

/nfi/tekst/system2.txt

THE NATIONAL FOREST INVENTORY OF NAMIBIA

- SYSTEM DESCRIPTION

National Forest Inventory Project of Namibia
Directorate of Forestry, Ministry of Environment and Tourism
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PART II: DESCRIPTION OF DATA PROCESSING SYSTEM

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PART I

GENERAL DESCRIPTION OF THE SYSTEM

- 1. DEFINITIONS**
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1. DEFINITIONS

Following terminology are used frequently in this text. The definitions are valid only for the West Tsumkwe inventory system.

Sample plot = Sample plot consists of 3 concentric circles. The radii of the circles are 10, 20 and 30 m. Trees with DBH less than 20 cm are measured within the smallest circle, trees with $20 < \text{DBH} < 45$ cm are measured in the 20 m circle, and trees with $\text{DBH} > 45$ cm are measured in the largest circle (see Figure 1).

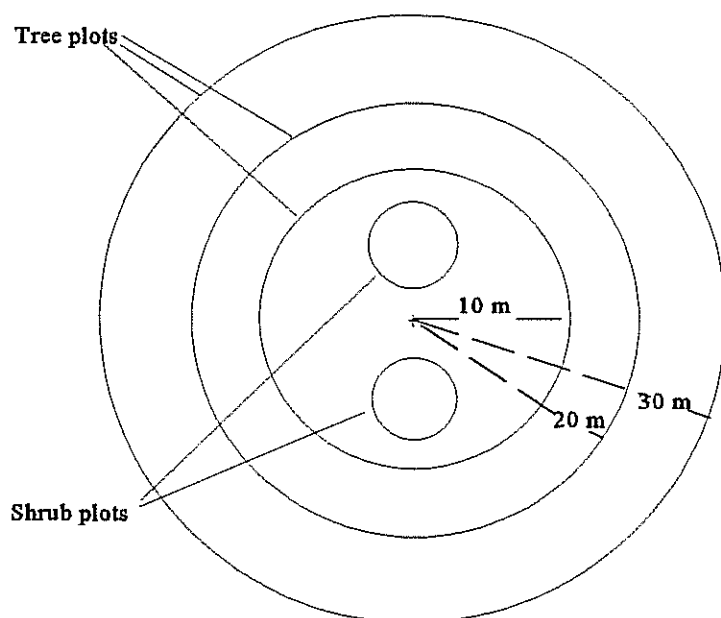


Figure 1. The plot design.

Cluster = Group of sample plots, in West Tsumkwe there are 3 plots in a cluster: plot no 2 is 100 m North from the plot no 1, and plot no 3 is 100 m North from plot no 2. All the plots are in the same vegetation unit.

Vegetation unit = Area that is homogeneous in respect to soil type, main species, species composition, density of tree layer and mean height of dominant trees

Sampling stratum = The inventory area is divided into different stratum using available information. In West Tsumkwe the area is divided in strata Forest and Other land with the help of vegetation maps. Sampling is done independently for these two strata and the sampling is more intensive for the Forest stratum.

Calculation stratum = any artificial class of trees or sub-area of the inventory area, e.g. vegetation type or Pterocarpus dominated woodlands.

2. SAMPLING METHODS

The National Forest Inventory System (NFIS) is based stratified cluster sampling. In the first version of the system (Western Tsumkwe, possible concession area) it is further assumed that there are 1-3 plots in each cluster and that the plots of a cluster are within same vegetation unit. The sampling design is described more detailed in Part III: Theoretical and Mathematical Background and Part V: Appendices.

3. MEASUREMENTS

For each cluster several variables describing the site and vegetation of the surrounding vegetation unit are registered. For each plot in a cluster some variables describing the immediate vicinity of the plot are registered. For each tree in a plot several variables describing the condition and size of the tree are registered. The trees in the first plot of each cluster are measured more detailed than the trees in other clusters. The shrub, grass and herb layers are measured only at the first plot of each cluster. The measurements are described more detailed in the Field Instructions (Part V).

Following field sheets are used for data collection:

1. stand description sheet,
2. enumeration sheet,
3. sample tree sheet,
4. shrub, regeneration, grass and herb sheet
5. plant specimen collection sheet
6. fixed point photographing sheet.

4. DATA PROCESSING

In the field, data are collected on data sheets listed above. At present, only sheet 1 - 4 are saved on computer and used for further processing. The main features of the data processing system as a flow chart are in Figure 2.

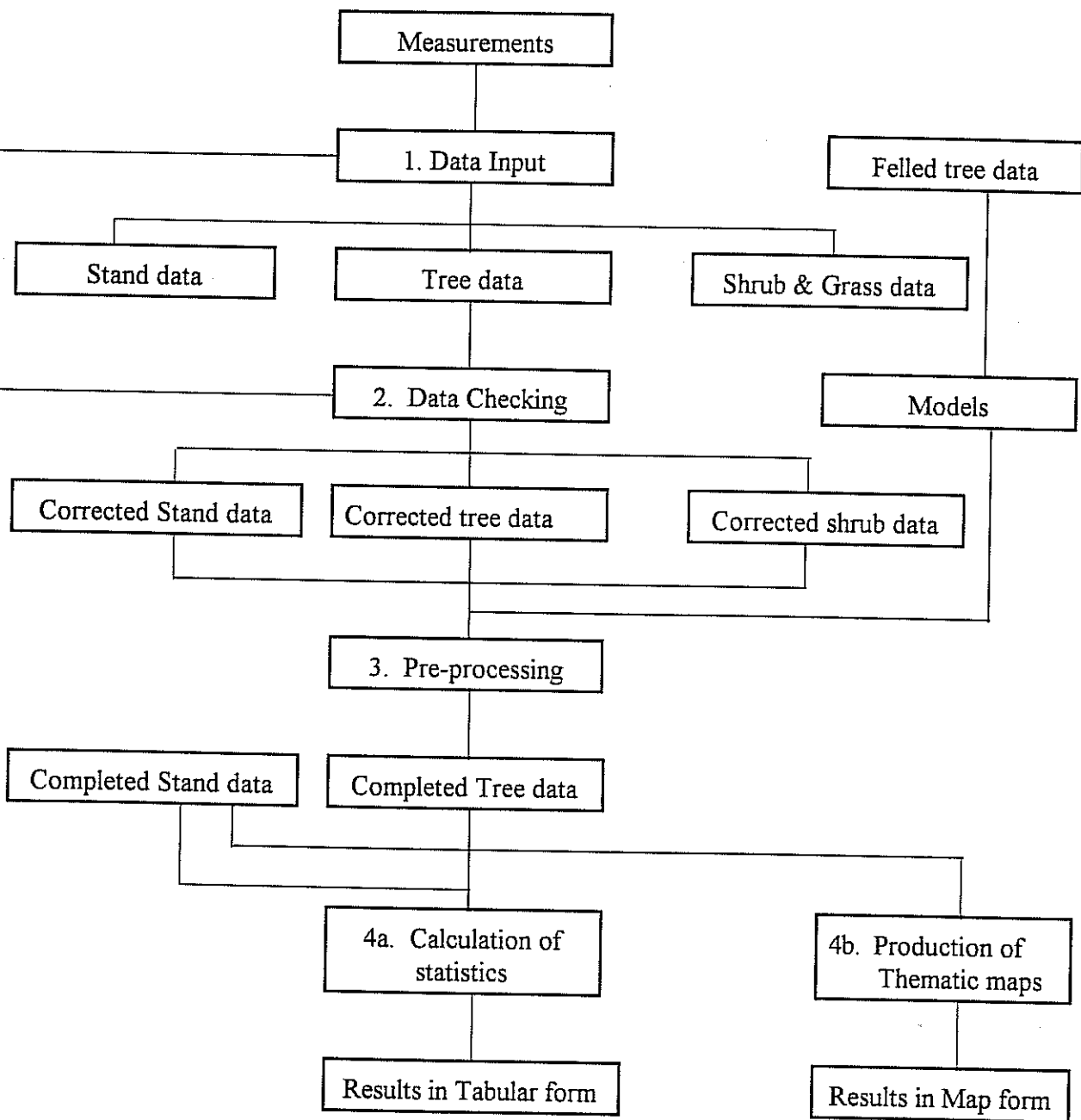


Figure 2. The data processing system as a flow chart.

PART II

DESCRIPTION OF THE DATA PROCESSING SYSTEM

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1. PROGRAMMING ENVIRONMENT AND TOOLS

All the data processing programs are in IBM compatible PC environment, operating system DOS 6.x and Windows 3.x. Data input, checking and pre processing are done with specific programs written in Fortran 77 language (MS-Fortran 5.0 have been used for compiling the programs). Tabulation of statistics is done with MS ACCESS x.x software. The map production is done with Idrisi for Windows software.

2. INPUT AND CHECKING OF THE DATA

2.1 Recommended organisation of data, programs etc

Following organisation of data files, programs, text files, data base files etc. is recommended.

Root

NFI

PROGRAMS	contains the source files of all the Fortran programs
WESBUS	contains the saved inventory data for West Tsumkwe and files necessary for running the entering, checking and pre-processing programs
DBAS	data and data base files for West Tsumkwe
MAPS	digitized maps for West Tsumkwe
REPORTS	inventory reports and related Excel files
TEMP	data entering and checking
HERERO	
DBAS	
MAPS	
REPORTS	
TEMP	
CAPRIVI	
DBAS	
MAPS	
REPORTS	
TEMP	
FELLED	contains the felled tree data
TEKSTIT	all the text files, including field instructions, this manual, etc.
HALLINTO	files related to the administration of the project
TILIT	files related to the book keeping and lists of equipment

2.2. Data entry

A program named CODE_1.EXE (source file CODE_1.FOR) is used for data entry. The number 1 in the name of the program indicates the version number. Number 1 is used for data from West Tsumkwe. If there are changes in the data when moving to other inventory areas, the testing program must be modified accordingly and new version number given to separate it from the first version.

The data entry is started by giving command:

CODE_1 <enter>

The display shows a menu with which you can select sheet that you want to entry (stand description, enumeration, sample tree or shrub sheet). After selecting the appropriate sheet, you can enter the data according to the instructions given by the program. For all sheets, you are supposed to first enter the header data. Each variable in the header are entered separately. The display is showing with "*" characters the number of digits expected for each variable.

After entering all the header data, the actual stand, enumeration, sample tree or shrub data can be entered. The whole record (=data line) are entered at one line. The display shows with the help of letters the number of digits for each variable. End of data is informed by typing END instead of data record. After this the main menu is displayed and you can select what sheet you want to enter next or quit the program

Note: if you make an error in entering a data row and you press enter, you can not any longer correct the error in this entering program. The best way is to write a remark on the sheet and correct the error by editing the data file in question.

2.3. Data files

2.3.1. File names

Each field sheet will be saved in one file. The CODE_1 program automatically gives names for the files. The naming of files is as follows.

Stand description data

The file name consists of two parts separated by decimal point. The first part is the cluster number of the first cluster in the entered sheet. The second part is always "STA". For example, if the number of the first cluster in the entered stand sheet is 25, the correspondig file will be named as: 025.STA (Note: 3 digits are always used for the cluster number)

This file contains stand description for all the clusters that were recorded on that sheet.

Enumeration data

There are usually 2 files for each measured cluster: one for plot number 2 and one for plot number 3. Only if the 3rd or 2nd plot have not been measured at all, the respective file does not exist. If all the 3 plots have been measured but some of them had no trees the corresponding file contains only header data (see Chapter 2.3.2). The file name consists of two parts separated by decimal point. The first part is the cluster number followed by plot number and the second part is always "ENU". For example, enumeration sheet measured at cluster 25 plot number 2 will be saved in file:

0252.ENU

and plot number 3 in file:

0253.ENU.

Sample tree data

The file name consists of two parts separated by decimal point. The first part is the cluster number

and the second part is always "SAM". For example, sample tree sheet measured at cluster 25 will be saved in file:

025.SAM

(Note: There is always one file for each measured cluster. If there were no trees at the sample plot, this file contains only the header data.)

Shrub etc. data

The file name consists of two parts separated by decimal point. The first part is the cluster number and the second part is always "SHR". For example, shrubs etc. sheet measured at cluster 25 will be saved in file:

025.SHR

(Note: There is always one file for each measured cluster. If there were no shrub at the sample plot, this file contains only the header data.)

2.3.2. File formats

The file format is the same as the format of corresponding data sheet, with few exceptions.

Stand description data files

The stand description files contain one record (data row) for each cluster. The first 18 characters are the header data (from the top of the field form) and following 40 character contain the stand data. Variables and corresponding columns are:

Variable	Columns	Data type
Sheet no	1 - 2	Integer
District	3 - 4	Integer
Map sheet	5 - 10	Character
Date, dd, mm, yy	11 - 16	Integer
Team	17 - 18	Character
Cluster	19 - 21	Integer
Position accuracy	22 - 23	Integer
Land type	24 - 25	Integer
Land use	26	Integer
Meas. plots	27	Integer
Geology	28	Integer
Surface sealing	29	Integer
Soil texture	30	Integer
Mean height	31 - 33	Integer
Crown coverage	34 - 36	Integer
Accomplished meas.	37	Integer
Grazing	38	Integer
Damages I	39	Integer
Severity I	40	Integer
Damages II	41	Integer
Severity II	42	Integer
Damages III	43	Integer
Severity III	44	Integer
Ownership	45	Integer
Regeneration	46	Integer
Soil colour	47-58	Character

Example:

```

-----1-----2-----3-----4-----5-----
1234567890123456789012345678901234567890123456789012345678
02011919AD190496NO266241513909110 410011 312.5Y 7/4
02011919AD190496NO245221513909 80 840011 315YR 7/4
02011919AD190496NO244211513909 43 800011 315YR 7/6

```

Enumeration data files

(In the Hereroland data there are no enumeration plots)

Usually, there are 2 files for each cluster (one for each enumeration plot). Only in cases when the plot number 2 or 3 has not been measured at all the corresponding file is missing. The enumeration data file begins with 1 record containing the header data (starting from cluster number). The following records are the tree records: one record per tree in a format exactly similar to the sheet. If there has been no trees at the plot the data file contains only header

record. Variables and corresponding columns are:

Header record

Variable	Columns	Data type
Cluster	1 - 3	Integer
Plot	4	Integer (2 or 3)
Deviation /	5	Character
Deviation	6 - 7	Integer (10 m)
Elevation	8 - 10	Integer (10 m)
Slope	11	Integer (Degree)
Aspect	12	Integer
Position	13	Integer
Distance from Roads	14	Integer
Dist. from settlement	15	Integer

Tree record

Variable	Columns	Data type
Tree number	1 - 2	Integer
Tree species	3 - 7	Character
Diameter	8 - 11	Integer (mm)
Status	12	Integer
Bearing	13 - 15	Integer (Degree/360)
Distance	16 - 19	Integer (cm)
Timber quality	20	Integer
Reason for low qual.	21	Integer
Crown class	22	Integer
Saw log length	23 - 25	Integer (dm)
Deformed base length	26 - 27	Integer (dm)

Example

```

-----1-----2-----
123456789012345678901234567
2442           0 45
01BURAF 2791194 880
02BURAF 2741215 540
03PTEAN 4121 26 7104 1 26
04PTEAN 588111815502 1 25

```

Sample tree data files

There is one file for each cluster. The sample tree data file begins with 1 record containing the header data (starting from cluster number) in the same way as enumeration data files. The following records are the tree records: one record per tree in a format exactly similar to the sheet. If no trees has been measured on the plot the corresponding file contains only header record. Variables and corresponding columns are:

Header record

See enumeration data files

Tree record

Variables **Tree number - Deformed base** (columns 1 - 27) see enumeration data files. Other variables:

Variable	Columns	Data type
Phenology	28 - 30	Character
Height	31 - 33	Integer (dm)
Leaning	34 - 36	Integer (dm)
Crown height	37 - 39	Integer (dm)
Canopy diameter I	40 - 42	Integer (dm)
Canopy diameter II	43 - 45	Integer (dm)
Damages	46	Integer
Severity	47	Integer

Example:

```

-----1-----2-----3-----4-----
1234567890123456789012345678901234567
2431      0      45
01TERSE  651282 830  1      X  38      12 36 34
02LONNE  22411741500 1      X  87      29 70 67
02LONNE  1951
03LONNE  29711761400 1      69      40 46 3314
03LONNE  2001

```

Shrub etc. data file

There is one file for each cluster. The shrub etc. tree data file begins with 1 record containing the header data (starting from cluster number) in the same way as enumeration data files. The following records are the tree records: one record per tree in a format exactly similar to the sheet. Variables and corresponding columns are:

Header record

Variable	Columns	Data type
Cluster	1 - 3	Integer
Plot	4	Integer (1)
Grass coverage S	5 - 6	Integer
Grass coverage N	7 - 8	Integer
Height class of grass	9	Integer
Herbs coverage S	10 - 11	Integer
Herbs coverage N	12 - 13	Integer
Height class of herbs	14	Integer

Shrub or seedling record

Variable	Column	Data type
Sub-plot code	1	Character (S or N)
Species	2 - 6	Character
No. in height class 1	7 - 9	Integer
No. in height class 2	10 - 12	Integer
...		
No. in height class 8	28 - 30	Integer
No. in crown class 1	31 - 33	Integer
No. in crown class 2	33 - 36	Integer
...		
No. in crown class 8	52 - 54	Integer

Example:

```

-----1-----2-----3-----4-----5-----
123456789012345678901234567890123456789012345678901234
243125223 0 0
SBAPMA          6 2          1 1 5 1
SGRERE          1 1 1          1 2          1
S?????         2          2
SBAUPE          2          1 1
NBOSAL          1          1
N?????         3 2          3 2
NBAPMA         2 7          2 5 1
NGRERE          2 1          2 1

```

2.4. Checking of data

Program named **TEST_n.EXE** (n stands for version number) has been compiled to check possible errors in the data. The program has been written with FORTRAN language (FORTRAN 77 compiled with Microsoft Fortran 5.0). The program works in IBM compatible PC's with DOS operating system. TEST_1.EXE 1 is used for data from Western Tsumkwe, TEST_2.EXE for East Tsumkwe and Omaheke data, and TEST_3.EXE has been designed for the data from Caprivi.

The TEST_n programs assume that names of the saved stand data files are listed in an ASCII-format file named *SAVED.LIS*. This file should contain one comment line and then in the following lines the names of the stand data files that should be checked, one file name per line. The program automatically looks also for the enumeration, sample tree and shrub data files for all the clusters that are described in the given stand data files (version TEST_2.EXE does not use enumeration files). The TEST_n.EXE programs use also file *CLUSTERS.LIS* that must contain the list of possibly existing clusters. The version TEST_3.EXE uses also file *TREE_SHR.LIS* containing species names (5 character codes). (Other wise TEST_3 is similar to TEST_1.FOR).

NOTE: The **TEST_n.EXE**, **SAVED.LIS**, **CLUSTERS.LIS** (and **TREE_SHR.LIS** for **TEST_3.EXE**) and all the data files to be checked must be in the same directory where the program is started.

The **TEST_n** programs write on the screen information on possible errors. The same information is written on file *ERRORS.LIS*.

NOTE: *ERRORS.LIS* file must not exist in the directory when the program is started (if it is already existing rename or delete it).

NOTE: The **TEST_n** programs do not modify the data - it only reads and informs on possible errors.

The **TEST_n** programs test for following possible errors.

Stand data

1. Existence of file
2. Existence of cluster number in the CLUSTERS.LIS file
3. Limits for all variables according to field instructions: e.g. if code 5 is the biggest possible value for a given variable, code 6 is not accepted.

Enumeration data

1. Existence of files (plot 2 and 3)
2. Matching of file name and cluster number in the header record
3. Limits of all the variables according to field instructions
4. Diameter vs. distance ratio: gives warning if a tree has been measured from a too far distance.
5. Species code
6. Length of saw log vs. length of deformed base (only Pterocarpus): saw log length should not be less than deformed base.
7. Quality class code vs. diameter (only Pterocarpus)

Sample tree data

- 1 - 7 as enumeration data
8. Diameter vs. height ratio: if DBH < 100 mm then H must be < 100 dm and if DBH > 150 mm then H must be > 30 dm (only standing trees).
9. Height vs. crown height: height must be at least 10 dm higher than crown height (only living trees)
10. Height vs. saw log height: height must be at least 20 dm higher than saw log length (only living Pterocarpus)
11. Height vs. canopy diameter: canopy diameter must not exceed 2.5 x height.

Shrub etc. data

1. Existence of file
2. Limits of all variables according to field instructions
3. Species codes
4. Total plant number by height classes (excluding classes 1 and 2) must equal to number by canopy classes for each species

3. DATA PROCESSING

3.1. Correction of species names

If some of the species have been misidentified they need to be corrected in the shrub, sample tree and enumeration files. A Fortran programme named SPE_C_nn.EXE (nn stands for version number) have been compiled to make the changes. Following versions of the programme have been compiled:

SPE_C_10.FOR used for West Tsumkwe data

SPE_C_20.FOR used for Hereroland data (no enumeration plots)

SPE_C_21.FOR used for Hereroland data, asks the name of the file to be checked

The programme is started by giving the command SPE_C_nn. The programme reads the names for the saved stand data files from SAVED.lis, that must be in the same directory where the programme is used (see later in the text a description for SAVED.LIS). The programme reads the tree and shrub files and if it finds a species that has been found incorrect, it automatically changes it. (The correct species have been edited in the programme). Naturally, the list edited in the programme is valid only for the specific data set, and must be re-edited for each inventory area.

The programme copies the correct records and rewrites the corrected records in files with naming similar to the naming described earlier, except that shrub files have extension .chr, sample tree files .csa, and enumeration files extension .cen. Stand data files are not changed or renamed (since they contain no species names).

Example. For cluster number 25 the file names are as follows:

025.shr -> 025.csh

025.sam -> 025.csa

0252.enu -> 0252.cen

0253.enu -> 0253.cen

3.2. Pre-processing of data

3.2.1 Programs and files needed in processing

A self made FORTRAN program named PRE_nn.EXE pre-processes the field data in form that can be easily handled with data base systems. nn in the name of the program indicates the version number. Following versions have been compiled:

PRE_1.FOR test version for West Tsumkwe data

PRE_11.FOR version used for West Tsumkwe without correcting species names, i.e. reads the data from .sta, .shr, .sam, .enu files.

PRE_12.FOR the final version used for West Tsumkwe, reads corrected tree and shrub files.

PRE_22.FOR version used for Hereroland data (no enumeration plots).

The PRE_nn programs use the following files:

SAVED.LIS

Lists the filenames containing stand description data. The first row of *SAVED.LIS* is a comment line, followed by names of data files, one name per line.

Example:

*** This is first SAVED.LIS for TSUMKWE district**

224.sta

334.sta

CLUSTERS.LIS

Lists all the cluster numbers that might have been measured. Contains also the UTM-coordinates for the first plot of each cluster and code for the sampling stratum. The first row is a comment line. Following lines contain cluster number, UTM east (meters), UTM south (meters), and the sampling stratum code, one line for each cluster (read with Fortran format: (I4,1X,F10.3,1X,F11.3,1X,A1))

Example:

*** HEADER: CLUSTERS IN TSUMKWE -96 NO,UTM-E,UTM-S**

0001,416768.938,7898935.000,F

0013,321768.938,7896435.000,S

0014,331768.938,7896435.000,F

Note: version PRE_22 reads only cluster number from the CLUSTERS.LIS file.

TREE_SHR.LIS

Lists all possible species codes that can be in the inventory data. Note: if you increase number of the species upto 198 or more, changes in the *PRE_m.FOR* are needed. The file contains also information on which volume model will be used for each species. The first line in the file is comment. Following lines contain the species code (must be five uppercase letters, 5 letters), space, and number of volume equation (integer in two coluns). The volume function number is needed because no volume function exist for most of the species. At present, functions are available for: BURAF (code 1), COMCO (2), LONNE (3), PTEAN (4), TERSE (5).

Example:

*** LIST OF TREE/SHRUB SPECIES FOR TSUMKWE**

ACAAT 5

ACAER 5

ACAEU 5

ACAFL 5

FIELD DATA FILES

The *m.STA*, *m.CSH*, *m.CSA*, *m.CEN* files (see the description of the data checking and input) of the clusters must be in the same sub-directory. (Version PRE_11.FOR uses .shr, .sam, .enu named files).

3.2.2 Output of the pre-processing

The **PRE_nn.EXE** program reads all the data files mentioned above. The program produces files: *STANDS.DAT*, *SHRUBS.DAT*, *TREES.DAT* and *REGEN.DAT*. The description of these files is as follows.

STANDS.DAT

- one record for each plot
 - each plot record contains following data that origins from 3 sources: a) Stand Description Field Form, b) header of the Enumeration and Sample Tree Field Forms, and c) calculated data from the Shrub, Enumeration and Sample Tree Field Forms. Variables are separated with commas.

A) Variables from Stand Description Sheet (see Field Manual)

- cluster, plot, district, inventory area (map sheet), date, team leader, position accuracy, land type, land use, measured plots, geology, surface sealing, soil texture, mean height, openness/coverage, accomplished measures, grazing, damages I, severity I, damages II, severity II, damages III, severity III, ownership, regeneration, soil color

B) Variables from the heading of enumeration or sample tree sheet

- elevation, slope, aspect, position, distance from roads, distance from settlement

C) Calculated or derived variables (See Part III, Chapter 2: Derivation of stand and tree variables for description of the calculation procedure)

- sampling stratum (F=forest, S=other, for other data not written), UTM east (meters, for the plot center), UTM south, dominant species, coverage of dominant species (%), second dominant species, coverage of second dominant species (%), coverage of trees (%), coverage of shrubs (%), coverage of grasses (%), coverage of herbs (%), mean height of trees (m), mean height of shrubs (m), height class of grasses (see field manual), height class of herbs, vegetation structure index, species diversity index (Simpson dominance), species diversity index (Shannon diversity), habitat diversity index (Simpson), habitat diversity index (Shannon), vertical diversity index (Shannon), species richness (=number of species in sample tree, enumeration and shrub sheets), species diversity index (MacIntosh)

NOTE 1: Calculated variables (coverages, indices etc.) have been written for all plots, even though they have been measured only for plot 1. The value measured and calculated for plot 1 has simply been copied for plots 2 and 3.

NOTE 2: Variables in categories A and B are exactly as described in Field Manual. Thus, for example the variable named "openness/coverage" is actually the result obtained with the densiometer instrument describing **proportion of open area**.

NOTE 3: Version PRE_22.EXE (Hereroland) replaces the UTM-coordinates and stratum code with space.

SHRUBS.DAT

One record for each cluster (because shrub measurements were done at plot 1, only). Variables are (separated by comma)

- district
- cluster
- plot (always 1)
- species code (see Field Manual)
- total coverage of the species (%) (calculated from the measurements, for the description of the calculation procedure see Part III Chapter 2: Derivation of stand and tree variables)
- number of individuals by the 8 height classes (1/ha, calculated)

TREES.DAT

The measurements on Sample Tree and Enumeration Field Forms have been processed into file *TREES.DAT*. The variables in the *TREES.DAT* are classified in two categories a) measured variables from the sample tree or enumeration sheet and b) calculated variables. There is one record for a tree (or a fork of a tree or a stem of a multi-stem tree). The variables in the record are (separated by comma):

A. Measured variables (see Field Manual)

- cluster, plot, tree no., species, diameter, status, bearing, distance, quality, reason for low quality, crown class, saw log length, deformed base length, phenology, height, leaning, crown height, canopy diameter 1, canopy diameter 2, damages, degree of damages

NOTE: For tally trees (trees on plots 2 and 3) variables only upto "deformed base length" have been recorded in the field - the rest of the variables listed above have missing values (space) for tally trees.

B. Calculated or derived variables (See Part III, Chapter 2: Derivation of stand and tree variables for description of the calculation procedure).

- number of stems in a forking or multi-stem tree, expansion factor (1/ha), crown area (m²), volume including branches (dm³), volume of branches less than 5 cm (dm³), saw log volume, total dry biomass including branches (kg), dry biomass of branches less than 5 cm.

REGEN.DAT

The measurements on the number of shrubs and seedlings recorded on the Shrub Field Form have been processed in *REGEN.DAT*. The variables in *REGEN.DAT* are: cluster number, plot number, species code, number of individuals (1/ha) in each of the 8 height classes. All the variables are separated with comma. The number of records per cluster varies from 0 to many according to the number of shrub species listed in the Shrub Field Form. For description of the calculation procedure, see Part III, Chapter 2: Derivation of stand and tree variables.

4. TABULATION OF INVENTORY STATISTICS

Tabulation of inventory statistics is done with Microsoft Access database software and Excel spreadsheet software. These programs work in Microsoft Windows 3.1x environment. Steps in the tabulation of statistics are:

1. Import of data in Access database
2. Running queries in Access
3. Summarising reports in Excel

An Access database with the name **WEST_TSU** have been used for tabulating the inventory results for West Tsumkwe and data base **HERERO** for Hereroland. The processing of actual inventory data have been done by re-importing the pre-processed field data in this data base and by running the designed queries and/or by designing additional queries.

The basic tables in the data base are:

AREAS, STANDS, TREES, REGEN

For Hereroland data there is an additional basic table: **CLUSTERS** containing the cluster (=plot) numbers, UTM-coordinates, UTM zone number, map sheet and sampling stratum for each cluster.

Table **AREAS** contains two fields: Stratum and Area. The stratum field contains the name of the sampling stratum and the area field contains the area of the stratum in hectares. The **STANDS** table contains all the variables in the *STANDS.DAT* file, the **TREES** table contains the variables in the *TREES.DAT* file, and **REGEN** table all the variables in the *REGEN.DAT* file.

4.1 Import of data in the **WEST_TSU** or **HERERO** database

Start the Access. Open database from the File/Open menu. The tables in the database are displayed.

AREAS

The areas of Forest and Savanna strata in Western Tsumkwe are written in the **AREAS** table. There is no need to change these figures when processing the data for Western Tsumkwe.

STANDS

NOTE: Before importing new data delete the old data from the table. Select **STANDS** table by clicking on it. Select Open from the menu. Select Select All Record from the Edit menu. All the data should be highlighted. Press DEL and confirm the deleting. Close the table.

Macro **IMPO_STAND** have been created for the data import. To run the macro, select Macros from the data base window. Select macro **Impo_stand** by clicking on it. Select Design from the menu. Check that the File Name path in the lower left corner of the display is correct. Press the ! Speed Button to run the macro and accept changes in the tables when prompted.

TREES

NOTE: Before importing new data delete the old data from the table. See the instruction above. Macro IMPO_TREES have been created for the data import. To run the macro, select Macros from the data base window. Select macro Impo_tree by clicking on it. Select Design from the menu. Check that the File Name path in the lower left corner of the display is correct. Press the ! Speed Button to run the macro and accept changes in the tables when prompted.

REGEN

NOTE: Before importing new data delete the old data from the table. See the instructions above.

Macro IMPO_REGEN have been created for the data import. To run the macro, select Macros from the data base window. Select macro Impo_stand by clicking on it. Select Design from the menu. Check that the File Name path in the lower left corner of the display is correct. Press the ! Speed Button to run the macro and accept changes in the tables when prompted.

4.2 Running queries in the data base

Note: Before tabulating any area statistics it needs to be calculated how many hectares each plot represents. This is done as follows:

A. Data from West Tsumkwe (data base WEST_TSU)

1. Check that table AREAS contains the correct areas for Forest stratum (F) and for the stratum of Other Land (S).
2. Run the query QNO_OF_PLOTS to produce table NO_PLOTS containing the number of measured plots in the two sampling strata.
3. Run the query Q_HA_BY_PLOT_STR to produce table HA_BY_PLOT_STR containing the data on how many hectares one plot in the two sampling strata represents.
4. Run the query QA_BY_PLOT to produce table A_BY_PLOT containing the number of each plot and cluster and the area (ha) that the plot represents.

B. Data from Hereroland (data base HERERO)

1. Check that table AREAS contains the correct areas for all the sampling strata.
2. Check that table CLUSTERS contains all the measured clusters.
3. Run the query QNO_OF_PLOTS to produce table NO_PLOTS containing the number of measured plots in the sampling strata.
4. Check from the table NO_PLOTS that there are at least 2 measured clusters in every sampling strata. If there are less records in table NO_PLOTS than in table AREAS then some of the strata did not have any measured clusters. In this case you must combine some of the strata in table AREAS and restart from Step 1.
5. Run the query Q_HA_BY_PLOT_STR to produce table HA_BY_PLOT_STR containing the data on how many hectares one plot in the two sampling strata represents.
6. Run the query QA_BY_PLOT to produce table A_BY_PLOT containing the number of each plot and cluster and the area (ha) that the plot represents.
7. Check the sum of hectares in table A_BY_PLOT (e.g. with Excel). The sum of areas must equal to the total area of the forest and savanna land in the whole area (8189867.05 ha). If the sum is less, probably some of the sampling strata have no measured plots and

this will cause that the stratum will be excluded from the further calculations.

After the steps described above running of queries is similar both in the WEST_TSU and HERERO data bases. Some examples of queries calculating area statistics, volumes etc. is in the following.

1. Number of measured trees by species: query QN_TREES.
2. Number of measured sample trees: QN_S_TREES
3. Area by dominant species: QA_SPECIES1
Note: Check that all the species names are in the table ScientificNames.
4. Dominant and second dominant species: queries QA_SPECIES and QA_SPECIES3. QA_SPECIES is run to calculate the total area of each species, then it is used in QA_SPECIES3 to calculate percentages.
5. Area by vegetation structural type: QA_VEGSTR.
6. Area by crown cover class and dominant species: QA_COVER.
7. Area by damaging agent and severity QA_DAMAGES.
8. Area of Pterocarpus and Burkea woodlands (where one of them is the dominant or second dominant species): QA_PTEANWOODLANDS.
9. Total and mean volumes and stem numbers by species: Query QA_AREA to make table AREA_TOTAL containing the total area and then query QVOL_SPE to calculate the stem numbers and volumes.
10. Number of PTEAN and BURAF trees per ha in dbh classes: QN_DBH.
11. Total volume and stem number of PTEAN and BURAF in dbh classes: QVOL_PTEAN.
12. Number of PTEAN and BURAF trees per ha in dbh classes on PTEAN and BURAF woodlands: QA_PTEANWOODLANDS and QN_DBH2.
13. Number and volume of timber sized PTEAN trees by quality classes: QN_PTEAN_TIMBER.
14. Number of damaged PTEAN and BURAF trees by damage severity classes: QN_DAMAGES.
15. Number of PTEAN seedlings per hectare by height classes on PTEAN and BURAF woodlands: QN_CLUST_PTEANWOODLANDS, QN_REGEN.
16. Maximum diameter for each species: Q_MAX_DBH.

17. Number of BURAF seedlings per hectare by height classes on PTEAN and BURAF woodlands: QN_CLUST_PTEANWOODLANDS, QN_REGEN_BURAF.

18. Number of species for each cluster: Q_SRICH.

19. Species diversity

Q_N_SPE_R calculates number of clusters where each shrub species was found. Q_N_SPE_T and Q_N_SPE_T2 do the same for trees.

20. Production of ASCII files for thematic maps:

Query Q_MAP calculates mean volume (of selected species, if wanted) to table Q_MAP_0, Query Q_ADD adds clusters with no measured trees by using tables Q_MAP_0 and STANDS and produces table V_MAP

21. Estimation of sampling error:

Produce table V_MAP for a given variable (mean volume, mean volume of *P. angolensis* etc.) as described earlier. Run query Q_RMSE1 to estimate the variances by sampling stratum. Run query Q_RMSE2 to estimate the sampling error by sampling stratum. Run query Q_RMSE3 to estimate the sampling error for whole area.

5. GENERATION OF REPORTS IN MAP FORM

As an example for preparing reports in map form is in the following the creation of map on mean volume of *Pterocarpus* trees . The steps are as follows.

1. Extracting data from ACCESS data base

Example: Mean volumes.

Step 1. Calculate mean volumes (of selected species) for each cluster.

Query Q_MAP produces table Q_MAP_0.

Step 2. Add clusters with missing values (=no measured trees) in the table

Query Q_ADD uses tables Q_MAP_0 and STANDS and produces table V_MAP

Note: Q_ADD and STANDS tables must be joined so that all records from table STANDS are selected (check the join properties).

Step 3. Export table V_MAP in delimited ASCII format

File > Export > Text delimited, check following options: write field names on first row, field separator is comma, select appropriate directory and file name. Default name for the file is V_MAP.TXT when table V_MAP is exported. (Note: the output file must be named with the extension .TXT)

2. Producing a thematic map with MapInfo

Step 1. Import table V_MAP

File > Open Table

Select the appropriate directory, select List Files of Type: Delimited ASCII, select the file, select option Delimiter is comma, select option First Row is Field Names.

Step 2. Create points for table V_MAP

Table > Create points, select table V_MAP, check the projection (UTM 34s), select field UTM_E for x and field UTM_S for y coordinates.

Step 3. View the result

Window > New Map Window

Step 4. Create thema

Map > Create Thematic Map

(Map window must be activated to get the Map menu)

- select Ranges

- select table VOL_MAP

- select field V_HA

Step 5. Customise ranges, legend

Recommendation for legend colours: only 5 classes + all others class possible to visualise with colors, use yellow for the lowest class, red for the highest, blue-red for the class of all others and autospread for the rest, symbol square, point size 24.

Step 6. Over lay roads etc.

File > Open Table, select WTSU_ROA table to overlay district border

File > Open Table, select WTSU_BOR table to overlay roads

(Note: Map Window must be active to overlay)

Step 7. Open index map

File > Open Table, select NAMIBIW table, select Preferred View: New Mapper to open new Map window

Step 8. Finilise layout

Window > New Layout Window, select Frames for All Open Windows

Note: The V_MAP map window must be active to get the legend in the layout window.

Note: Check that no extra map windows are opens, since all the open windows will be in the layout window

Work space files PTE1.WOR - PTE6.WOR contain examples of thematic maps produced in MapInfo.

Step 9. Modify layout

PART III

THEORETICAL AND MATHEMATICAL BACKROUD

1. SAMPLING

- 1.1. Sampling in West Tsumkwe**
- 1.2. Sampling in East Tsumkwe and Omaheke**
- 1.3. Sampling in Caprivi**
- 1.4. Sampling in Okavango**

2. CALCULATION OF DERIVATED STAND AND TREE VARIABLES

- 2.1 Stand variables (in STANDS.DAT)**
- 2.2 Shrub variables (in SHRUBS.DAT)**
- 2.3 Tree variables (in TREES.DAT)**
- 2.4 Regeneration variables (in REGEN.DAT)**

3. ESTIMATION OF INVENTORY STATISTICS

- 3.1 Area estimates**
- 3.2 Estimation of stem numbers and mean volumes for a plot**
- 3.3 Estimation of stem numbers, mean and total volumes for a calculation stratum**
- 3.4 Estimation of sampling error**

Appendix 1. List of sample plots for East Tsumkwe and Omaheke

Appendix 2. The sampling strata for Caprivi

Appendix 3. Regression models for crown diameter

Appendix 4. Volume and Biomass equations

1. SAMPLING

1.1. Sampling in West Tsumkwe

Background

Western Tsumkwe is used here in the meaning of area from 19°00'S to 19°30'S and from 19°00'E to 20°15' E. Thus, the area covers also the southern most parts of Okavango. Khat (*Pterocarpus angolensis*) is quite frequent in the area. Therefore, the only operating saw mill in Namibia is in this area. Since there is no reliable information on the forest, especially khat timber, resources, the Directorate of Forestry regarded this area as a suitable area to start the inventory.

Typical for the area are large, smoothly formed sand dunes running from East to West. Between dunes there are also large flat areas. The khat forests are either on the top of dunes or on the flat areas, but never in the valley of two dunes close to each other. The lowest areas are typically *Acacia* dominated shrub land.

Sampling design

To guarantee reliable inventory results for the area, it was decided that fairly intensive stratified systematic cluster sampling is applied. The area is divided in two main strata: forest and other areas. The stratification is based on the vegetation maps produced by the VMP. A systematic grid of clusters are located on the forest stratum with the distance of 5 km between clusters. At the stratum of other areas the grid is 10 by 10 km. The cluster consists of 3 sample plots located in a line from South to North at 100 m interval. The plots within a cluster should fall in the same vegetation unit. If this would not happen, the plots 2 and 3 are moved according to a systematic rule (see the Field Manual). If it is not possible, following the instructions, to allocate all the 3 plots in the same vegetation unit, the plot(s) falling outside the vegetation unit are not measured. Thus, the cluster can in some (rare) cases consist of only 2 or 1 plots.

1.2. Sampling in East Tsumkwe and Omaheke

Background

In this paper East Tsumkwe is meaning the parts of Tsumkwe magisterial district that are East from 20°15'E. Omaheke is used in the meaning of Okarara and Otjine magisterial districts excluding the fenced farmland in the southern parts of Otjine.

The East Tsumkwe and Omaheke are mostly savannah type of vegetation. Forests (woodland) are few and small in size. Typical for the eastern parts of the area are large sand dunes running from East to West. Dry rivers (Omurambas) running mostly from East to West are also typical for the eastern and middle parts of the area. The Aha mountains form a separate land formation unit. The area is sparsely populated but new farms are being established on the best sites.

At present, the only usable information to support the inventory is the Vegetation Maps, that stratify the area according to vegetation type (forest, savannah, grassland, agriculture etc.), dominant tree species, density of canopy and mean height of tree/shrubs. In Omaheke area the maps include information on land form (dune, interdune, valley, pan etc.), also. Experience from West Tsumkwe has shown that the Vegetation Maps are fairly reliable in stratifying between vegetation types, in most cases the dominant species information is also reliable, though not very detailed.

Sampling design

On the base of the facts described above following sampling scheme was been planned for East Tsumkwe and Omaheke. The area were stratified according to vegetation type (3 classes: forest, savannah, other) and dominant species using the Vegetation Maps. Only forest and savannah classes were included in the sampling. The area is further divided into 3 sub-areas (see Appendix 1). For each of the 3 sub-areas, 6 map sheets (1:50 000) were selected so that they represent different parts of the sub-area. 100 sample points on a systematic grid of 1 km by 1 km were located on a selected map sheet so that the grid covers as many vegetation types as possible. One point from the middle of the grid was selected for the first field plot. Then, the neighboring points were selected so that 2 field plots for each sampling stratum (vegetation unit) found under the grid sheet was obtained. After selecting sample points on all of the 6 map sheets, number of plots on each vegetation unit is checked. If there are less than 2 plots at any unit, additional plots are located subjectively close to the the already selected plots. If there was more than 8 plots at any vegetation unit, the number was reduced by rejecting some of the plots on those map sheet that have most sample plots.

This procedure produced 122 clusters for the whole area. 117 of them were measured in the field. After measurments it was decided to combine al the 3 sub areas in to one area. Further, some of the original sampling strata needed to be combined due to lack of field data. The lists of the final sampling strata and sample plots are in Appendix 1.

1.3. Sampling in Caprivi

Background

In this text, Caprivi is used in the meaning of Caprivi and Mukwe magisterial districts. Typical for Caprivi area is dune formations in the Caprivi strip and river over-flow areas. Dunes are clearly narrower than in e.g. Tsumkwe region. Both the dunes and rivers cause that the vegetation units are smaller than in most other parts of the country. Vegetation Mapping project has produced vegetation maps for the whole Caprivi.

Sampling design

The inventory area was divided into 12 sampling strata using the Vegetation Maps produced by VMP. For each sampling stratum it has been defined in before hand how many field clusters should be measured. As a minimum was regarded 10 clusters for the smallest strata and as a maximum 40 clusters for the largest strata. Sampling intensity is higher for dense forests than for open forests. The list of sampling strata and their area is in Appendix 2.

15 map sheets covering evenly the whole area was selected for sampling. A systematic grid of sample clusters was drawn on a each selected mapsheet. Each cluster consists of 20 plots located in two parallel lines running from South to North. The distance between these lines is 5 km in East-West direction. The distance between plots in a line is 1 km. After locating all the plots in the 15 vegeation map sheets, the number of plots in each stratum was checked. If there was too many clusters in any stratum, the number was reduced by dropping out every n'th plot. If there was too few clusters in any stratum, the number was increased by selecting more sample points from the drawn grid so that they are close to the clusters to be measured.

The final number of sample clusters is 300. Each cluster consists of 3 plots exactly as in West Tsumkwe.

1.4. Sampling in Okavango, proposal.

Background

Okavango area is fairly homogeneous. Typical for the southern and western part of the region are large dune formations (running from East to West). There are some dry rivers running through the area, the biggest one is Omatako running through the whole region in South - North direction. Smaller dry rivers are found in the most eastern and most western part of the area. In the North, the region is bordered by the Okavango river. Areas near the river are densely populated. The dense population is causing degradation of forest resources. Most of the other areas are fairly densely forested, therefore the region is worth of relatively intensive sampling. There is no reliable maps available showing for example the land types . However, the dry rivers are clearly visible in the Satellite Image Maps (SIMs) produced by VMP. The data on dry river beds is available also in digital form in NRSC.

Sampling design

The sampling scheme is similar to the scheme applied in Caprivi. Number of clusters should be 300 - 400 for the whole area.

2. CALCULATION OF DERIVED STAND AND TREE VARIABLES

2.1 Stand variables (in STANDS.DAT)

The derived standwise variables are:

sampling stratum (F=forest, S=other), UTM east (meters, for the plot), UTM south, dominant species, coverage of dominant species (%), second dominant species, coverage of second dominant species (%), coverage of trees (%), coverage of shrubs (%), coverage of grasses (%), coverage of herbs (%), mean height of trees (m), mean height of shrubs (m), height class of grasses (see field manual), height class of herbs, vegetation structure index, species diversity index (Simpson dominance), species diversity index (Shannon diversity), habitat diversity index (Simpson), habitat diversity index (Shannon), vertical diversity index (Shannon), species richness (=number of species in sample tree, enumeration and shrub sheets), species diversity index (MacIntosh)

SAMPLING STRATUM

taken from file CLUSTERS.LIS

UTM EAST and UTM SOUTH

- plot 1: coordinates taken from CLUSTERS.LIS
- plot 2 (and 3): typically 100 m is added in the southing of plot 1 (2); if plot has been moved in East instead of South then 100 m is added in the easting instead of southing etc.

DOMINANT SPECIES, COVERAGE, SECOND DOMINANT SPECIES and COVERAGE

- for living sample trees (plot 1) crown area is estimated as presented in the description of treewise calculations later
- for living tally trees (plots 2 and 3) crown area is estimated with a function as presented later
- the crown area is divided by the area of the plot circle (314.16, 1256.63, or 2857.43 m², according to the DBH of the tree) and multiplied by 100 to get the coverage in %
- the calculated percentages are summed by species and divided by 3 to get the cluster mean
- the species with highest cover percentage is the dominant species, the species with next highest cover is second dominant species

COVERAGE OF TREES

- treewise coverages of the sample trees (plot 1) are summed as described as above and cluster mean calculated

NOTE: only sample trees measured at the 1 plot are used for calculating this.

COVERAGE OF SHRUBS

- sum of shrub coverages by species, see description of shrub calculations later

COVERAGE OF GRASSES AND HERBS

- taken from the Shrub etc field sheet

MEAN HEIGHT OF TREES

- mean height of trees measured at plot 1 (sample trees) is calculated

MEAN HEIGHT OF SHRUBS

$-\frac{\sum n_i h_i}{\sum n_i}$, where i =height class (2,...,8), n_i number of individual in height class i , h_i =mean height of height class i

- NOTE: the first class is not used when calculating the mean

HEIGHT CLASS OF GRASSES AND HERBS

- taken from the Shrub etc. sheet

VEGETATION STRUCTURE INDEX

- defined according to coverage and height of trees, shrub and grasses as follows (code in bold):

If Tree Cover > 0.1 % then Forest, Woodland, Thicket or Bushland

If Shrub Height < 1m or (Shrub Cover < 10 % and Shrub Height > 1m) then Forest or Woodland

If Tree Cover > 75 % then Forest

If Tree Height > 20 m then High Forest 1

If Tree Height 11-20 m then Tall Forest 2

If Tree Height 5-10 m then Short Forest 3

If Tree Height < 5 m then Low Forest 4

If Tree Cover 11-75 % then Closed Woodland

If Tree Height > 20 m then High Closed Woodland 5

If Tree Height 11-20 m then Tall Closed Woodland 6

If Tree Height 5-10 m then Short Closed Woodland 7

If Tree Height < 5 m then Low Closed Woodland 8

If Tree Cover 1-10 % then Open Woodland

If Tree Height > 20 m then High Open Woodland 9

If Tree Height 11-20 m then Tall Open Woodland 10

If Tree Height 5-10 m then Short Open Woodland 11

If Tree Height < 5 m then Low Open Woodland 12

If Tree Cover < 1 % then Sparse Woodland

If Tree Height > 20 m then High Sparse Woodland 13

If Tree Height 11-20 m then Tall Sparse Woodland 14

If Tree Height 5-10 m then Short Sparse Woodland 15

If Tree Height < 5 m then Low Sparse Woodland 16

If Shrub Cover > 10 % and Shrub Height > 1m then Thicket or Bushland

If Tree Cover > 10 % then Thicket

If Tree Height > 5m then Short Thicket 17

else Low Thicket 18

If Tree Cover < 10 % then Bushland

If Tree Height > 5m then Short Bushland 19

else Low Bushland 20

If Tree Cover < 0.1 % then Shrubland or Grassland	
If Shrub Cover > 0.1 % then Shrubland	
If Shrub Cover > 10 % then Closed Shrubland	
If Shrub Height > 2 m then High Closed Shrubland	21
If Shrub Height 1 - 2 m then Tall Closed Shrubland	22
If Shrub Height < 1 m then Low Closed Shrubland	23
If Shrub Cover 1-10 % then Open Shrubland	
If Shrub Height > 2 m then High Open Shrubland	25
If Shrub Height 1 - 2 m then Tall Open Shrubland	26
If Shrub Height < 1 m then Low Open Shrubland	27
If Shrub Cover < 1 % then Sparse Shrubland	
If Shrub Height > 2 m then High Sparse Shrubland	29
If Shrub Height 1 - 2 m then Tall Sparse Shrubland	30
If Shrub Height < 1 m then Low Sparse Shrubland	31
If Shrub Cover < 0.1 % then Grassland or Herbland	
If Grass dominant then	
If Grass Cover > 10 % then Closed Grassland	
If Grass Height > 1 m then Tall Closed Grassland	34
If Grass Height < 1 m then Short Closed Grassland	35
If Grass Cover 1-10 % then Open Grassland	
If Grass Height > 1 m then Tall Open Grassland	38
If Grass Height < 1 m then Short Open Grassland	39
If Grass Cover < 1 % then Sparse Grassland	
If Grass Height > 1 m then Tall Sparse Grassland	42
If Grass Height < 1 m then Short Sparse Grassland	43
If Herb dominant	
then Herbland	45

SPECIES DIVERSITY INDEX (SIMPSON'S DOMINANCE)

$\sum n_i(n_i-1) / N(N-1)$, where n_i = cover-% of species i , N =total cover of all species calculated over all species in sample tree, enumeration and shrub forms

SPECIES DIVERSITY INDEX (SHANNON)

$-\sum p_i \cdot \ln(p_i)$, where $p_i = n_i/N$, \ln = natural logarithm

HABITAT DIVERSITY INDEX (SIMPSON)

as species diversity indices but n_i = coverage of layer i , i = (tree, shrub, grass layer)

HABITAT DIVERSITY INDEX (SHANNON)

as species diversity indices but n_i = coverage of layer i , i = (tree, shrub, grass layer)

VERTICAL HABITAT DIVERSITY INDEX (SHANNON)

as species diversity index put n_i is height of the specific layer (tree, shrub or grass) and N is the height of the highest layer

SPECIES RICHNESS

number of species in sample tree, enumeration and shrub sheets of a cluster

SPECIES DIVERSITY INDEX (MacIntosh)

$\sqrt{(\sum n_i^2)}$, where n_i = cover percentage of species i

2.2 Shrub variables (in SHRUBS.DAT)

TOTAL COVERAGE OF THE SPECIES

The number of individuals by species and by crown diameter classes (0 - 0.5 m, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2.5 - 3, 3+ m) has been measured for the first plot of each cluster

Crown areas (c_i) for each crown diameter class have been derived as follows:

class 0-0.5m: $c_i = \text{PHI} * (0^{**2} + 0.5/2) / 2 = 0.02454 \text{ m}^2$

(mean of the areas of the circles with radius = lower limit and radius = upper limit of the crown diameter class)

class 0.5-1.0 = $\text{PHI} * (0.5/2^{**2} + 1.0/2^{**2}) / 2 = 0.12272 \text{ m}^2$

etc.

Crown coverage for each species is estimated by:

$\sum (n_i * c_i)$, where n_i = number of individuals in crown diameter class i , c_i = crown area of a shrub in class i , crown areas are 0.02454, 0.12272, 0.49080, 1.2763, 3.4544, 4.0250, 5.9887, 9.9211 m², for classes 1, ..., 8, respectively

The above calculated sum is the coverage (m²) of shrubs on 100 m² area (two circles with 3.99 m → area = 100 m²); thus it is also the coverage in percents (%)

NUMBER OF INDIVIDUALS AT EACH HEIGHT CLASS

sum of number of individual by species and height class, see description of calculations for REGEN.DAT later

2.3 Tree variables (in TREES.DAT)

NUMBER OF STEMS IN A FORKING OR MULTI-STEM TREE

The number of stems with the same tree number in a plot data .

EXPANSION FACTOR (1/HA)

The radius of the sample plot depends on DBH of the tree to be measured.

The areas of the sample plots and the expansion factors are in following setup

(Area = $\text{PHI} * r^2$, Expansion Factor = $10\,000 \text{ m}^2 / \text{Area}$)

DBH, cm	Plot radius, m	Area, m ²	Expansion Factor
5-20	10	314.16	31.8309
20-45	20	1256.636	7.9578
45+	30	2827.431	3.5368

CROWN AREA (m²)

For living sample trees (plot 1), two diameters of the canopy have been measured, from these measurements the crown area is calculated as follows:

$C_AREA = \text{PHI} / 4 * (D_C1 * D_C1 + D_C2 * D_C2) / 200$, where

C_AREA = crown area, m²

D_C1 = 1st measured crown diameter, dm
 D_C2 = 2nd measured crown diameter, dm

For enumeration trees (plots 2 and 3) the crown diameters have not been measured, therefore, the mean crown diameter is estimated with regression models estimated from the sample tree data (see Appendix 2), then, the crown area is estimated as:

$C_AREA = PHI/4*(D_CE*D_CE)/100$, where
 D_CE = estimated crown diameter, dm

VOLUME INCLUDING BRANCHES (dm³) and
 VOLUME UPTO 5 CM (dm³)

The volumes are estimated with regression models estimated from the felled sample tree data, see Appendix 2.

SAW LOG VOLUME (dm³)

Saw log volume is calculated as:

$V_SAW = PHI/400 * DBH*DBH * (H_LOG - H_DEF)$, where
 V_SAW = volume of the 1st saw log, dm³
 DBH = breast height diameter, cm
 H_LOG = measured length of the log, dm
 H_DEF = max(1, measured length of defect on base), dm

TOTAL DRY BIOMASS INCLUDING BRANCHES (kg) and
 DRY BIOMASS EXCLUDING BRANCHES LESS THAN 5 CM

The biomasses are estimated with regression models estimated from the felled sample tree data, see Appendix 2.

2.4 Regeneration variables (in REGEN.DAT)

NUMBER OF INDIVIDUALS BY HEIGHT CLASSES AND SPECIES

The number of individuals in each height class by species have been measured inside the two 3.99 m radius plots, the area of the two circles is thus 100 m².

The number of individuals per hectare in each height class is obtained by multiplying the measured number by 100.

3. ESTIMATION OF INVENTORY STATISTICS

3.1 Area estimates

Area of any calculation stratum is estimated by summing the areas represented by the plots in the calculation stratum:

$$A = \sum a_{i, \text{str}}$$

The area represented by a plot i in stratum str ($a_{i, \text{str}}$) is estimated by dividing the land area of the sampling stratum (in West Tsumkwe stratum 1 is Forest and stratum 2 is other land) by the number of plots in the stratum:

$$a_{i, \text{str}} = \text{AREA}_{\text{str}} / N_{\text{str}}$$

3.2 Estimation of stem numbers and mean volumes for a plot

The radius of the sample plot depends on the dbh of the tree to be measured. Thus, the number of stems that each measured tree represents depends on the dbh of the tree as follows:

DBH, cm	Plot radius, m	Area, m ²	Expansion Factor
5-20	10	314.16	31.8309
20-45	20	1256.636	7.9578
45+	30	2827.431	3.5368

(Area = $\text{PHI} \cdot r^2$, Expansion Factor = $10\,000\text{m}^2/\text{Area}$)

The number of stems per hectare in a plot is estimated as follows:

$$N = \sum f_i, \quad \text{where } f_i = \text{expansion factor of the tree } i$$

$\sum = \text{summation over the trees on the plot.}$

Correspondingly, the number of trees in any sub-group, like tree species, is calculated by summing over the trees that belong in the sub-group.

The mean volume, m³/ha, of the growing stock is calculated as follows.

$$V = \sum f_i v_i \quad \text{where } v_i = \text{volume estimate of the tree } i$$

$\sum = \text{summation over the trees on the plot.}$

The mean volume of growing stock in any sub-group, like tree species or diameter class, is calculated by summing over the trees that belong in the sub-group.

3.3 Estimation of stem numbers, mean and total volumes for a calculation stratum

Let V_j = mean volume (m³/ha) of growing stock on plot j ,
 N_j = number of stems (1/ha) on plot j , and

$a_{j, str}$ = area represented by plot j in stratum str .

Then, the total volume of growing stock for a calculation stratum CS is estimated as:

$$V_{CS} = \sum V_j a_{j, str}, \quad \text{where } \sum = \text{summation over plots in the calculation stratum.}$$

The total number of stems for a calculation stratum is estimated as:

$$N_{CS} = \sum N_j a_{j, str}, \quad \text{where } \sum = \text{summation over plots in the calculation stratum.}$$

The mean volume of growing stock in a calculation stratum is estimated as:

$$VM_{CS} = \sum V_j a_{j, str} / \sum a_{j, str}, \quad \text{where } \sum = \text{summation over plots in the calculation stratum.}$$

The stem number per hectare in a calculation stratum is estimated as:

$$NM_{CS} = \sum N_j a_{j, str} / \sum a_{j, str}, \quad \text{where } \sum = \text{summation over plots in the calculation stratum.}$$

The two last formulas can be used also in the following form:

$$VM_{CS} = \sum (V_j a_{j, str} / \sum a_{j, str}) \text{ and}$$

$$NM_{CS} = \sum (N_j a_{j, str} / \sum a_{j, str}).$$

For practical reasons, the form presented above is used in the example queries. When this form is used, the area estimate ($\sum a_{j, str}$) must be estimated first and then the summation of the volumes or stem numbers can be done in a separate query.

3.4. Estimation of sampling error

There is no generally valid formula for estimating the sampling error for systematic sampling applied in the sampling schemes described earlier. The formula for stratified random can be applied, however, since the distance between clusters is high (5 km in West Tsumkwe and 1 km in the other areas). When estimating the error, cluster of the 3 plots is used as sampling unit (not the plot, except in East Tsukwe and Omaheke where are no clusters).

Appendix 1. List of sampling strata and sample plots in East Tsumkwe and Omaheke

Sampling strata

stratum	SumOfarea	CountOfplots	ha per plot
FAc	10757.49	3	3585.83
FAe	21300	5	4260
FAf	8821	4	2205.25
FAt	59795	3	19931.66667
FBu	54979.68	4	13744.92
FGu	2086.7	2	1043.35
FMx	321584.1	11	29234.91818
FTp	50156.7	4	12539.175
FTs	62040	4	15510
SAf	59904	3	19968
SAh	21957	2	10978.5
SAm	811509	13	62423.76923
SAt-Ae	44123	3	14707.66667
SBp	45900	2	22950
SCa	7290	2	3645
SDc	47477	4	11869.25
SMx-Ac	3262626.1	21	155363.1476
STp	5953.18	2	2976.59
STs	3291607.1	25	131664.284
Total	8189867.05	117	

List of sample plots.

cluster	utm_e	utm_s	map_sheet	utm_zone	stratum
501	485836.3	7889167	1920BB		34 FTp
502	485823.3	7890200	1920BB		34 FTp
503	486784.6	7888157	1920BB		34 SMx-Ac
504	485819.7	7888187	1920BB		34 SMx-Ac
505	486750.4	7886245	1920BB		34 STs
506	485743.8	7886238	1920BB		34 STs
507	485946	7828610	1920DB		34 SMx-Ac
508	486946.9	7828643	1920DB		34 FTp
509	486933.3	7827616	1920DB		34 SMx-Ac
510	486944.3	7826609	1920DB		34 SMx-Ac
511	484949.5	7826578	1920DB		34 FTp
512	481973.2	7830611	1920DB		34 STs
513	480956.1	7830615	1920DB		34 STs
514	491488.4	7834298	1920DB		34 STp
515	492475.4	7834319	1920DB		34 STp
516	435813.9	7885082	1920AB		34 SMx-Ac
517	433818.4	7881059	1920AB		34 FMx
518	432797.2	7881030	1920AB		34 FBu
519	431780.3	7881074	1920AB		34 FAc
520	431782.7	7882051	1920AB		34 FBu
521	436836.1	7881081	1920AB		34 FMx
522	435832.4	7881074	1920AB		34 FMx
523	437811.9	7880095	1920AB		34 SMx-Ac

524	438827.1	7880075 1920AB	34 SMx-Ac
525	433889.3	7833062 1920CB	34 SMx-Ac
526	433884.9	7834079 1920CB	34 SMx-Ac
527	432872.1	7833044 1920CB	34 STs
528	432901.5	7834083 1920CB	34 STs
529	427125.5	7843022 1920CB	34 FGu
530	428171.8	7843004 1920CB	34 FGu
531	326423.4	7834472 1919CB	34 FAc
532	326398	7835467 1919CB	34 STs
533	327392.9	7835470 1919CB	34 STs
534	326454	7833476 1919CB	34 SMx-Ac
535	325401.8	7834465 1919CB	34 FAc
536	322437.4	7832430 1919CB	34 SMx-Ac
537	322464.9	7833452 1919CB	34 SMx-Ac
538	381413.3	7832409 1919DB	34 FBu
539	381393.7	7833431 1919DB	34 FBu
540	381346.2	7834418 1919DB	34 FMx
541	383398.8	7833463 1919DB	34 STs
542	380401.2	7834383 1919DB	34 FMx
543	380396.7	7835397 1919DB	34 STs
544	386388.1	7830451 1919DB	34 SMx-Ac
545	354208	7629355 2119BC	34 FMx
546	354222.7	7630354 2119BC	34 FMx
547	350259.6	7632448 2119BC	34 FAe
548	350261.1	7631462 2119BC	34 FAe
549	349219.7	7628416 2119BC	34 FAe
550	384574.4	7637264 2119BD	34 STs
551	384564.8	7636270 2119BD	34 FTs
552	383599.9	7636265 2119BD	34 FMx
553	382599.3	7636302 2119BD	34 FMx
554	382635	7637285 2119BD	34 SAm
555	385571.5	7636244 2119BD	34 SMx-Ac
556	381594.3	7636283 2119BD	34 SAm
557	386575.5	7637302 2119BD	34 SMx-Ac
558	385473.8	7636697 2119BD	34 FTs
559	491899.3	7627017 2120BD	34 STs
560	492908.6	7627014 2120BD	34 STs
561	492912.6	7626019 2120BD	34 SAT-Ae
562	491883.3	7626016 2120BD	34 SAT-Ae
563	437538.8	7632858 2120AD	34 SAf
564	436572.3	7633843 2120AD	34 SAf
565	435578.1	7636846 2120AD	34 SAm
566	434586.5	7636811 2120AD	34 SAm
567	432583.6	7639833 2120AD	34 FAf
568	433646.4	7639840 2120AD	34 FAf
569	447443.8	7640109 2120AD	34 SCa
570	446446.1	7640085 2120AD	34 SCa
571	430692.8	7630797 2120AD	34 SAh
572	429598.9	7631654 2120AD	34 SAh
573	384355	7744758 2019DB	34 STs
574	383550	7720290 2019DB	34 SDc
575	385370	7745751 2019DB	34 STs

576	388321	7744755 2019DB	34 SDc
577	486027	7747138 2020BD	34 STs
578	487054	7745179 2020BD	34 SAf
579	486050	7745189 2020BD	34 SAf
580	488009	7748170 2020BD	34 SMx-Ac
581	484001.6	7748837 2020BD	34 SMx-Ac
582	485019.1	7749861 2020BD	34 FAf
583	485987.6	7749900 2020BD	34 FAf
584	482016	7747111 2020BD	34 SAm
585	483009.8	7748701 2020BD	34 SBp
586	482019	7748968 2020BD	34 SBp
587	404510	7714733 2020CA	34 STs
588	404516	7713810 2020CA	34 STs
589	388862	7718173 2019DB	34 SDc
590	383210	7719211 2019DB	34 SDc
591	482029	7739279 2020BD	34 SMx-Ac
592	333508.8	7635789 2119AD	34 STs
593	334508.6	7634769 2119AD	34 SAm
594	333531.6	7634759 2119AD	34 SAm
595	331505.6	7635756 2119AD	34 SMx-Ac
596	331490.8	7636707 2119AD	34 SMx-Ac
597	277794.5	7665844 2118BB	34 SAm
598	277759.4	7666821 2118BB	34 FMx
599	277734.1	7667869 2118BB	34 SAT-Ae
600	276783.1	7665857 2118BB	34 SAT-Ae
601	276743	7666840 2118BB	34 FTs
602	276734.3	7667843 2118BB	34 FTs
603	279697.6	7668885 2118BB	34 FMx
604	227473.5	7748024 2018AD	34 STs
605	227458.6	7748975 2018AD	34 STs
606	225502.5	7751025 2018AD	34 FAT
607	225532.5	7752044 2018AD	34 FAT
608	231443.7	7751996 2018AD	34 SAm
609	303963	7699717 2019CC	34 SAm
610	302816	7698935 2019CC	34 SAm
611	467742	7787367 2020BA	34 STs
612	470502	7787525 2020BA	34 STs
613	174231.2	7745089 2017BD	34 SAm
614	173220.3	7746094 2017BD	34 STs
615	176191.3	7746089 2017BD	34 FAe
616	176203.9	7745111 2017BD	34 FAT
617	172285.1	7742061 2017BD	34 FAe
618	178159.1	7746112 2017BD	34 FAT
619	322337.3	7752912 2019AD	34 SAm
620	322321	7753936 2019AD	34 STs
621	323302.9	7753976 2019AD	34 STs
622	323302.1	7752931 2019AD	34 SAm

Appendix 3. Regression models

Crown diameter

Function: $D_{CE} = a_0 + a_1 \cdot DBH$, where

D_{CE} = crown diameter, dm

DBH = breast height diameter, mm

a_0, a_1 = parameters

Parameter estimates:

Species group	a_0	a_1
1 (BURAF)	-0.0440968	0.23204433
2 (COMCO)	9.42059311	0.16118693
3 (LONNE)	18.1643637	0.1193828
4 (PTEAN)	13.1674695	0.16861123
5 (TERSE)	22.1467477	0.0761412

Volume and Biomass equations

A. Model for total volume, including branches

BURAF and TERSE:

Function $\ln(v) = a_0 + a_1/d + 0.5 \cdot RMSE^2$

Parameter estimates:

	a_0	a_1	RMSE
BURAF	8.5946711	-58.711626	0.160239
TERSE	7.1366145	-39.232256	0.210370

COMCO, LONNE and PTEAN

Function $v/d^2 = a_0 + a_1 \cdot d + a_2 \cdot d^2$

Parameter estimates:

	a_0	a_1	a_2
COMCO	0.131381668	0.0180767	-9.05E-05,
LONNE	0.396588	0.0077865	0.0
PTEAN	0.6670607	-0.0084083	0.0002143,

B. Conversion from volume to biomass (air dry biomass)

$B = c \cdot v$

Species	c
BURAF	0.805, if $d < 30$ cm 0.770, otherwise
COMCO	0.881, if $d < 25$ cm 0.770, otherwise
LONNE	0.977, if $d < 25$ cm 0.854, otherwise

PTEAN 0.598, if $d < 30$ cm
 0.524, otherwise
 TERSE 0.754, if $d < 20$ cm
 0.616, otherwise

C. Biomass for stem and branches less than 5 cm in diameter

Function $B5/B = a0 + a1/d$

Parameter estimates:

BURAF	0.0468932	2.9833058
COMCO	0.0956231	1.3644359
LONNE	0.071344	3.5334357
PTEAN	0.0344962	2.9576978
TERSE	0.1000	4.57949

D. Conversion from B5 to V5

$V5 = B5/c$

Species	c
BURAF	0.78814
COMCO	0.8366406
LONNE	0.92292
PTEAN	0.6140766
TERSE	0.662765

PART IV

BUILDING MODELS

1. CROWN DIAMETER MODELS

2. VOLUME AND BIOMASS FUNCTIONS

2.1 DATA COLLECTION

2.2 DATA PROCESSING

1. CROWN DIAMETER MODELS

The sample tree data collected on the first plot of every cluster are used for estimating crown diameter models. These models are needed to estimate the crown size for those tree that have no measured data on the crown size (the enumeration trees).

The pre processed sample tree data in TREES.DAT is used for estimating the models. In the NFI_EXAM data base a query Q_SELECT_CROWN has been created to select living sample tree with crown diameters measured from the TREES table. The resulting table can be taken in Excel spreadsheet programme. The crown diameter models (see Appendix 2 in Part III) are estimated with Excel.

2. VOLUME AND BIOMASS MODELS

2.1 Collection of data

A specific data of felled trees need to be collected for estimating the biomass and volume functions. The data are collected only for the most frequent species. For example, in West Tsumkwe data were collected only for *Burkea africana*, *Combretum collinum*, *Lonchocarpus nelsii*, *Pterocarpus angolensis* and *Terminalia sericea*. The sample trees can be selected subjectively because there is no possibility to collect large representative data. The sample trees should be selected so that they represent the whole diameter distribution of the species in the inventory data. At present, data have been collected in Tsumkwe. When moving to new woodland areas (Okavango, Caprivi) the existing data must be completed by measuring few sample trees more for the above listed species if these occur in the new areas. Further, sample tree data need to be collected for the new species that occur frequently in the new areas but are not represented in the sample tree data from Tsumkwe.

The field instructions for collecting felled sample tree data are in Part V.

2.2 Processing of sample tree data

2.2.1 Entering of data

Data of felled sample trees are collected on Stand Description Sheet, Sample Tree Sheet, Sample Tree Sheet - Biomass Study and Sample Disc Sheet. The Stand Description and Sample Tree Sheets are the same sheets that are used in the inventory data collection, with the following exceptions in the Stand Description Sheet

1. the cluster number is replaced with Tree Species code (5 characters) and Tree number (3 digits), and
2. the Soil Colour field is replaced with UTM Southing and UTM Easting fields.

The data entry is done with a Fortran programme called FELCODE.EXE. The programme works in the same way as the CODE_1 programme for entering inventory data. The programme is started by giving command:

FELCODE <enter>.

The programme asks which data are entered: Stand Description, Sample Tree or Felled

Sample tree data.

The Stand Description data are saved in a file that gets the name according to the first Tree number on the sheet. For example, if the first tree has number 1, the file is named as **001.FST**. The file format is the same as for the inventory stand data files, with the exceptions that cluster number is replaced with tree species and tree number and soil color is replaced with the UTM coordinates.

The Sample Tree data are saved in a file that gets the name according to the first Tree number on the sheet. For example, if the first tree has number 1, the file is named as **001.FSA**. The file format is the same as for the inventory sample tree data files.

The Sample Tree - Biomass Study data are saved in files so that there is one file for each tree. The files are named according to the tree number, for example, if the tree number is 1 the file name is **001.FEL**. The format of the file is exactly the same as the form. In the first line (record) of each file there is following data:

- Tree species (5 characters)
- Tree number (3 digits)
- Height, dm (3 digits)
- Stump height, cm (2 digits)
- Bark thickness at 1.3 m, mm (3 digits)
- Decay diameter, mm (4 digits)
- Decay length, dm (3 digits)
- Weight of branches < 5 cm, g (6 digits) (note: the decimal comma is not saved)
- Weight of branches > 5 cm, g (6 digits) (note: the decimal comma is not saved)
- Weight of waste, g (6 digits) (note: the decimal comma is not saved)

In the following records are the data measured for the different poles, two records for each pole exactly in the same way as on the sheet. The fields in the first record are:

- Pole code (one character)
- Diameter at base over bark, mm (4 digits)
- Diameter at base under bark, mm (4 digits)
- Diameter of heart wood at base, mm (4 digits)
- Diameter at top over bark, mm (4 digits)
- Diameter at top under bark, mm (4 digits)
- Diameter of heart wood at top, mm (4 digits)
- Pole length, dm (3 digits)
- Diameter at 1 m distance from the base, mm (4 digits)
- Diameter at 2 m distance from the base, mm (4 digits)
- Diameter at 3 m distance from the base, mm (4 digits)
- Diameter at 4 m distance from the base, mm (4 digits)
- Diameter at 5 m distance from the base, mm (4 digits)
- Diameter at 6 m distance from the base, mm (4 digits)
- Diameter at 7 m distance from the base, mm (4 digits)

The fields in the second record are:

- Quality of log (1 digit)

- Length of the log, dm (3 digits)
- Sweep, cm (2 digits)
- Quality of 2nd log (1 digit)
- Length of the 2nd log, dm (3 digits)
- Sweep, cm (2 digits)
- Quality of 3rd log (1 digit)
- Length of the 3rd log, dm (3 digits)
- Sweep, cm (2 digits)
- Quality of log 4th (1 digit)
- Length of the 4th log, dm (3 digits)
- Sweep, cm (2 digits)

The Sample Disc data are saved with editor in file DISCS.DAT. Each variable is separated with space. The fields are:

- Species (5 characters)
- Tree number (3 digits)
- Disc code (one character)
- Wet weight for sample disc with bark, g (4 characters) Note: no decimal comma
- Volume for sample disc with bark, cm³ (4 characters) Note: no decimal comma
- Dry weight for sample disc with bark, g (4 characters) Note: no decimal comma
- Wet weight for sample disc without bark, g (4 characters) Note: no decimal comma
- Volume for sample disc without bark, cm³ (4 characters) Note: no decimal comma
- Dry weight for sample disc without bark, g (4 characters) Note: no decimal comma

2.2.2 Processing data

A Fortran programme **NAMFEL.EXE** combines data from the Sample Tree data files, Sample Tree - Biomass Study data files and Sample Disc data file. The Sample Tree data files should be combined in one file - in the data from the West Tsumkwe the data are combined in **4_57.FSA**. There should be a file **FELLED.LIS** containing the tree numbers of the felled trees. The trees should be listed in the file in a 3 digit field, one record for each tree. An example:

```
001
002
003
```

The sample disc data should be in **DISCS.DAT**

The programme is started by giving command **NAMFEL <enter>**. The programme reads the above mentioned files (**FELLED.LIS**, **4_57.FSA**, **DISCS.DAT** and **nnn.FEL**, where **nnn** is the tree number of each felled tree listed in **FELLED.LIS**). The programme calculates the volumes of each pole and each log in a pole. It also sums the volumes by quality classes. The classes are:

- 1 = timber quality d > 45 cm
- 2 = timber quality d 35 - 45 cm
- 3 = timber quality d 25 - 35 cm
- 4 = timber quality d 10 - 25 cm
- 5 = timber quality d < 10 cm
- 6 = waste.

The timber quality means here that the log is at least 1.2 m long and straight enough for a saw log

or a pole.

The programme uses the sample disc data for calculating conversion between volume and weight. The programme asks for a name for the file to be created (give name FELLED.DAT, for example) Finally, the programme writes in the file following information:

- species code
- tree number
- volume of stem and branches $d > 10$ cm, dm³
- volume of quality class 1 logs, dm³
- volume of quality class 2 logs, dm³
- volume of quality class 3 logs, dm³
- volume of quality class 4 logs, dm³
- volume of quality class 5 logs, dm³
- volume of quality class waste, dm³
- volume of branches d 5-10 cm, dm³
- volume of branches $d < 5$ cm, dm³
- dry weight of stem and branches $d > 10$ cm, kg
- dry weight of branches d 5-10 cm, kg
- dry weight of branches $d < 5$ cm, kg
- moisture (wet weight/dry weight)
- height of the tree, measured after felling, dm
- stump height, cm
- thickness of bark at 1.3 m, mm
- length of decay, dm
- diameter at 1.3 m
- quality class of the tree
- saw log length measured before felling, dm
- length of deformed base, dm
- height of the tree measured before felling, dm
- leaning, dm
- crown height, dm
- crown diameter 1, dm
- crown diameter 2, dm

The data record is written with format statement:

```
FORMAT(A5,'',I3,9(' ',F8.1),3(' ',F8.1),'',F5.3,'',I3,'',I2,'',I3,'',I3,'',I4,'',I1,7(' ',I3))
```

The data file can be imported in Excel, and necessary analysis done using the Excel software.

PART V

FIELD INSTRUCTIONS

National Forest Inventory Project

Field Instructions:

Collection of sample tree data
for volume and biomass tables.

Compiled by: Chakanga, M., Juola, V. & Korhonen, K.T.
Directorate of Forestry, Namibia
3.7.1996

PART I. MEASUREMENT OF TREES

1. BACKGROUND

The aim of the data collection is to establish mathematic models for estimating volume and/or biomass of most important Namibian tree species. For practical reasons, biomass of foliage is excluded from the scope of this data collection. The data collection is related to the other field work of National Forest Inventory Project. Thus, data will be cumulated each year when the inventory covers new areas.

The data will be collected on

- 1) total above ground biomass including wood and bark of stem
- 2) basic density of wood to convert biomasses to volumes and vice versa
- 3) utilisable volume of saw able timber species
- 4) diameter increment for those species that show annual rings (*Pterocarpus angolensis* according to present knowledge)
- 5) percentage of heart wood.

2. SELECTION OF SAMPLE TREES

Data will be collected on following species (diameter range in the NFI data in brackets)

- 1) *Pterocarpus angolensis* (5 - 70 cm)
- 2) *Burkea africana* (5 - 51 cm)
- 3) *Combretum collinum* (5 - 45 cm)
- 4) *Lonchocarpus nelsii* (5 - 34 cm)
- 5) *Terminalia sericea* (5 - 34 cm)

The measured sample trees should represent the whole diameter distribution found in the NFI data. Therefore, number of sample trees in different diameter classes should be as follows:

Species	Diameter class, cm							Total
	5-15	15-25	25-35	35-45	45-55	55-65	65+	
PTEAN	2	2	2	2	2	3	3	16
BURAF	2	2	2	2	3			11
COMCO	2	2	2	2				8
LONNE	3	3	3					9
TERSE	3	3	3					9

Total								53

(Data may be completed later if there is time for field work. Especially more large trees might be felled and also some data for multi stemmed individuals and some other species collected.)

The trees can be selected on sites that are reasonably well accessible. The inventory plot data can be used for finding sites

where wanted tree species occur. However, trees must not be felled from the inventory plots.

3. SITE DESCRIPTION

The stand where the sample tree is growing is described using the Stand Description Field Sheet used in the National Forest Inventory (NFI) field work (see manual for details, form has been only slightly modified). Following variables in the sheet must be recorded:

District

Inventory area (map sheet)

Date

Tree number

Trees are numbered sequentially by species so that for each species the first felled tree is number 01 etc.

Tree species

Species codes are the same as in NFI Enumeration Sheet.

Land type

Land use

Geology

Surface sealing

Soil texture

Mean height

Crown coverage

Accomplished measures

Grazing

Damages

Severity of damages

Ownership

Regeneration

UTM Coordinates

The UTM Coordinates of the tree are taken from the GPS and recorded in meters.

The Sample Tree Field Sheet used in the NFI must be filled for every tree before felling, also. In this sheet following variables describing the site must be recorded:

Date

Elevation

Slope

Aspect

Position

Distance from roads

Distance from settlement

Southing and Easting in UTM coordinates

The coordinates are measured with GPS (averaging mode) and recorded in respective columns in meters.

4. MEASUREMENTS ON SAMPLE TREES

4.1. Measurements before felling

The NFI Sample Tree Sheet must be filled for each sample tree before felling (see NFI manual). Only Bearing and Distance from plot center have been removed from the NFI sheet and base diameter and UTM coordinates added. Following variables in the Sample Tree Sheet must be recorded:

Tree number

Trees are numbered sequentially starting from 01 for each species

Tree species

Diameter at 1.3 m height

The diameter is measured from the direction that will be facing up after felling.

Status

Timber quality class

Reason for low quality

Crown class

Saw log length

Length of deformed base

Phenology

Height

Leaning

Crown height

Canopy diameters

Damages

Degree of damages

Stump diameter

The height where the tree will be cut for felling is estimated and the diameter at this height measured. The diameter is measured from the same direction as the DBH.

Before felling the tree the height of 1.3 m must be marked. Also, the direction where the DBH and stump diameter were measured must be marked. Before felling it is also important to debark the base of the stem (in the location where the felling cut is done). Otherwise the sand inside the bark will destroy the saw.

4.2. MEASUREMENTS AFTER FELLING THE TREE

When measuring the tree the tree is divided in 4 components (see Figure 1):

1. stem and branches with diameter ≥ 10 cm
2. stem and branches with $5 < \text{diameter} < 10$ cm
3. stem and branches with diameter < 5 cm
4. waste pieces in forking points.

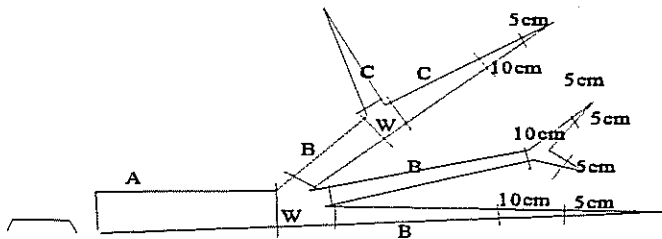


Figure 1. Division of a tree in different components. A, B and C are poles from different forking points; W is waste pieces around forking points; 10cm is branches with diameter less than 10 cm but at least 5 cm; 5cm is branches with diameter less than 5 cm.

After felling the tree the measurements go in the following sequence.

1. Total height of the tree
2. Stump height
3. Thickness of bark at breast height
4. Measurements on the first pole (main stem), taking sample discs
5. Measurements on the second poles, etc. At the same time some of the team members can start cutting off the small branches (diameter less than 5 cm) and weighing them.
6. Measurement on the branches with $5 \text{ cm} < \text{diameter} < 10 \text{ cm}$, taking sample disc to represent these branches.

All the measurements taken are recorded on the Felled Sample Tree Sheet as follows:

1. Tree number
2. Tree species
3. Height

The total height is measured by placing a measuring tape on the stem so that 1.3 m is exactly on the mark of BH. Recording unit is dm.

3. Stump height

The height of stump is measured by reading the stump height from the tape that is located on the stem as described earlier. Recording unit is cm.

4. Thickness of bark at breast height

The thickness of bark at BH is measured by sawing with manual saw two parallel lines (appr. 7 cm apart from each other) rectangular to the stem. The sawing must be deep enough so that piece of bark can be removed. After removing the bark the thickness can be measured with a ruler and recorded in millimeters.

5. Diameter of decayed base

If the stem is partly decayed from the base the diameter of the decayed part is measured and registered in millimeters.

6. Length of decay defect

If the stem is partly decayed from the base the length of the decay defect is measured and registered in dm. The end point of the defect can be found by cutting small pieces of the stem with power chain saw.

7. Weight of branches with $d < 5$ cm

All the branches with diameter less than 5 cm are cut off and piled on a plastic tarpaulin. When the pile is heavy enough (40 - 70 kg) the tarpaulin is lifted with rope with a string scale attached. The mass is recorded on the sheet and after measuring all the branches the different measurements are summed and result recorded on the respective column. NOTE: Before starting any weight measurements the scale must be tared to zero while an empty tarpaulin is hanging on the scale.

NOTE: 3 scales can be used for scaling: one with maximum 100 kg and accuracy 1000 g, one with maximum 50 kg and accuracy 500 g and one with maximum 20 kg and accuracy 200 g. Always use the smallest possible scale to get the best accuracy.

8. Weight of branches with $5 \text{ cm} \leq d \leq 10 \text{ cm}$

All the branches with diameter between 5 and 10 cm are cut off and piled on a plastic tarpaulin. When the pile is

heavy enough (40 - 70 kg) the tarpaulin is lifted with rope with a string scale attached. The mass is recorded on the sheet and after measuring all the branches the different measurements are summed and the result recorded on the respective column. NOTE: Before starting any weight measurements the scale must be tared to zero while an empty tarpaulin is hanging on the scale.

9. Weight of waste pieces

All the waste pieces from forking points are cut off and piled on a plastic tarpaulin. When the pile is heavy enough (40 - 70 kg) the tarpaulin is lifted with rope with a string scale attached. The mass is recorded on the sheet and after measuring all the waste pieces the different measurements are summed and result recorded on the respective column. NOTE: Before starting any weight measurements the scale must be tared to zero while an empty tarpaulin is hanging on the scale.

10. Pole code

The main stem starting from stump is always coded as A. If there are several stems starting from the same stump, all these are coded with code A. All the branches starting from the first forking point are coded with pole code B, all the branches starting from the second forking point are coded with C etc. (see Fig. 1)

11. Diameter over bark at base of the pole

The diameter including bark at the base of the pole is measured for every pole. If the base is deformed, the diameter should be measured immediately after the deformed part. Measuring unit is mm.

12. Diameter under bark at base of the pole

The diameter under bark is measured from the cut cross section in millimeters.

13. Diameter of heart wood at the base of the pole

The diameter of the heart wood is measured from the cut cross section in millimeters, if visible.

14. Diameter over bark at the top of the pole

15. Diameter under bark at the top of the pole

16. Diameter of heart wood at the top of the pole

17. Length of the pole

The length of the pole is measured with measuring tape. The tape should be used so that it is following all the main sweeps of the pole to get the true length of the pole (not the shortest distance between top and base). Measuring unit is cm.

18 - 24. Diameter over bark at 1 m distances from the base
Diameters are measured at points 1 m, 2 m, 3 m, 4 m, and 5
m from the base. Naturally if the base is less than 5 m,
not all these diameters can be measured. Measuring unit is
mm.

25 - 36. Description of timber/other logs

The pole is divided into logs for timber or other use. Logs for other use can be small in diameter (down to 10 cm), saw logs must be 45 cm in diameter. The length of each log is measured. If there is waste pieces between adjacent logs, the length of this piece is measured and recorded as well. At maximum, 4 logs and waste pieces can be described for each pole. The description of logs is as follows:

25. Quality code for the first log

1 = Timber, diameter at top at least 45 cm, not strongly curving and if sweeping it must be still possible to get straight pole with at least 15 cm heart wood

2 = Pole or future timber log, as above but diameter less than 45 cm i.e. expected to come a log as in class 1

3 = Not timber or pole quality

26. Length of the first log

Recording unit is dm.

27. Sweepness of the first log

The degree of sweep is measured as shown in figure 2. Recording unit is cm.



Figure 2. Sweepness is measured by placing a rod or rope on the stem so that one end is at middle of the stem at the point where sweep starts and the other end is middle of the stem at the end point of the sweep. Sweepness is the distance x, that is distance of the rod or stretched rope from the middle of the stem at the point where the sweepness is the biggest.

28 - 30. The same as 25 - 27 but for the second log.

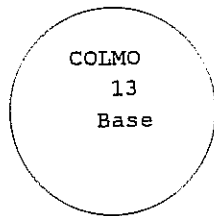
31 - 33. The same as 25 - 27 but for the second log.

34 - 36. The same as 25 - 27 but for the second log.

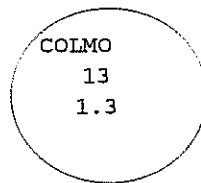
4.3 NUMBERING OF TREES AND DISCS

In order to avoid mismatching discs cut from one particular tree with discs from another tree, all trees and corresponding discs must be uniquely numbered in the felling order, from 1 to nth felled tree. Each disc must bear the (a) tree number (e,g, 1), (b) species code (e,g. COMCO). In case of the Age and Increment discs add the word "Base" for the base disc for age determination or the number "1.3" for the disc taken at Diameter at Breast Height for increment determination.

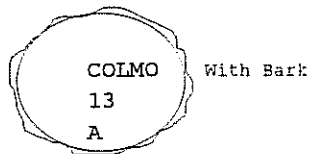
Age Disc



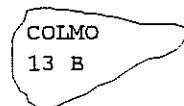
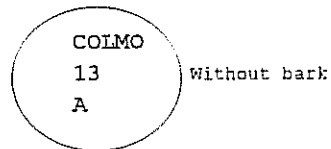
Increment Disc



Density Disc



Density Disc



PART II. PROCESSING OF SAMPLE DISCS

1. TAKING OF THE DISCS

1.1. Discs for measuring increment and age

One disc is taken at the height of 1.3 m for increment measurements. Another disc is taken at the stump height for measuring the age of the tree. The tree species code and tree number are written on each disc. Further, code 1.3 and AGE are written for the increment and age disc, respectively.

1.2. Discs for measuring basic density

When separating the A, B, C etc. poles, sample discs are taken for each pole group so that there are two discs representing poles with code A, two discs for poles with code B, etc. One of the discs is taken with bark and one without bark. If the diameter of the disc is more than 20 cm, a section of the disc is taken instead of the whole disc. The thickness of the disc should be 2 - 10 cm so that only thin discs are taken for large discs and thicker discs for small discs.

Two discs are taken also from the branches with diameter between 5 and 10 cm - one with bark and one without bark. No sample discs are taken for the branches with diameter less than 5 cm.

Tree number, species code and code A, B, C etc. (indicating the pole) are written on the discs. Code X is used for the disc from branches with diameter 5 - 10 cm.

NOTE: All discs for basic density must be closed in plastic bags immediately after cutting.

2. MEASURING THE DISCS

2.1. Increment and age

Increment and age will be measured in laboratory in Windhoek.

2.2. Basic density

The wet weight, dry weight and volume of each disc is measured for defining the basic density. All these measurement are done with an electric scale in the base camp.

First the wet weight of each disc is measured. Then, a small bucket filled with water is placed on the scale and the scale is tared to zero. The disc is carefully forced below the water surface with the help of a thin metal stick. The reading of the scale shows the volume of the disc. After this the disc is put in an open place for 2 days to let it dry. The dry weight of the disc is measured.

All these measurements are registered on the Basic Density Sheet as follows.

1. Tree number
2. Tree species
3. Sample disc code

The code written on the disc should be one of the following: A, B, C, D, E, F, or X.

3. Wet weight of the disc with bark

The weight of the sample is measured with electric scale and recorded in grams. NOTE: The scale must be tared to zero before each measurement.

4. Volume of the disc with bark

See instructions above for measuring.

5. Dry weight of the disc with bark

See instructions above for measuring.

6. Wet weight of the disc without bark

The weight of the sample is measured with electric scale and recorded in grams. NOTE: The scale must be tared to zero before each measurement.

7. Volume of the disc without bark

See instructions above for measuring.

8. Dry weight of the disc without bark

See instructions above for measuring.

