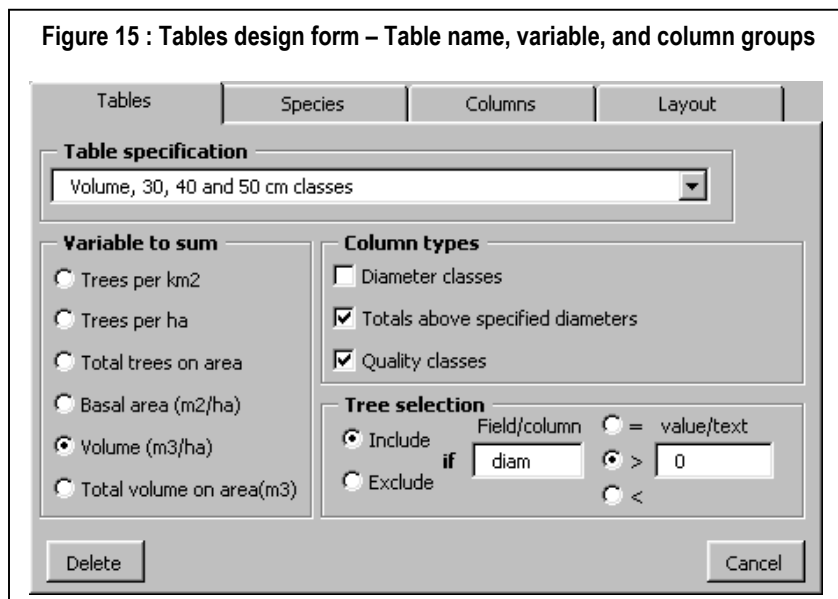
The Design form settings for the Trees, Species and VolEqn (volume equations) tabs are standard and do not need to be changed from the defaults supplied with EiPAC.XLS at <\\SERVER\D\BIOMETRICS\EIPAC>. They correspond to the field names and linkages shown in Figure 3 which are standard within the EI master database, and should be linked directly through the working database as illustrated in Figure 11.

However, if used with entirely different inventory data (for example the old FRP data from the Budongo 1990 inventory), they could be modified to accommodate a different database.

### Stand Table specifications for EiPac

The Table button (see Figure 10) will bring up a form that allows the layout and contents of stand tables generated by EiPac to be specified. This has several tabs, which relate to different aspects of the table layout

and contents. Figure 15 shows the initial *Tables* tab. In the *Table specification* frame is a pull-down list of all defined table names. When one of these is selected, all the settings on the form will be adjusted accordingly. If a new name is typed into this area, then when the form is closed (except with the Cancel button or *E*sc key), current settings will be saved under that name. The Delete button removes the current table specification from the stored list.



The *Variable to sum* frame selects which variable will be shown in the stand table.

The *Column types* frame selects which of the three main types of column specified on the Columns tab will be shown.

The *Tree selection* frame is an obsolete input from the GEMFORM program from which EiPac was derived. It will be removed in later

versions of EiPac, but for the moment should be left as illustrated or confusion may result.

When the Species tab is selected, the form will appear as shown in Figure 16. The *Species columns* frame allows several possible variants of species nomenclature to be displayed.

**Figure 16 : The Species tab of the tables design form**

However, for the EI data species list, there is no field for common names, so this should not be checked. Normally it should be left as shown.

The *Sub-totals* frame can group according to the species grouping field, which for the EI species list is the column called *Class* (see Figure 3). The classification of species for sub-totalling can be modified by editing the *Class* column.

Sampling errors can be shown for the group sub-totals and for the grand total of all species if the relevant box is checked. Sampling error % is defined as the standard error of a mean value, over the mean, expressed as a %. The reliable minimum estimate (RME) is the lower confidence interval of the mean at the stipulated probability level.

The *Species sort order* frame refers to the order of species within groups. This may be alphabetically in order of species code, common name or botanical name. It may also be in descending order of abundance (most common species first). Abundance can be expressed as total frequency or basal area. The latter corresponds closely to listing species in descending order of volume.

The *Group order* frame determines the order in which the groups appear. If Alphanumeric is selected, they will appear in ascending alphabetic or numeric order of group code. With the *As per list* option, the groups can be listed in any arbitrary order, and will then appear in that order in the stand table.

The *Columns* tab specifies how the various columns of the table should be set up. These are in three groups: Diameter classes, cumulative diameter classes, and quality classes. The presence of any or all of these types of column is controlled by the switches on the *Tables* tab, as noted in Figure 15.

In the *Diameter classes* frame are listed the lower bounds of the diameter classes to be shown. The list in the example is 10, 30, 50, 70, 90. This would set up diameter classes

**Figure 17 : The Columns tab of the tables design form**

10-30, 30-50, 50-70, 70-90, and 90+ cm. Class limits are interpreted so that a tree of exactly 30.00 cm, say, would be included in the class above, and one of 29.99 in the class below. Any trees below the lowest class will be ignored.

In the *Totals above diameter limits* frame are listed cumulative diameter classes. The example shows 30, 40, 50. This will give three columns, including all trees of 30 cm +, trees of 40 cm+ and trees of 50 cm +. These columns can have sampling error and reliable minimum estimates shown alongside. The RME may be to any specified level of confidence, although 95% is conventional. Probability values less than 50% or greater than or equal to 100% will cause an error, and will be ignored, with results output at 95% probability.

The *Quality classes* are based on the values in the *Quality* field of the *Trees* tab on the Inventory design form. For the EI data, this field is called *Quality* (see Fig 3), and may contain values from 1-5. The quality class labels are given in the right hand text box, and the corresponding value ranges in the right box. The example shown will produce three quality classes, with values 1-2 in a column labelled *Relict*, value 3 in a column labelled *Fair*, and values 4+ (ie 4 and 5) in a column labelled *Good*. Only trees 30 cm and above will be included in these summary columns, based on the setting in the *Minimum diameter for quality classes* box.

The method of constructing quality classes can be normal or cumulative, according to the selected option. With normal classes, the column bounds 1,3,4 will give classes 1-2, 3, 4+. With cumulative classes, the columns will represent all trees of quality 1 or better, of quality 3 or better, and of quality 4 or better.

The *Layout* tab of the tables design form controls various details of paper size, colour scheme, headings, and generated worksheet names.

In the *Page layout* box, the table may be specified as either in Landscape or Portrait orientation. If the *Scale to fit page* option is selected, the printed table will be scaled to be exactly one page wide in the selected orientation, although the length may still be several pages. If the *White background* is checked, the output is optimised for printing in black and white.

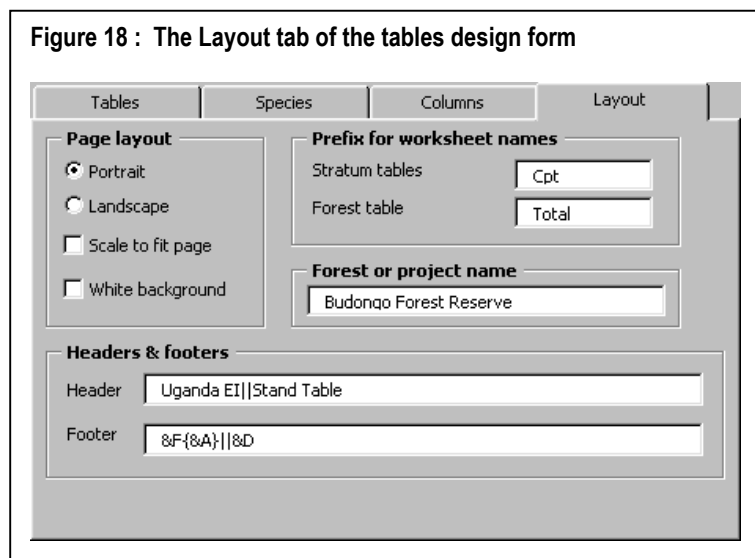


Figure 18 : The Layout tab of the tables design form

The *Headers & Footers* section defines settings for the header and footer to the Excel sheet. For both header and footer, this consist of three text regions, separated by the bar (|) character. The first is text at the left of the header or footer; the second is the centred text; the third is right-justified text. Special codes can also be inserted. There are many of these, described in the Excel Visual Basic Help pages, but for practical use, only the following are of importance:

- &F ..... Workbook (file) name
- &A ..... Worksheet name
- &D ..... Date of printing
- &P ..... Page number
- &N ..... Total number of pages

The *Prefix for worksheet names* applies to the generated tables. Each table will occupy one worksheet in an Excel workbook. The individual stratum tables will be on sheets that will be named according to the *Stratum tables* prefix given in this section, plus the Stratum ID (which may be compartment, block number, etc., according to the settings discussed on page 15). The final summary sheet for all strata will have the sheet name indicated by the *Forest table* entry.

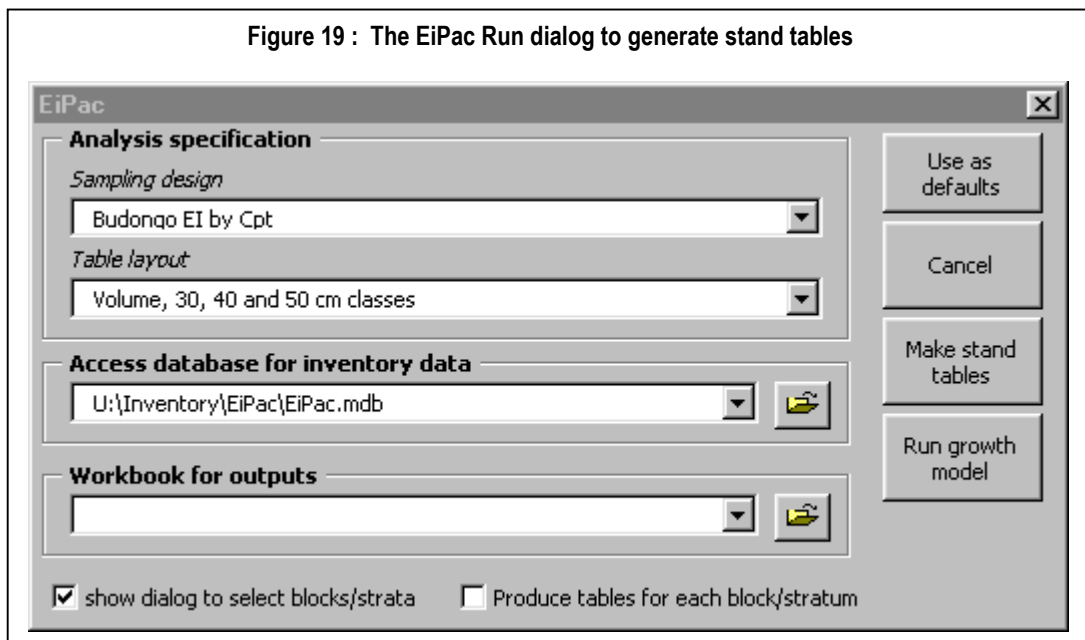
The *Forest or project name* will appear in the main title for each table, and should accordingly identify the general locality or project for the inventory.

### Generating EiPac stand tables

Having set up the database linkages and details of the inventory design with the *Design* form (pages 12-16), and the layout of the stand table with the *Table* form (pages 16-19), then the tables may be generated by using the

*Run* form.

This appears as shown in Figure 19 when the Run button is clicked (see Figure 10).



The entries in the *Analysis specification* box will default to the last sampling design and table layout viewed, but others can be selected from the pull down list if appropriate. The *Access database for inventory data* should refer to the intermediate or working database shown in Figure 11. The *Workbook for outputs* can either be an existing workbook name, or may be left blank. If it is left blank, then a name in the form ~EiPac (n).xls will be generated, where *n* will be a digit from 1 upwards to give a new file name. It will be saved in the same directory as the EiPac.xls application.

If the output workbook is a workbook that is already opened, then a warning message will occur, advising that any changes in the open workbook may be lost when it is closed and re-opened. For this reason, it is not recommended to use a workbook that is already open unless it has first been saved.

Ticking the *Show dialog to select blocks/strata* checkbox brings up a popup list which allows only selected strata to be output and summarised. The *Produce tables for each block/stratum* checkbox



will, if ticked, result in a table for each stratum. If it is clear, only a summary table will be produced, for all strata.

To produce stand tables, the Make stand tables button should be pressed. At this point, the program will actually begin to read the data, and will generate error messages if the design specifications do not accord with the linked database. If it runs normally, the output workbook will be opened or created, and sheets generated in it containing the stand tables according to the table layout settings.

The Run growth model button is discussed in the next section. However, the growth models have not been fully calibrated for Uganda, and results from this are unlikely to be realistic until this process has been completed.

The Use as defaults button will close the form, but will save all the choices of design, table layout, database file, output file, and stratum selection options as defaults, so they will appear next time the form is opened.

The Cancel button will close the form without saving changes or selections.

### **Growth modelling facilities in EiPac**

EiPac includes a simple cohort model that can be applied to estimate sustainable yields from natural forests in Uganda. Providing this facility did not form part of the consultant's TORs, but it was a part of the GEMFORM package that was converted to EiPac, and remains intact for use when needed.

To be useable, it requires calibration. This involves a number of fairly simple steps. First of all, species need to be grouped by their likely growth characteristics, and their growth rates estimated. The procedures involved were briefly discussed at the training workshop held in Masindi on 10-12th September on EI and ISSMI. The typical mature sizes and ecologies of common species need to be assessed, and increments can then be estimated from the MYRLIN chart shown in Figure 20. The detailed procedures and technical background are described at [www.myrlin.org](http://www.myrlin.org) and in Alder *et al* (2002).

The various linked databases and tables then need to be updated to reflect the estimates. In the species list in the master EI database and in ISSMI is a field called *Model* which is reserved for the model code for each species. At the moment this field contains arbitrary entries that were used to test the functioning of the EiPac growth modelling module. These need to be edited to correct values.

The model codes link to a table of typical sizes, increment and mortality estimates, which at the moment are contained in the spreadsheet called *Uganda provisional growth models*, which will be found at <\\SERVER\D\BIOMETRICS\EIPAC>. However, the values in this table are not necessarily correct, as it has been used purely for testing purposes.

The growth model in EiPac is designed to provide useful information in terms of sustainable yields or annual allowable cuts, in terms of volumes and trees/ha, given different felling diameter limits and felling cycles. This information will considerably extend the usefulness of the EI for planning purposes.



## ISSMI developments

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### Modifications to ISSMI

The ISSMI software has now reached a relatively stable degree of maturity. However, there were several operational issues that required the consultant's assistance during this visit. These were as follows:

- ❑ The Silviculture screen of ISSMI was amended to remove the minimum number of harvestable trees to enter a block. The parameter was confusing, and given other protection and selection criteria, did not add anything useful. The selection process was tested thoroughly with various options during this process, and appears to work robustly.
- ❑ A new report was added to facilitate block selection. This is applied after the tree selection process has been done for a compartment, and lists harvestable volumes, numbers of harvest, seed and reserve trees by blocks, ordered with the blocks with highest volume first.
- ❑ The location selection dialogs were modified for consistency so that all reports now allow polyblock selection. Formerly, several reports could only select the data to be output to the compartment level, resulting in masses of unwanted output. Now specific blocks within a compartment can be selected to list.
- ❑ The Excel-based tree mapper was amended to eliminate a bug that had arisen after conversion to Excel 2000. This was because of differences in the default data access library (ADO on Excel 2000, DAO in Excel 97). Version numbering was also added on the status bar to avoid ambiguities over which version was in use. Formatting of tree lists on blocks was improved. New routines were written to replace the Excel 97 QueryTables object, which no longer functions in Excel 2000<sup>11</sup>.
- ❑ The Visual Basic QuickMapper was amended to improve error handling when empty block coordinates or block size were found. The installation kit was amended for compatibility with Windows 2000. ActiveX objects used by the QuickMapper are now loaded into the application directory instead of the Windows system directory.
- ❑ The ISSMI database (called *ISSMI data.mdb*) was converted to Access 2000 and moved from the older ISSMI computer onto the server. The converted database is called *ISSMI data2.mdb*.

These changes were thoroughly tested on all the computers. A test was also made on entering ISSMI data to the central database simultaneously at two workstations without any problems (the same test was also successful with EiSys).

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<sup>11</sup> Discovering and resolving this completely opaque and probably unintended (by Microsoft) difference between Excel 97 and Excel 2000 took the consultant the better part of a day!

## **Tree selection and other practical issues**

During field visits to Mabira on 5th September and Budongo on 11th September, there was considerable discussion about practical aspects of tree selections on the ground. The following suggestions and issues arose:

- ❑ *Validity and currency of tree maps and lists.* It was evident that rangers and foresters attempting to apply ISSMI on the ground were using maps which were purely the consultant's trial efforts to test software, and did not apply any sensible selection criteria. This clearly led to a poor perception of the practicability of ISSMI's tree selections. It does not appear that, apart from the consultant's efforts, the tree selection process has been independently applied or tested using thoughtfully determined criteria. There is also clearly a need for the maps to show in summary form the selection criteria applied and to be date stamped by the computer.
- ❑ *Accessibility of ISSMI outputs to foresters.* It appeared doubtful that rangers and foresters could easily or on demand obtain block maps and lists for specific areas covered by ISSMI, or were even fully aware of their availability. As will be discussed below, their needs to be a coherent and well-organised management process if ISSMI is to be effective on the ground.
- ❑ *Gaps and the selection of trees.* At the moment, ISSMI does not take account of gaps when making tree selections. Rather, it seeks to avoid over-concentrated felling by applying a minimum distance criteria between trees to be harvested. It was apparent on the ground that selected trees were often at the edge of large gaps and were not good choices. The spatial analysis could be improved quite easily to try and restrict the occurrence or extension of large gaps.
- ❑ *Use of coded notes in selection.* The quality coding on a 1-5 scale should be supplemented by using the coded note information when making selections. This would be especially helpful for the many trees of quality class 3 - notes often indicate the presence of major problems such as strangler figs or decay which would prevent the use of such trees in practice.
- ❑ *Discretion in modifying selections.* The forester on the ground needs to have discretion in changing a selection. Even with perfect logic, perfect selections will not be made in practice in every case, because the spatial error in stock survey, which is of the order of  $\pm 10$  m, means that gaps and position relative to stream buffers or other sensitive sites will never be perfectly delineated. However, where changes are made the block map should provide a feedback mechanism in the form of a *Notes* section which can be properly filed for reference and checking at a later stage.
- ❑ *Issues regarding species group.* The present species grouping system is not very practical. It implies a fixed list for all forest reserves, that involves several steps to change. There is a need for a system that is more simple to apply at the compartment level, so that it can be used after discussions with pitsawyers and other marketers of timber to establish a local and current list of realistically commercial species. For ease of use this should be integrated with the *Silviculture* form, where selections are made.
- ❑ *Feedback regarding stumps.* There needs to be a mechanism and form (preferably integrated with the block map) to allow stump checks to be fed back into ISSMI.
- ❑ *Durability of paint marks.* The areas inspected were 2-3 years old, and some tree numbers are becoming difficult to read. ISSMI tree numbers should remain legible for up to 5

years if the system is to be effective for control at present rates of harvesting (which are very low). This requires attention to detail. Painters should be properly trained and equipped to clean and maintain brushes. Good quality paint should be provided. Monitoring is required to ensure that paint is not thinned down before use.

It appeared to the consultant that, although there are practical issues with regard to block maps and tree selection that occur at the software level, these should not prevent the use of ISSMI on the ground as a control and management system for harvesting. Some 3,500 ha of compartments have now been partially or completely covered since 1999, including the following compartments:

Budongo	B5, N2, N8, N13, W26,W37, W38
Bugoma	1, 8
Busowe	1
Kalinzu	34
Kasyoha-Kitomi	6
Lwamunda	1
Mabira	189, 192
Mwola	2
Towa	1, 1a

In each of these areas there is detailed information on tree location, species, diameter, stem quality, and coded notes over all or most of the compartment. The stem quality is not completely reliable for the earlier surveys and should be somewhat discounted, but the data is quite adequate to undertake good pilot projects for the detailed control and management of pitting and silviculture at the block level.

#### **Bottlenecks to more effective use of ISSMI**

The consultant considers that the following points represent the main current bottlenecks to the fuller application of ISSMI on the ground:

- *Management organisation.* ISSMI needs to be applied as part of a concerted and consistent effort to manage compartments for harvesting. It should be set in the context of a forest management plan (this is discussed more in the next section). The planning of harvesting through ISSMI needs to consider appropriate species for harvesting, apply the selection process, determine which blocks should be felled, allocate blocks to sawmillers, and perform control on the ground, in a consistent manner. During this process, the TSS needs to be fully engaged to produce any required maps in a timely and efficient manner.
- *Software inefficiencies.* The software can be improved in terms of ease and quality of mapping, by replacing the present block mapping and quick mapping<sup>12</sup> applications by a program based on the ESRI MapObjects library. This would provide much faster and better facilities. In this scheme, the consultant would look at the possibility of making selections (the present *Silviculture* screen) interactively on the maps, and providing thematic displays at the block level to ease the process of block allocation.

These are not large issues. Clearly, any method or form of effective forest management on the ground requires a similar degree of management organisation. The improvements to the mapping and selection side of ISSMI require only some 5-6 days work by the consultant.

<sup>12</sup> The QuickMap utility was written in 1999, before the consultant acquired MapObjects 2.1, and is slow and inefficient compared with ESRI's software. The EiMap utility is an example of a MapObjects-based package. It provides excellent mapping and I/O facilities but required only about 3 days programming from start to finish.

There is probably a training issue for senior forest managers, to enable them to access and use ISSMI outputs directly over the LAN without reference to the TSS. Now that the Nkawa site is introducing a more extensive LAN, forest managers should be able to use ISSMI directly. A short training course (1-2 days with hands-on computer exercises over the LAN) would facilitate this.

# Tree volume studies

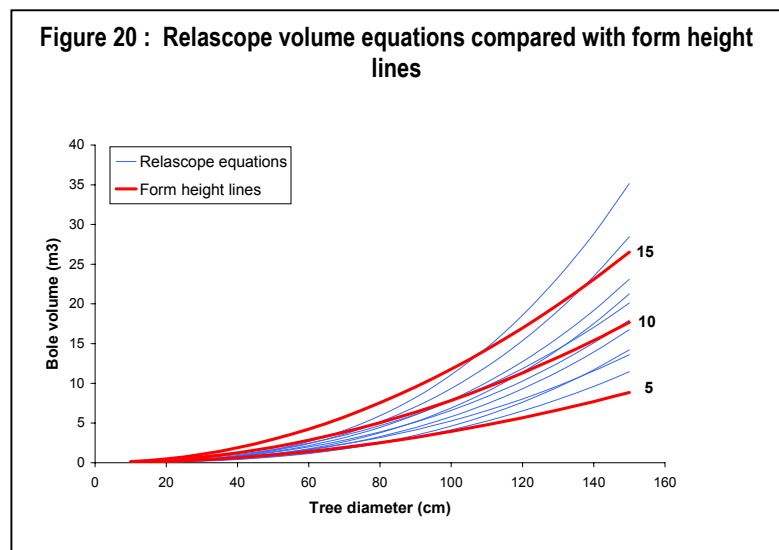
## Current status

There is a great need for reliable natural forest tree volume tables. Existing volume equations used for ISSMI and EI volume calculations are based on the FRP Relascope volume studies. As described in the authors February 1999 report (Alder, 1999a), the very large number of tree measurements made by Relascope during the FRP (37,135 sample trees retained after cleaning for errors) were grouped into 11 volume tariff groups. The equation used was:

$$\begin{aligned} & V/G = \alpha + \beta \cdot D && \text{(form used to fit regression)} \\ \text{or} & V = k \cdot D^2(\alpha + \beta \cdot D) && \text{(form for volume calculation)} \end{aligned}$$

where V is volume in m<sup>3</sup>, G is tree basal area in m<sup>2</sup>, D is tree diameter in cm, and  $\alpha$  and  $\beta$  are coefficients, and k is the constant 0.00007854 (or  $\pi/40,000$ ). In the EI and ISSMI databases, the table VolEqn (see Figure 3) gives the coefficients for each tariff group. In the Species list table, the field VolEqn gives the Tariff code for each species.

When actual volume lines for the tariff groups are compared with volume lines for constant form heights (the ratio V/G) as shown in Figure 20, about half of the volume equations are below form heights of 10. This is rather atypical for natural forest, where the author would expect most lines to be above 10, with a median around 12-15 (see eg. Fig 5 in Alder, 1999d, comparing volume equations form various countries in terms of form height). Returns from volumes harvested also suggests that the existing volume equations are biased on the low side.



It is for this reason that the consultant stressed the importance of measuring a destructive sample of up to 2000 felled trees. Detailed sampling forms, instructions, and procedures were prepared in the June 1999 report (Alder, 1999c), and a field training exercise was carried out in Kalinzu FR.

In the consultant's December 2000 report (Alder, 2000) it was noted that very little data had actually been collected, and it was recommended that this exercise be given much higher priority.

At the present time, there are now 92 trees in the felled sample database, distributed by species as listed:

<i>Maesopsis eminii</i>	62
<i>Cordia milenii</i>	16
<i>Parinari excelsa</i>	10
<i>Alstonia boonei</i>	4
<i>Cynometra alexandrii</i>	1
<i>Newtonia buchananii</i>	1
<u>Others</u>	<u>3</u>
Total	97

This is already potentially useful in providing a basis for direct comparison with the existing lines. However, many more sample trees need to be collected.

### Future work

It is highly desirable to re-activate this work and bring it to a conclusion. There are three coordinated aspects that need to be considered:

- *The numbers and sizes to be sampled from each species.* The consultant had expected from mid 1999 to monitor progress in collecting data and provide updated guidelines with regard to species and size classes to be sampled. There is now a wealth of data from EI and ISSMI sampling on species frequencies and sizes, and it should be possible with about 1 days work to recommend a specific sample in terms of numbers and size classes. This is important because simple felling trees at random will tend to over-sample smaller sizes and more common species. Suggested sampling locations can be identified from existing ISSMI and EI data.
- *Formation of a field team equipped and budgeted to complete the work.* This needs to comprise a vehicle, chainsaw and accessories, and five-man measurement team, including one professional officer and one chainsaw operator. Felling and scaling 5 trees per day over a 6-month period, it should be possible to increase the sample to about 700 trees.
- *Revisions to the data entry software.* This software currently only provides for data entry. Checking and tree net and gross volume calculation need to be added. A simple Excel spreadsheet is needed to show how the volume equations can be elaborated. This should be done fairly soon, as it not a good idea to build up large masses of unchecked data.

This exercise should aim to achieve completion by the end of 2003, with final analysis and published report on revised net (defect free) and gross bole volume equations by species and revised tariff groups before the end of that year.

## Permanent sample plots in natural forest

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### Database modifications

The database used to enter and store the PSP data is called EPHRU, an acronym for Editing of PSPs for the High forest Region of Uganda. This was designed for the project by the consultant in June 1999 (Alder, 1999c).

During the present visit, three minor modifications were made to improve ease of operation and maintenance:

- ❑ Screen colours and layout were revised for greater simplicity and clarity.
- ❑ The database was split into an Access application, containing the data entry form and species lookup macros, and a database, containing only the PSP data. This split database model works better on networks and is much easier to maintain and upgrade, as only the Access application needs to be modified, without disturbing the data. The application is called EPHRU2.MDB, and the database PSP DATA.MDB.
- ❑ The application and database were converted to Access 2000.

EPHRU2 was tested on Windows 2000 and Windows 98 workstations, with the database on the central server. The method of updating links when the application is installed on a new machine was demonstrated to TSS staff. This involves :

- (i) Opening EPHRU2 whilst bypassing the start-up macros. This is done with all MS Office applications (Word, Excel, Access) by holding the shift key down whilst double-clicking on the file from the Windows Explorer to open it.
- (ii) Deleting all the linked tables that are visible in the database window (this only deletes the links, not the original data).
- (iii) Re-creating the links using the menu selection *File ▶ Get external data ▶ Link tables*. The Access database PSP DATA on the server should be located, and all database tables in it selected for the links.
- (iv) Close EPHRU2 and then re-start it normally.

### Current status

records are empty). The table opposite shows the distribution by reserves and years of establishment. Given that it is unwise during this early phase of the PSP programme to allow too long to elapse between re-measurements, there are now 22 plots from 1999 that should be re-measured before the end of 2003, 7 plots during 2004, 11 plots in 2005, and 10 plots in 2006.

This needs to be programmed in to the project operations over the next four years.

It is also critical that data in the system is carefully checked manually against data entry forms, and this situation of the 'lost plot' data resolved.

There are 50 PSPs currently stored in the PSP database, with possibly another 2 present as 'lost plots' (there is tree data for two further plots, but the plot header

Forest	Established	Plots
Budongo	1999	22
	2000	1
	2002	1
Bugoma	2000	6
Kalinzu	2001	4
Mabira	2001	7
	2002	9
<i>(trees, but plot header empty)</i>		2
<b>Total</b>		52

### PSP re-measurement issues

There are several important things that need to be done just before, and over-lapping with, the first re-measurements of the PSPs. These are as follows:

- ❑ *Design of re-measurement forms.* These should be printed from the computer, listing tree numbers, species and approximate diameter (to nearest cm), but with space for recruit trees at the bottom.
- ❑ *Software to check re-measurements* by cross linking with first measurement, both on entry and as a batch report of errors. (On-entry checking will trap typing errors, but has to be by-passable by the operator if there are inconsistencies on the field forms that need to be resolved later. Batch reports list out all errors on a plot for detailed reconciliation).
- ❑ *Field training in re-measurement.* This needs to be coordinated with the testing of the re-measurement form, in case there are issues arising in its use. There are also practical issues about tree numbers for recruits, refreshing paint marks, assessment of mortality-related factors on the ground, etc.

Once data for a significant number of plots have been entered (preferably all 22 due for measurement in 2003), then the preliminary analysis should be undertaken. This involves four aspects:

- ❑ Review of data cleaning undertaken so far, and final cleaning of the data. This has to be rigorous, due to the sensitivity of mortality and recruitment estimates to small errors.
- ❑ Development of software to calculate increment, mortality and recruitment rates.
- ❑ Updating of provisional growth models based on the first PSP results.
- ❑ Training in the analysis and use of the PSP data.

Thereafter, further PSP measurement and analysis should run smoothly, without involving the consultant again.



## Synthesis and conclusions

### Management role of biometric inputs

It is useful to recall that the four main topics that the consultant has been dealing with in the current and preceding consultancy missions should all have important relevance to sustainable management of natural forest. These relative roles are described in the table below.

Activity	Application
EI	<i>Exploratory inventory defines the available species in a forest, giving indications of their stem quality and size classes, the total quantities available, and distribution at the compartment level. This can be used to decide at a reserve level which species should be promoted and which protected, appropriate diameter class limits, and to sequence the compartments into felling series. Approximate AAC for the forest can be estimated (using the growth model option of EiPac), giving an idea of what level of harvesting may be permitted and encouraged. This can be analysed at the species level for those species under pressure. EI should be used to produce a concise management plan for the reserve, and especially to sequence compartments into 5-year felling coupes. However, EI does not give sufficient information for planning at or below the compartment level.</i>
ISSMI	<i>The integrated stock survey and management inventory is primarily a planning, control and monitoring tool at the compartment level. When a compartment has been assigned for felling within a 5-year coupe, then the ISSMI survey should be performed just before the start of that period, and about ¼ of the best 4-ha blocks assigned for felling. This is premised on the 15-year cycle discussed in the next section. These blocks should be organised into polyblocks, and made available to sawmillers on a license basis. The license should include a specified list of trees permitted to be felled. Rangers should verify that sawmillers are aware of the boundaries of polyblocks and the tree numbering system. When a block is completed, a return should be made of trees actually felled. This should be randomly checked by stump surveys. The block level information (from management plots) can also be used to indicate areas for remedial treatment. Districts should have a large format compartment map with blocks and trees plotted on the wall, and use it to plot and control operations over the 5-year period.</i>
Volumes	<i>EI and ISSMI are both based on volume calculation. The accuracy of this depends on having unbiased volume equations, which at the moment do not exist in Uganda. It is critical to the accuracy of the planning process that the volume sampling work is completed as soon as possible.</i>
PSPs	<i>Estimates of allowable cut and sustainable yield, and assessment of forest response to different diameter limits, felling cycles, and silvicultural treatments depends critically on growth, mortality and recruitment rates. PSPs provide the empirical basis for these growth estimates, and are therefore a key requirement for sustainable forest management.</i>

### EI and ISSMI in the planning process

The consultant has on several occasions recommended that ISSMI be regarded as an operation to be applied cyclically, based on a 15-year cycle. It is also generally accepted that recommendations for a 60-year felling cycle are silviculturally sound. These two premises together imply that during any one period of operations, no more than ¼ of the ISSMI blocks on a compartment should be harvested.

Practically speaking, given the low rates of harvesting and the large size of most compartments, it is desirable to allocate compartments for felling as 5-year periodic blocks.

This leads to the following procedures that should be applied during the planning process:

- ❑ A concise management plan should be drawn up for a reserve, using the best available information, that covers a nominal 15-year period. This plan should include a zone map, and estimates of stocks and yields for significant timber species from each compartment. It should include estimates of allowable cut and wood flows from the forest over the 15-year period, by major species. It should sequence compartments for felling by 5-year periodic blocks, whilst also closing to felling any compartments which are in too damaged a condition to be felled in any degree during the planning period.

Sequencing 5-year periodic blocks within a 15-year cycle implies four groups of compartments: The immediate 5-year period, 6-10 years, 11-15 years, and those completely closed during the plan period because of degradation. (To justify maintenance within the production zone, these latter should receive some positive ameliorative treatment).

- ❑ ISSMI should be applied in the compartments sequenced for the current 5-year period. The tree and block selection process would be carried out using locally devised criteria, especially with respect to species, and in consultation with DFOs and sawmillers representatives. It is important for ultimate management control that the latter should have some feeling of ownership with regard to the decision-making process.
- ❑ Large scale wall-maps (A1 size) should be prepared for these compartments for use in District Offices as a control device. This will also ensure the transparency of management that will be required for monitoring and maintaining certification.
- ❑ A schedule should be prepared of  $\frac{1}{4}$  of the blocks in the compartment which are richest in millable timber. Depending on the type of usage (pitsawing, portable sawmills, mechanised logging), blocks may be grouped into smaller or larger polyblocks, and licensed individually or in groups. Compromises may be made in assigning the 'best' blocks into the top  $\frac{1}{4}$  in order to give coherent groups if mechanised felling is adopted, but the maximum total area felled in the compartment should not exceed  $\frac{1}{4}$  of total area, in order to respect a 60-year felling cycle. The licensing process will be partially on demand, and partially driven by a pro-active encouragement of new industries<sup>13</sup>, but will be stretched over a 5-year period for the whole periodic block (which may be several compartments).
- ❑ As operations proceed, rangers will monitor operations on the ground using maps of blocks and schedules of trees to be felled. They would be authorised to change selected trees on a discretionary basis, but obliged to file a return of any changes made. These would be entered in the ISSMI database as a monitoring device. ISSMI survey teams would select and randomly stump survey some blocks to ensure compliance with tree lists and returns of field alterations.

These are the core activities of ISSMI and EI within a planning and management context. It is envisaged that at the second cycle, EI would not be required as ISSMI itself provides a detailed Continuous Forest Inventory (CFI) system, with considerable data for future planning. EI might be used to monitor compartments outside the ISSMI process (*eg.* those considered too damaged for current operation).

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<sup>13</sup> The consultant believes that there must be an evolution in Uganda towards the re-introduction of mechanised sawmilling using portable mills or tractor extraction. Pitsawing is economic only on the basis of the very low real wages and royalty fees actually paid.

ISSMI may also be used to identify polyblocks in which enrichment or ameliorative planting should be applied. These will be in two categories:

- ❑ Those which are felled and then artificially restocked, because the management inventory plots and ground inspection indicate inadequate regeneration.
- ❑ Those in which relict removal is practiced, followed by re-stocking. This may involve managed charcoal burning to add value to the improvement felling process.

### **The cost of selection forest management**

Any system of polycyclic selection management in the tropics requires stock survey, tree selection, numbering of stock trees, and some method of monitoring to control actual fellings. These systems have for example been applied in Ghana for many years, and have been re-introduced (after lapses following the end of the colonial period) in Belize, and Guyana. In Costa Rica and Brazil DFID supports projects of this type, and in Ecuador they have been supported by ITTO. No doubt similar methods are applied in other countries. Some form of effective stock survey is regarded as the *sine qua non* for forest certification schemes in the tropics.

ISSMI is directly comparable. Its main advantage over some other methodological variants is that it has from the beginning been planned around modern capabilities for data processing, and is therefore more integrated and effective on the ground. It also incorporates management inventory plots, reducing costs through a combined operation, and providing more appropriate information for planning purposes (simple stock surveys are quite deficient in this respect, because smaller trees are not sampled).

Typical stock survey and harvest planning costs are around €20-€35 per ha (Reid & Rice, 1997). ISSMI costs are around Ushs. 30,000/-, or €16 per ha<sup>14</sup>. However, the ISSMI figures are for direct costs only, and do not include supervisory overheads or vehicle depreciation, or the cost of its use for monitoring. Let us assume therefore that the full cost may be around €25 per ha including all associated activities and overheads.

Assuming ISSMI is applied as discussed in the preceding section, on a 15-year cycle, then annual per ha costs will be about €25/15 or €1.67 per ha.

The total production zone that may be appropriate for management under ISSMI is not more than 140,000 ha (Osmaston, 2000, p 9). This gives an upper limit to the annual costs of ISSMI – with all the associated activities of monitoring, protection, control, harvest allocation, etc. – of €234,000. (Osmaston estimates around €350,000 including a number of other assumptions).

Sustainable yields per ha are likely to be of the order of 0.5 m<sup>3</sup>/ha/yr. If revenues of around €10 per m<sup>3</sup> (18,000/-) can be collected, then average income would be around €5 per ha, giving a revenue:cost ratio of about 3:1, and a total income over the production area of €700,000 annually.

The cost estimates do not include any component for ameliorative treatments or re-stocking, but neither does the revenue estimate include the benefits that might result from such treatments.

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<sup>14</sup> For the purposes of the approximate estimates given here, the Euro (€) and US\$ can be regarded as equivalent.

Both the costs and revenues are likely to appear small when set against the possibilities for the plantation sector, but do suggest that with prudent management, the high forest sector managed under ISSMI should give a net positive cashflow, of the order of €500,000 annually.

### **Progress since previous visits**

There have been many improvements and developments since the consultant's first visit in late 1998, and it is useful to summarise these, to emphasise that much positive progress has been made by the Forestry Department relative to forest biometrics, data

processing, and its application.

- ❑ The TSS has developed a good degree of self-engendered efficiency in the use of ArcView and Access, in routine data processing, and in the production of key information for the reports and studies. This has included the installation of a LAN within the TSS, and migration of various database projects to Office 2000 and Windows 2000.
- ❑ The field operations for ISSMI have achieved a high degree of efficiency, with a fairly large cadre of personnel well-trained in the operation. ISSMI has been tested as a method of field control, although not thoroughly or routinely applied.
- ❑ The exploratory inventory has been adopted and applied in the field with only minimal inputs from the consultant.
- ❑ The new-series PSPs have been established with minimal technical assistance inputs.

It is clear in talking to foresters and rangers in Uganda that there is a high general level of competence and insight with regard to issues of practical forest management. The consultant is in little doubt that ISSMI as a management technique is a completely practical system in terms of current human resources.

### **Recommended further work**

Various issues and topics requiring further specialist inputs have been noted through the body of this report. These are summarised below:

- ❑ ISSMI requires about 1 month additional work to improve the ease of use of the mapping component, to improve the tree selection algorithm relative to maximum permitted gap size and provide more balanced species selection for seed trees, and to provide an integrated manual. It would also be a good idea with the LAN in place at Nakawa to have hands-on computer training for senior managers in using ISSMI for detailed planning, and to associate this work with the specific and serious application of ISSMI to compartment management in localities that have already been surveyed.
- ❑ EI: The EiPac growth model should be fully calibrated for Uganda so that it can be used for estimating allowable cuts. It should be slightly modified to allow for multiple diameter limits and outputs by species, as this is relevant to the management system in Uganda, and full training in its use provided to senior managers wishing to apply it for planning purposes. This is about 1 month's work.
- ❑ PSPs: There is a need for two periods of work on the PSP software. The first should be done just before re-measurement of PSPs is scheduled to begin, which itself should be during 2003. This involves preparation of re-measurement forms, and data entry and checking software for re-measurement. This would be coordinated with field training in re-measurement, and testing of the data entry and checking software, and would include documentation covering the procedures. About 1 month is required.

The second period of PSP work should be about 6 months or a year later, when re-measurements on the first group of 22 plots have been completed and entered in the computer, checked and cleaned using the procedures described above. At this time, the procedures for calculating increment, mortality and recruitment should be added, and training provided in the application of these results to updating preliminary growth projections. Assistance and guidance should be given to the writing of a technical paper on these results. About 1 month is required for this.

- Volume studies. It has been recommended that the acquisition of tree measurements be prioritised during 2003. At some stage (it could be done immediately, using available data, but would be better when 200-300 trees have been felled and measured) there should be the finalisation of routines within the tree volume database to calculate volumes, and preparation of a demonstration Excel file for their analysis, showing how to fit and test regressions for significant differences, and the relative strengths and weaknesses of different volume equations. About 1 month is required for this work, which it is expected may involve a good deal of time cleaning up the data by reference to original field forms, and would involve training in the analysis.

## Conclusion

Field and data processing procedures for ISSMI and EI have now reached a good stage of efficiency on the ground and in the office. Large amounts of data have been collected. The primary need over the next 2-3 years is to demonstrate that these methods can be applied effectively to forest planning and control on the ground.

The new phase of permanent sample plot work begun in Uganda from 1998 is maturing, with the first re-measurements falling due in 2003. It is important to note that this is a critical period, and further work on software and field procedures needs to be done in a coordinated way if the re-measurements (and the plots themselves) are to be useful.

The volume studies started in 1999 have become stalled due to low prioritisation, but remain on the critical path for effective forest management. Existing equations are certainly biased too low, and it is important for all economic and planning calculations to have better estimation tools for volumes.

There has been very considerable progress since the consultant's first involvement in the project in 1998, and this is clearly part of a continuing and ongoing process. The consultant is confident that the final links in the chain, of implementing the various field and office procedures discussed in this report, in terms of strong management and control of the natural forest reserves, will be accomplished over the next 3-4 years on the basis of the momentum established so far.

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