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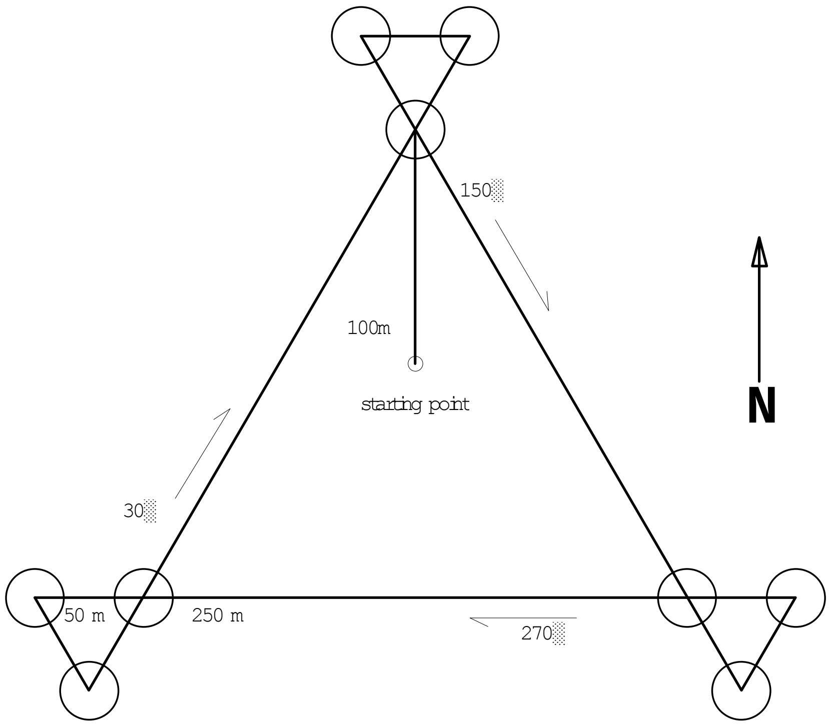
Guidelines for a Reconnaissance Forest Inventory
-Draft-



Mission Report on Forest Resources Assessment and Forest Management
within the Scope of the
Bhutan - German Integrated Forest Management Project

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Report on a

short term consultancy

on

FOREST RESOURCES MANAGEMENT

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Bhutan - German Integrated Forest Management Project

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Annexes:

Acronyms

AAC	annual allowable cut
BG-IFMP	Bhutan - German Integrated Forest Management Project
CV%	coefficient of variation
FMU	Forest Management Unit
FRPA	Forest Resources Potential Assessment
FRDS	Forest Resources Development Section
FSD	Forestry Services Division
GIS	Geographic Information System
GPS	Geographic Positioning System
LUPP	Land Use Planning Project
LUPP-map	LUPP land use working maps, scale 1:50.000
PLOT	tailor made EDP program for forest inventory analysis
PIS	Preinvestment Survey
PIS-map	PIS-map at scale 1:50.000
RFI	Forest Reconnaissance Inventory
SE%	standard error
topo-map	topographic map with 40m height lines, scale 1:50.000

Summary

Within the scope of the Bhutan-German Integrated Forest Management Project a proposal for an improved concept on Forest Resources Planning was made (SCHINDELE, 1995 a).

This concept is based on a three level planning approach consisting of:

- Forest Resources Potential Assessment
- Reconnaissance Survey
- Forest Management Planning

The idea of the new concept is to improve the information provided by the forest management plan without increasing the work load for FRDS. In future the basic unit for stand description, silvicultural planning, monitoring and evaluation should be the individual stand or at least the subcompartment. Operational planning would then no longer required.

The reconnaissance survey should be carried out in forest areas which have been identified as potential forest areas during the first planning step (FRPA Forest Resource Potential Assessment). It should provide the necessary information for decision makers, whether the concerned forest area is suitable to be taken under management and whether a forest management unit should be opened or not.

The reconnaissance survey should consist out of the following four components:

- Reconnaissance Forest Inventory
- Economic Feasibility Study
- Socio-Economic Study (PRA,RRA)
- Preliminary Environmental Impact Assessment

In the following only the first component, the Reconnaissance Forest Inventory (RFI) is described. It has to be mentioned, that the RFI has always to be seen in context with the other components and the above mentioned planning steps of the new forest resources planning

approach. Without changing the management planning system, there is no need for a reconnaissance inventory.

The present **Guideline for a Reconnaissance Forest Inventory** describes the inventory design and explains the preparation of a RFI on the example of the potential Forest Management Unit (FMU) of Gogona (Wangdue District). Guidelines for the implementation of the field work are provided in the **Reconnaissance Forest Inventory Field Manual**. For data processing and analysis the **updated version of the PLOT-program** has to be used which is attached together with a brief documentation at the end of this guideline.

The FRI is designed in such a way that the preparation of the inventory and the implementation of field work can be carried out for an average FMU in less than three month. The design chosen is a **stratified satellite inventory based on randomly distributed cluster samples**. For the purpose of the FRI a sampling error of +/- 20% of the average gross volume per ha on 95% confidence level is sufficient. By using the relascope the time requirement for sampling is reduced, slope correction is no longer required. Log grading, as well as assessment of site and other parameters is not needed at that planning stage. For the identification of the cluster location Geographic Positioning Systems (GPS) will be used, which will also grant compatibility with the Geographic Information System (GIS) of FRDS.

Planning and preparation of a RFI could be entirely done by the Forest Management Planning Unit of FRDS as only already existing and available information (namely PIS/LUPP maps, SPOT imagery, topo-maps) is required. However, assistance by the GIS-Unit would be helpful, but is no prerequisite. Thus time consuming cooperation and coordination processes with other units or sections can be avoided.

The presented inventory design has to be regarded as a draft concept. It is proposed to test this design while implementing a RFI for the potential forest area of Gogona under practical conditions and to optimize it according to the experiences made in the field.

1 Objective of the Reconnaissance Forest Inventory

According to SCHINDELE, 1995 (a), forest resources planning should be based on the following three level planning approach which is briefly described in the following:

Forest Resource Potential Assessment

It should be the objective of the FRPA to identify on a macroplanning level all forest areas which have a potential for future forest management. As already proposed (and carried out for the Districts of Punakha and Wangdue) the FRPA should be a result of a GIS-based analysis combining LUPP landuse data and stand information derived from various inventories (SCHINDELE, 1995 a, b).

Reconnaissance Survey

The Reconnaissance Survey should contain a more detailed assessment of a particular forest area which has been defined as potential during the FRPA. It should provide all the necessary information required to enable decision makers to decide whether a potential forest area should be managed as a FMU or not. In particular, the Reconnaissance Survey should consist out of the following four components:

- Reconnaissance Forest Inventory
- Economic Feasibility Study
- Socio-Economic Study (PRA,RRA)
- Preliminary Environmental Impact Assessment

Only if all these four components of the Reconnaissance Survey would come to a positive result the proposal to open a FMU should be made to the decision makers.

Management Planning

As it is done already now, for every FMU a detailed Forest Management Plan should be elaborated which has to provide all the information required by the manager for sustainable forest management for a planning period of 10 years. The basic unit for stand description, planning, monitoring and evaluation should, however, be the stand or, at least, the subcompartment. Information should be derived from detailed forest inventory, aerial photo interpretation and intensive field truthing. The calculation of the AAC should be based on the individual silvicultural planning for each stand. Management planning should be confined to those areas which should be managed within the ten years planning period. Depending on the silvicultural systems applied, this would vary between 10% to 40% of the total area for the first planning period.

Compared to the present system of forest resources planning, the proposed approach would provide more detailed and accurate information on forest management planning level with approximately the same input on financial and human resources. The implementation of operational planning would no longer be required.

The objective of the RFI in context of the above sketched overall forest resources planning approach can be defined as follows:

Objective 1:

The RFI provides information for decision makers whether it is worthwhile to open a particular potential forest area as a FMU.

Results:

- estimate of total gross volume and increment per diameter class and species/species group
- area statistics for different forest strata (potential management areas)
- estimate of exploitable commercial timber volume
- estimate of potential AAC based on total gross volume and increment
- final boundary of FMU
- observations on wildlife, minor forest products, human impacts and biodiversity

Most of these informations are also required for the elaboration of the other components of the Reconnaissance Survey: the Economic Feasibility Study, the Socio-Economic Study and the Preliminary Environmental Impact Assessment.

Objective 2:

To provide information for the subsequent planning step, the forest management planning.

Results:

- identification of protection areas with and without yield
- preliminary identification of priority areas for production (mature and overmature stands)

2 Description and Justification of Selected Inventory Design

The RFI has been especially designed to fulfill the above mentioned objectives. Beside this the following other criteries were taken into consideration:

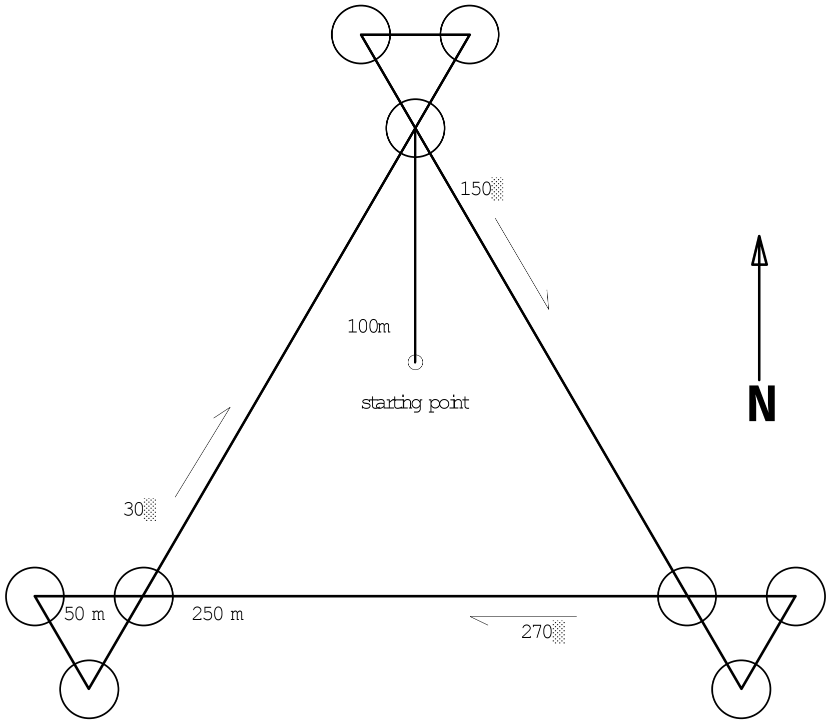
- financial and human resources input should be kept to a minimum
- data analysis should be possible by using PLOT-program
- time consuming cooperation and coordination procedures between different sections or units should be avoided
- for RFI preparation only already existing and available information should be used
- design should be easily understandable and practical
- required training and education input should be kept to a minimum
- the sampling error of the average gross volume per ha should not exceed +/- 20% on 95% confidence level

The inventory design selected can be described as a

stratified satellite inventory based on randomely distributed cluster samples.

The sampling design consists out of satellites of triangular shape with a triangular arrangement of relascope sampling clusters which are randomely distributed according to the size and coefficient of variation (CV%) of each stratum (see figure 1).

Figure 1: Sampling design



While the main triangle is called satellite, the smaller triangles are clusters. Each satellite consists out of three clusters, each cluster consists out of three relascope samples.

Why stratification?

Stratification means that the whole potential forest area is subdivided into different strata. Objective of the stratification is:

- to reduce the total number of sample plots required, and
- to obtain a more specified presentation of the results.

The number of sample plots required depends on the coefficient of variation (CV%), the tolerated standard error (SE%) at a given confidence level. While the tolerated SE% and the confidence level remains the same, if stratified and unstratified sampling methods are compared, the CV% changes for different strata.

Example:

Stratum Type	**CV%**	**P_i**
Fir Forest	50%	0.2
Blue Pine	105%	0.1
Mixed Conifer	70%	0.4
Broadleaf	85%	0.3
Combined all	85%	1.0

(source of CV% LAUMANS, 1994)

t-value on a confidence level of 95% $\approx$ 2
t = t-value
P_i = area weight
n = total number of plots
n_i = total number of plots per stratum i
CV% = coefficient of variation (eg.: for total gross volume per ha)
SE% = standard error

Total number of sample plots without stratification:

$n = t^2 * (CV\%^2)/(SE\%^2)$

$n = 4*(85^2)/(20^2) = 73$

Total number of sample plots with stratification:

$n = t^2 * (\sum P_i*CV_i\%)^2/SE\%^2$

$n = 4*((0.2*50+0.1*105+0.4*70+0.3*85)^2/(20^2) = 55$

For the above mentioned example, the total number of sample plots required to obtain an estimate within the same preciseness level is 73 plots for unstratified sampling and 55 plots for stratified sampling.

The CV% for different forest strata can be derived from FRPA- or PIS-data.

For the calculation of the optimal number of sample plots per stratum see chapter 3.2.1 Stratification.

Why random distribution?

As mentioned above, stratification of the forest area reduces the number of sample plots required. Based on the CV% of each stratum, the required number of sample plots within this stratum is known. Now, how to distribute these sample plots within the stratum? The stratum itself can consist out of a different number of forest areas which vary in size and shape. Thus it is very difficult or even impossible to lay out the sample plots systematically within a stratum.
On the other hand a random distribution of sample plots allows an unbiased estimate of the standard error which is not the case with a systematic sampling (ZÖHRER, 1980).

How to distribute sample plots randomely within a stratum is described in chapter 3.2.2 Distribution of Samples.

Why satellites?

The most time demanding process during inventory field work is the identification of the sample plot location, especially if the total number of sample plots required is low (as it is the case for reconnaissance inventories). In this case, if systematic sampling would be applied, the distance of the grid lines would be fairly large and thus the walking distance would be quite far. If sample plots are arranged as satellites the time required to identify the sample plot location can be reduced considerably, as more samples can be taken within one area. If the distance between these samples are large enough they can be treated as independent samples.

In designing a sampling system always the time required to gather information should be in an acceptible relation to the quantity and quality of information gathered. For the RFI a time requirement of two (in difficult terrain: three) days for the assessment of one satellite sample was the condition set. A triangular arrangement of relascope clusters which are 250 m appart seems to be adequate for the particular terrain condition of Bhutan. This might have to be adjusted during field tests.

Why clusters?

A cluster is a number of sample plots arranged in a particular pattern, which are treated statistically as one sample. The distance within these sample plots is usually quite close, so these sample plots cannot be regarded as independent from each other. The reason for cluster sampling is to reduce the CV% and by this the total number of sample plots required. As mentioned above, the most time demanding process is the access to the sample plot location. Once you are there the time required for sampling (if the number of data collected is limited) is comparatively low. So it is of advantage to concentrate several sample plots at one location if this finally reduces the CV%. In case of the RFI a triangular arrangement of three relascope samples in 50 m distance from each other seems to be adequate.

Why relascope sampling?

Relascope sampling, compared to fixed sample plots usually allows a more precise estimate of the volume, as the probability to be selected as a sample tree is dependent from it´s basal area. As larger the basal area of a tree, as larger naturally is it´s volume. Additionally, in a natural forest big trees account for the largest proportion of the standing volume compared to the smaller trees. Now, if the target is to estimate the volume of a stand, it is better to concentrate on large trees, as then a higher percentage of the actual volume is assessed. (Fixed sample plots on the other hand give a better estimate of the number of stems).

Another advantage of the relascope is that no sample plot has to be surveyed. To survey a fixed sample plot (whether it is a circle, square or rectangle) is quite difficult in a mountaneous terrain like Bhutan. Slope correction has to be done in all directions which needs a lot of table work and field survey. Deviations from the defined sample plot size is one of the main factors for biased results. For relascope sampling using the Bitterlich Mirror Relascope no additional slope reduction procedures have to be undertaken as this is done automatically by the instrument itself. Also the realscope can be used for a lot of other measurements, like height, slope, upper diameters, etc.

Finally, for relascope sampling the number of inventory crew members can be reduced , as the laborous task of surveying a fixed plot is no longer required.

What data should be collected and why?

The cost of a forest inventory has to be in a sound relation to the information provided. Generally not more data should be collected than are really needed and which will be actually used during subsequent data processing. The type of data to be collected therefore depends from:

1. the objective of the inventory
2. technical feasibility of data collection
3. quality of information
4. cost/benefit ratio.

The objective of the RFI is to provide information for the decision makers whether it is worthwhile to open a particular forest area as a FMU. The most important information therefore required is an estimate of the potential harvestable timber, the annual increment and the actual size of the managable area. It would be of greatest interest, of course, to know the actual log recovery rate but because of 2. and 4. this is not possible (remark: to estimate the log recovery is not yet satisfactorily solved. Log grading on standing trees, as it is done presently by management planning inventories, is time consuming and quite difficult. It is therefore proposed by SCHINDELE, 1995 d, to develop log recovery functions for the most important commercial species/species groups)

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On reconnaissance level it makes not much sense to know eg. the average number of natural regeneration, the stoniness, topsoil colours and other site parameters, if we cannot say where those parameters appear and how they are distributed (point 3. and 4.). However, data which can be easily assessed and which are of value for the other components of the Reconnaissance Survey (Preliminary Environmental Impact Assessment, Socio-Economic Study, Economic Feasibility Study) should be included. Even if the quality of information (point 2.) is low, it may give hints for the other sections where to concentrate in their studies (example: signs of shokshing, evidence of snow lepards, etc.).

Another aspect is, that for data analysis the PLOT-program should be used. Therefore, all the data have to be collected which are required to run the program.

Based on these considerations it is proposed to collect the following data:

<u>for each cluster:</u>

- name of inventory unit
- number of cluster
- name of crew leader
- date
- average altitude
- accessibility

<u>for each sample:</u>

- altitude
- accessibility

- tree species code
- diameter at breast height
- total height total height (only for one sample per cluster)

- signs of human impact
- signs of wildlife

For the purpose of a RFI it would be sufficient to identify only the commercial species. On the other hand, for the Preliminary Environmental Impact Assessment information on biodiversity is required. Therefore, all the different tree species should be identified according to the species list attached in the „Reconnaissance Forest Inventory Field Manual“ and in the „Guidelines for Forest Management Inventory Field Work“ (LAUMANS, 1994)

How to measure the individual data is described in detail in the RFI-Manual (SCHINDELE, 1995 c).

3 Preliminary Guidelines for a Reconnaissance Inventory based on the Example of the Potential FMU of Gogona

The inventory design described and the related guidelines have been drafted based on field checks, theoretical considerations and on experiences made in other countries having similar terrain and forest conditions. However, before introducing the design on a larger scale it has to be intensively tested and verified. For this purpose it is proposed to implement a RFI for the potential forest area of Gogona, Wangdue Dzongkhag. In the following, the individual steps in RFI implementation are described based on this example.

3.1 Selection of Inventory Area

The FRPA, which has been carried out for Wangdue and Punakha Dzongkhags, indicates those forest areas which fulfill the following criterias (SCHINDELE, 1995 a, b):

- forest canopy cover > 40% (for broadleaved and Chirpine forests > 80%)
- on slopes below 75% (or with limitation < 100%)

To be managed as a FMU the following criterias have to be additionally considered:

- to be permanently managed and to justify the set-up of a forest infrastructure the potential area should have a size of at least 4000 ha;
- the relief should not be too difficult, the percentage of inoperable areas (areas above 100%) should be within limits, otherwise road construction and the set up of harvesting systems would be not economic;
- the forest must be accessible and/or road construction must be economically feasible and environmentally sound.

The valuation of the above mentioned criteria has to be based on expertise valuation of the FRPA-map. The selected potential FMU-boundary should follow distinct terrain features, such as ridges, rivers, mountain peaks, etc. The deliniation should be carried out on a topo map scale 1:50.000 based on the results of the FRPA-map (the example for Gogona is attached in Annex 3.1).

3.2 Preparation of Inventory

The preparation of the RFI should be done by the Forest Management Planning Unit of FRDS. Assistance by the GIS-Unit would be helpful, is however not a prerequisite.

The following data and records are required:

1. excerpt from FRPA-map at a scale 1:50.000
2. PIS-map at a scale 1:50.000
3. LUPP land use maps at a scale 1.50.000
4. topographic map with 40 m contour lines at a scale 1.50.000
5. SPOT satellite image (if available)
6. CV% for different forest strata

3.2.1 Stratification

After the potential FMU has been deliniated, the area has to be subdivided into different strata. This should be done based on LUPP- and PIS-maps and verified with SPOT imagery. Experiences made during field truthing exercise in forest management planning have shown, that LUPP maps are quite accurate as far as forest/non forest boundaries are concerned. For forest land-use, however, there are sometimes misinterpretations in the LUPP-maps, especially as far as crown closure is concerned (LAUMANS, 1995). For this purpose the PIS-maps give a more precise information especially in remote areas, where there was hardly any human impact since their preparation.

To carry out stratification based on aerial photo interpretation would be too time consuming and would even be not relevant on reconnaissance level.

The individual steps for the stratification of a selected potential area are described in the following:

1. exclude all non-forest areas based on LUPP land use working maps (Annex 3.1);
2. mark and exclude all areas which have not been considered as potential (excerpt of FRPA-map), see Annex 3.1;
3. stratify the remaining potential forest areas based on PIS-map and LUPP land use working map and verify with SPOT satellite imagery (Annex 3.2.1);
4. calculate the area of each stratum (Annex 3.2.2).

ad 1.) The determination of forest/non forest areas has to be based on LUPP land use working maps. The FRPA-map does not indicate forest/non forest areas, but potential/non potential areas. For the Reconnaissance Survey however, the total forest area is of interest.

ad 2.) The RFI should only be carried out in areas which are at present considered as potential for forest management.

ad 3.) The remaining potential area should now be stratified based on the information obtained from the PIS- and LUPP-maps. Criteria for stratification are density class, forest type and slope class (<75%, 75%-100%). The total number of different forest strata should not exceed 10. Each forest strata may consist out of a different number of areas or substrata, which should have at least a size of 50 ha, smaller units have to be allocated to a neighbouring stratum of similar crown density. If there are distinct differences in land use and density class between PIS and LUPP, then verification based on SPOT imagery is necessary. Finally the individual substrata should be serially numbered starting in the northeast corner of the map. The numbers should consist out of two digits, the first should indicate the type of stratum, the second one the serial number of the area or substrata (eg.: 1.3 would be the third area of stratum 1). The final stratification including numbering should then be transfered to a transparent topo-map scale 1:50.000 with 40 m altitude lines (the example of the stratification map of Gogona is attached in Annex 3.2.1).

ad 4.) After the stratification is completed the areas of the individual substrata have to be calculated. This can either be done with the assistance of the GIS-Unit of FRDS or by using a planimeter or by applying the dot counting system (see example for potential area of Gogona attached in Annex 3.2.2).

3.2.2 Distribution of Samples

The total number of samples required depend from the target sampling error (SE%), the confidence level and the coefficient of variation (CV%). For the purpose of a RFI the tolerated SE% for the average gross volume per ha should be +/- 20% at a confidence level of 95%. As already previously described in chapter 2, stratification reduces the required number of samples.

The distribution of samples within the inventory area has to be done in the following way:

1. calculation of the optimal number of samples per stratum;
2. distribution of samples to the substrata of each stratum;
3. selection of sample location based on random figures;
4. preparation of a inventory base map 1:25.000 and a survey description.

<u>ad 1.) Calculation of the optimal number of samples per stratum</u>

Based on the total area and the CV% of each stratum the optimal number of samples per stratum has to be calculated according to the formulas below. The example for the potential area of Gogona is attached in Annex 3.2.3.

$$n = t^2 * (\sum P_i * CV_i\%)^2 / SE\%^2$$

$$n_i = n * (P_i * CV_i\%) / \sum (P_i * CV_i\%)$$

t-value on a confidence level of 95% $\approx$ 2
t = t-value
P_i = area weight of stratum i
n = total number of plots
n_i = total number of plots per stratum i
SE% = standard error
$CV_i\%$ = coefficient of variation (for total gross volume per ha) for stratum i

To get reliable results per stratum, as a rule of the thumb at least 5 sample plots, or 2 satellite samples, should be allocated in each stratum (LAUMANS, 1994).

An estimate of the CV% for different forest strata can be derived from LAUMANS (1994) or SCHINDELE, 1995 b.

ad 2.) Distribution of samples to the substrata of each stratum

The best way to distribute samples among the different substrata (areas) of each stratum is the distribution proportional to area according to the formula below (the example for Gogona is attached in Annex 3.2.4).

$n_{ji} = n_i * p_j$

n_i = number of samples per stratum i
n_{ji} = number of samples per substratum j
p_j = area weight of substratum j

ad 3.) Selection of sample location based on random figures

The selection of the sample location is done randomely. The following steps have to be carried out, which are described in more detail below:

- overlay a coordinate system on the startification map;
- use random number table (Annex 4) and select random numbers;
- transfer sample location based on randomely selected coordinates to stratification map;
- determine terrestrial coordinates of sample location.

Overlay the transparent stratification map on a mm-paper. Then select random numbers with the help of random number table which is attached in Annex 4 (remark: the random figures given in this table ranges from 0-400 which is equal to a distance of 20 km. This should be suitable for most of the potential areas. If the size of the potential FMU is larger a new table should be created using any suitable computer program eg. EXCEL, LOTUS, etc.).
First select any pair of columns randomely (eg. with a dice). Then select the first pair of coordinates and transfer them to the mm-paper. The first column indicates the x-, the second column indicates the y-coordinates.

Based on the table prepared for the required number of samples per substrata (see also Annex 3.2.4) the location of the individual samples have to be selected based on the coordinates of the random figure table. To get a good distribution of samples and to make shure that all relascope samples of one inventory satellite are located within the same substratum, only those sample locations should be selected which are

- at least 500 m apart from the next sample, and
- at least 200 m away from the substratum boundary.

If the coordinates selected from the random figure table does not fulfill these criterias, or if the selected coordinates fall outside the selected forest area or into a substrata where all the samples are already allocated, skip it and use the next pair.

If all the samples are distributed to the individual substrata they have to be numbered as follows: AA10 - AA90, AB10-AB90, ... ZA10 - ZA90, starting at the norteast corner of the potential forest area. It is important to do the numbering in that way, otherwise the PLOT-program would not accept the plot number.

Then, for each sample location GPS- and GIS-compatible coordinates have to be specified. The terrestrial latitude and longitude have to be derived from the 1:50.000 topo map. They have to be specified as degrees, minutes and fractions of a minute (eg. 27° 31.06). The GPS which will be used during field survey for the identification of the sample location has to be set accordingly (see RFI-Manual). According to MÄÄTTÄ (1993) one minute corresponds in Bhutan approximately to:

latitude: 1852 m
longitude: 1650 m

0.01 minute corresponds then on a map at a scale of 1:50.000 to 0.36 mm (latitude) and 0.33 mm (longitude).

<u>Example:</u> if the sample location is 32 mm east of the 27° 5’ longitude and 16 mm north of 89° 25’ latitude the terrestrial coordinates would then be:

longitude: 27° 05’ + (32/0.33)*0.01’ = 27° 05.97’
longitude: 89° 25’ + (16/0.36)*0.01’ = 89° 25.44’

ad 4.) Preparation of a inventory base map 1:25.000 and a survey description

If all the samples are distributed and numbered, the 1:50.000 stratified topo-map has to be enlarged to a scale of 1:25.000 on transparent foil. This is then the inventory base map which will be used for field survey. From this map a set of at least 5 blueprints should be copied, the original should be kept by the Forest Management Planning Section of FRDS.

To facilitate the identification of the sample location in the field a table has to be prepared indicating a description of the sample plot location containing the following information (for an example see also Annex 3.4).

Sample No.:	eg. AA10
Substratum:	eg. 3.2
Longitude:	eg. 89° 38.67’
Latitude:	eg. 27° 30.89’
Altitude:	eg. 2740 m
Description:	eg. on steep slope 350m east of deep valley

3.3 Field Work

Field work has to be carried out by a specilist RFI-team, which had been trained in the use of GPS and the relascope (see Chapter 5, Required External Inputs). The team should consist out of the following members:

1 teamleader

1 assistant

3 helpers

Beside the ordinary inventory equipment the team has to be equipped with one GPS-compass (or alternatively a GPS and a hand compass), one Bitterlich Mirror Relascope, an altimeter and a diameter tape.

For further details on field survey see the RFI-Manual (SCHINDELE, 1995 c).

3.4 Data Analysis

For data analysis the updated version of the PLOT-Program has to be used. The procedure is almost the same as for regular inventories and is described in detail by KOWALCZYK (undated) and LAUMANS (1995).

For a RFI the *system variables* have to be set as follows:

Relascope Sample: Y	Basal Area Factor: 4
Cluster Sample: Y	Number of plots per cluster: 3
Size Major Plot (ha): 0.000	Size Minor Plot (ha): 0.000
Totals for conifers reported? Y	Totals for broadleaves reported? Y
Site & Stand recorded? Y	Wildlife recorded? Y
- heights recorded? Y	- special recorded? N
- crown class recorded? N	- log grades recorded? N
- timber potential recorded? N	Regeneration recorded? N
- radial increment recorded? N	- bark thickness recorded? N
- permanent plots recorded? N	
- line description recorded? N	
- height of codominants reported? N	
- new landuse codes used? N	

A description on the updated version of the PLOT-Program and a set-up disc is attached in Annex 5.

3.5 Analysis of Results

The RFI, as one component of the Reconnaissance Survey, has to be carried out first, as it provides information for the other three components, which are:

- Economic Feasibility Study
- Socio-Economic Study
- Preliminary Environmental Impact Assessment

The results from the assessment of the human impact will provide background information for the Socio-Economic Study, the results on the observation of wildlife and from relascope sampling (species distribution) will be of high value for the Environmental Impact Assessment.

However, the main results of the RFI are required for the Economic Feasibility Study which are:

- areas and distribution of different forest strata and of potential areas;
- average gross volume per stratum for different diameter classes and species/species groups;
- annual increment per stratum for different diameter classes and species/species groups;
- total gross volume and annual increment for the whole FMU area.

Based on these informations cost/benefit calculations can be carried out considering costs of infrastructure, transport of timber, revenue from timber exploitation etc.

4 Consequences for Forest Management Planning

One of the most important advantages of the proposed forest resources planning concept is, that it is already checked on reconnaissance level whether forest management in a particular area would be

- sustainable in the long run,
- economically sound,
- and environmentally and socially acceptible.

This information is obtained at present during the course of management planning. At this stage already a lot of human and financial resources have been invested (implementation of detailed inventory, aerial photo interpretation, field truthing, etc.) and it is very unlikely that finally the decision is made that it is either not worthwhile or not acceptible to open a particular area as a FMU. Thus by introducíng the new concept a realistic decision could be made at an earlier stage with a minimum on human and financial input.

On the other hand the results of the RFI would enable a much more detailed forest management planning which will be briefly described in the following:

In Bhutan most of the potential forest areas are natural forests of high stability. Thus, from the ecological point of view, there is no need for any silvicultural intervention. However, there is an urgent need to supply the local demand on wood from sustainably managed FMU´s, otherwise the trend of forest depletion in accessible areas would increase dramatically.

It is the policy of the Forest Department to manage a FMU permanently, which means more or less that the annual allowable cut (AAC) within a FMU should always be at about the same level. This implies of course, that yield regulation is based on harvestable standing stock, increment, cutting cycle and area. Now, when a new forest area is taken under management, forest exploitation will only be carried out in a part of the area while the others remain untouched. Depending on the silvicultural system (eg. selective cutting, clear felling, etc.) and the harvesting technique applied (eg. cable crane logging) the area of intervention within a 10 years planning period varies between 10 - 40% of the total area. Now, what sense does it make to carry out intensive field inventories in areas which are not subject of intervention within the planning period? On the other hand, if field investigation could be itensified and concentrated in those areas which should be managed within the planning period (preferably mature and overmature stands), stand description, planning, monitoring and evaluation could be based on much smaller units such as subcompartments or even stands. This would allow a more realistic calculation of the AAC (which could be based on individual silvicultural planning) and improve sustainability in the long run. With the introduction of such a gradual management planning procedure a more precise and detailed planning would be possible with almost the same amount of human and financial input.

The RFI as described in this guideline would provide the required information. The estimate on the standing stock, increment and area distribution of different forest strata would allow the calculation of a preliminary sustainable AAC. With the information on forest type and condition and on terrain features, the potential silvicultural systems and harvesting methods could be identified. Based on this, the area demand for the subsequent forest management planning period could be estimated and the areas of intervention could be preselected. For the final selection detailed aerial photo interpretation and field truthing would be necessary.

Finally, the knowledge on the CV% of the different fiorest strata would allow a more precise planning of the forest management inventory.

5 Required External Inputs (Recommendations to BG-IFMP)

5.1 Training

As previously mentioned a specialised inventory team should carry out the RFI. It is proposed to select staff which are already experienced in inventory field work. Additional training is then only required for:

- the use of GPS for field orientation and identification of the sample location;
- the use of the relascope in sample tree selection and in slope and height measurement.

The training should consist out of a theoretical introduction and of intensive practical field exercise.

5.2 Equipment

Most of the inventory equipment is already available at FRDS. Additionally required are the following:

- 2 GPS-compass (preferably SILVA GPS compass with SILVA navimap) or GPS (preferably Magellan 5000 PRO)
- 2 Bitterlich Mirror Relascope
- 4 diameter tapes

The advantage of a GPS-compass is that the direction to reach a certain location is directly indicated by the instrument. It can also be used as an ordinary compass. The navimap is linked with the GPS-compass and shows directly on the map the present position, even if longitude and latitude are not indicated on the map. With these instruments orientation in the field becomes very simple as there is no need for the calculation of directions and distances. This makes it easy to bypass difficult terrain and to find the most convinient way to the determined sample location.

5.3 Technical Assistance for the Development of Guidelines for Other Components of a Reconnaissance Survey

As previously mentioned, the Reconnaissance Survey should provide the necessary information to enable decision makers to decide, whether a particular forest area has a potential for timber exploitation and long-term sustainable forest management and should therefore be managed in future as a FMU. The harvestable timber volume and the growth potential of the forest, which can be derived from the RFI, is however not the only criteria to base this decision on.

Even of higher importance is whether sustainable forest management is economical in the long-run. For this purpose, cost-benefit analysis have to be implemented taking especially into account the cost for the set-up and maintenance of forest infrastructure (such as roads, logging camps, cable cranes, timber utilkization units, etc.) and the timber market potential. Additionally other relevant economical aspects have to be considered adequately.

Forest management on the other hand has to be socially acceptible and environmentally sound. Before investing in detailed forest inventory and management planning both of these aspects have to be critically analysed.

It is therefore proposed to BG-IFMP to assist the FRDS of FSD in the elaboration of standards and criterias for the other components of the Reconnaissance Survey which should consist of the following:

- **Economic Feasibility Study;**
- **Socio-Economic Study;**
- **Premliminary Environmental Impact Assessment.**

Annex 1

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Annex 2

Example of Tally Sheet

Annex 3

Example for Potential FMU of Gogona

Annex 3.2.2: Distribution of Forest Strata at Gogona

Stratum 1: fir forest, density > 60%

Substratum No.	Area in ha
1.1	52
1.2	345
1.3	48
1.4	29
1.5	96
1.6	79
1.7	47
1.8	78
1.9	130
1.10	207
1.11	176
1.12	85
1.13	123
1.14	277
1.15	53
total	1825

Stratum 2: fir forest, density < 60%

Substratum No.	Area in ha
2.1	125
2.2	77
2.3	40
total	242

Stratum 3: mixed conifer, density > 60%

Substratum No.	Area in ha
3.1	358
3.2	500
3.3	548
3.4	386
3.5	472
3.6	97
3.7	1126
3.8	177
3.9	38
3.10	56
3.11	178
3.12	84
total	4020

Annex 3.2.2, page 2

Stratum 4: mixed conifer, density < 60%

Substratum No.	Area in ha
4.1	33
4.2	286
4.3	164
total	483

Stratum 5: broadleaves mixed with conifer

Substratum No.	Area in ha
5.1	440
total	440

Stratum 6: broadleaves

Substratum No.	Area in ha
6.1	287
total	287

Non potential areas: 1380 ha

Total area Gogona: 8679 ha

Annex 3.2.3: Stratum Area and CV% for Gogona

Stratum	Area in ha	Area Weight	CV%	No. of Samples
1 fir forest, density > 60%	1825	.250	50	8.2
2 fir forest, density < 60%	242	.033	50	1.1
3 mixed conifer, density > 60%	4020	.552	70	25.4
4 mixed conifer, density < 60%	483	.066	70	3.0
5 broadleaves mixed with conifer	440	.060	85	3.4
6 broadleaves	287	.039	85	2.2
total	7299	1.000	-	43.3

Source: LAUMANS (1994)

$$n = t^2 * (\sum P_i * CV_i\%)^2 / SE\%^2$$

$$n_i = n * (P_i * CV_i\%) / \sum (P_i * CV_i\%)$$

$$n = 4 * (.25*50 + .033*50 + .552*70 + .066*70 + .06*85 + .039*85)^2 / 400 = 43.3$$

To get reliable results per stratum, as a rule of the thumb at least 5 sample plots, or 2 satellite samples, should be allocated in each stratum (LAUMANS, 1994).

The satellite samples will be distributed as follows

Stratum	No. of Samples
1 fir forest, density > 60%	3
2 fir forest, density < 60%	2
3 mixed conifer, density > 60%	9
4 mixed conifer, density < 60%	2
5 broadleaves mixed with conifer	2
6 broadleaves	2
total	20

Annex 3.2.4: Distribution of Samples to Substrata for Gogona

Stratum 1: fir forest, density > 60%

Substratum	Area in ha	Area Weight	No. of Satellites
1.1	52	.029	-
1.2	345	.189	1
1.3	48	.026	-
1.4	29	.016	-
1.5	96	.053	-
1.6	79	.043	-
1.7	47	.026	-
1.8	78	.043	-
1.9	130	.071	-
1.10	207	.113	1
1.11	176	.096	-
1.12	85	.047	-
1.13	123	.067	-
1.14	277	.152	1
1.15	53	.029	-
total	1825	1.000	3

Stratum 2: fir forest, density < 60%

Substratum	Area in ha	Area Weight	No. of Samples
2.1	125	.517	1
2.2	77	.318	1
2.3	40	.165	-
total	242	1.000	2

Stratum 3: mixed conifer, density > 60%

Substratum	Area in ha	Area Weight	No. of Samples
3.1	358	.089	1
3.2	500	.124	1
3.3	548	.136	1
3.4	386	.097	1
3.5	472	.117	1
3.6	97	.024	-
3.7	1126	.280	3
3.8	177	.044	-
3.9	38	.010	-
3.10	56	.014	-
3.11	178	.044	1
3.12	84	.021	-
total	4012	1.000	9

Annex 3.2.4: page 2

Stratum 4: mixed conifer, density < 60%

Substratum	Area in ha	Area Weight	No. of Samples
4.1	33	.068	-
4.2	286	.592	1
4.3	164	.340	1
total	483	1.000	2

Stratum 5: broadleaves mixed with conifer

Substratum	Area in ha	Area Weight	No. of Samples
5.1	440	1.000	2
total	440	1.000	2

Stratum 6: broadleaves

Substratum	Area in ha	Area Weight	No. of Samples
6.1	287	1.000	2
total	287	1.000	2

Annex 3.4: Survey Description for Samples

Satellite	Substrata	Longitude	Latitude	Alt.	Description
AA1	1.2	27° 7.62’	90° 26.04’	3200	south of small valley
AA2	1.10	27° 4.83’	90° 24.72’	3440	
AA3	1.14	27° 6.68’	90° 27.40’	3380	approx. 300 m north of pasture
AA4	2.1	27° 8.24’	90° 24.88’	3700	on steep slope
AA5	2.2	27° 6.27’	90° 27.43’	3640	approx. 600m west of AA3
AA6	3.1	27° 8.33’	90° 25.97’	3600	on steep slope
AA7	3.2	27° 7.03’	90° 24.31’	3030	on gentle slope
AA8	3.3	27° 7.88’	90° 23.61’	3230	
AA9	3.4	27° 5.15’	90° 23.20’	3020	on upper slope of broad valley
AB1	3.5	27° 4.70’	90° 24.28’	3340	
AB2	3.7	27° 5.15’	90° 25.42’	3280	close to small valley
AB3	3.7	27° 4.64’	90° 26.08’	3230	on gentle slope
AB4	3.7	27° 5.46’	90° 26.31’	3150	on gentle slope
AB5	4.1	27° 8.94	90° 26.39’	3570	near Phobjica Prot. Area
AB6	4.2	27° 6.09’	90° 23.97’	3000	
AB7	4.3	27° 3.55’	90° 24.35’	3530	
AB8	5.1	27° 7.48	90° 22.86’	3160	south of small valley
AB9	5.1	27° 8.15’	90° 22.78’	3330	
AC1	6.1	27° 6.81’	90° 22.81’	2910	on gentle western slope
AC2	6.1	27° 6.00’	90° 23.21’	2880	

Annex 4

Random Number Table

Random Number Table (created with EXCEL)

x	y	x	y	x	y	x	y	x	y	x	y
387	117	166	3	135	46	194	275	49	119	133	299
125	95	215	149	16	215	109	117	134	55	264	183
142	270	224	226	159	66	265	193	296	293	228	0
14	110	4	157	28	258	110	121	186	100	115	180
8	69	11	210	168	111	170	290	229	193	134	127
137	175	112	60	159	235	59	0	291	277	80	142
16	61	195	34	115	224	126	183	44	148	118	105
229	59	24	129	289	111	37	67	254	283	220	156
67	281	135	176	209	120	257	187	48	203	286	96
51	189	89	106	292	289	186	113	77	107	164	232
148	270	169	235	130	93	272	164	2	74	61	290
168	170	140	67	176	156	202	92	235	52	39	294
295	59	75	212	36	182	186	298	76	63	226	105
148	210	34	285	113	67	73	223	146	286	244	298
67	60	159	60	207	144	80	38	134	157	13	123
262	48	219	31	29	34	278	86	119	99	41	167
73	233	152	74	121	39	151	172	236	248	140	148
72	266	264	60	105	26	265	166	206	175	40	178
164	274	257	42	127	83	174	182	204	10	242	6
16	253	92	198	288	168	217	254	266	29	57	109
9	20	258	245	165	249	163	189	260	294	249	115
204	168	137	144	127	154	28	208	152	114	161	64
9	183	134	7	238	74	195	269	4	223	245	119
157	142	286	78	257	14	114	131	119	25	243	2
118	145	31	235	242	25	40	187	165	179	222	151
173	132	78	297	173	208	227	32	90	257	97	77
285	34	167	193	119	183	202	267	12	54	176	261
80	151	244	189	147	202	169	98	257	264	24	88
294	91	91	100	15	97	70	59	10	202	192	269
184	102	135	129	293	236	32	290	159	286	65	286
15	269	247	151	231	208	5	24	166	116	269	231
5	65	284	215	114	77	100	173	99	198	165	125
206	73	244	62	162	159	34	180	202	246	45	294
139	229	136	240	271	262	76	39	97	260	272	108
69	183	270	100	87	40	78	89	65	117	209	261
222	2	131	132	110	223	116	218	216	27	157	7
146	299	286	92	219	72	104	13	257	167	233	124
18	298	248	155	96	80	267	52	134	180	294	156
256	175	227	169	92	230	122	67	71	21	41	131
160	109	20	244	25	281	118	258	152	83	121	178
131	17	106	278	152	256	90	244	190	64	98	104
189	201	288	298	174	228	82	112	258	290	68	248
212	156	263	27	46	161	63	54	225	100	62	174
110	2	239	231	78	170	89	232	225	2	257	272
90	79	79	133	158	145	237	191	88	242	137	125
212	248	166	293	7	282	86	106	273	25	232	192
120	238	99	117	230	182	267	112	240	276	161	185
103	2	177	256	95	252	124	124	28	24	263	102
131	146	214	136	10	237	123	48	33	80	198	96
294	209	136	126	179	61	238	4	80	130	157	174
88	177	214	22	298	273	144	117	19	185	202	21
130	283	160	292	141	160	255	250	199	28	104	71

Annex 5

Updated Version of PLOT-Program (including documentation)

Documentation of Changes and User`s Guide for Updated PLOT-Version

General Remarks

The PLOT-Program is a tailor made program which has been especially developed for forest management inventory in Bhutan. It is installed at the FRDS Forest Resources Development Section and is permanently in use for the analysis of management inventories. It is very complex and can be adjusted individually to different inventory systems. However, the option for relascope sampling or for the calculation of clusters samples has not been included.

It has been programmed in FOXPRO and it is available in a DOS and a WINDOWS version. To run it under WINDOWS95, however creates problems (insufficient memory). It consists of about 260 programs containing numerous procedures and functions, and about 900 supporting data files. The operation of the PLOT-Programme is well documented in „User`s Manual for <PLOT> System. However, the PLOT-Program has been changed several times without proper documentation. This had led to a situation, that many of the original datafiles have been changed, new ones have been added, but the old ones have not been erased and it is therefore quite difficult to find out which ones are actually used. On the other hand compatibility of the latest version with the previous ones is not given. For example, the latest version of PLOT cannot recalculate old inventories without changing memory variables in the system.

Today, staff of FRDS is well trained in the operation of the PLOT-Program. This was the reason for the wish of the FRDS, that any new type of inventory should be designed in such a way, that it can be analysed by the PLOT-Program. Because of the complexity of the program, it is however extremely difficult to incorporate changes or to adjust it to new conditions. However, for the purpose of the new designed reconnaissance forest inventory (RFI) the option for relascope and cluster sampling had to be added, which was in fact a very time consuming and difficult task.

This paper documents the changes which had to be incorporated into the PLOT-Program and describes it`s use for the analysis of the RFI. Attached to it is a disc for updating the PLOT-Program.

As the new version of the PLOT-Program has not been fully tested yet (no RFI has been implemented so far) it is strongly proposed to install an own PLOT-Version on a separate computer or in an own drive. This would garantee that the analysis of management inventories would not be affected, in case software problems would appear. If the new PLOT-Version is tested to its full extent (analysis of at least one RFI) it could be finally installed. It should be mentioned here, that it would have been almost more simple to prepare an own program for the analysis of the RFI than to change PLOT.

1 Update of PLOT-Program

The installation of the PLOT-Program is described in the „User`s Manual for <PLOT> System“ which is, together with the program itself, available at FRDS.

To update this version simply insert the attached update-disc into the disc drive and type:

a: update

Now all the changed databank and program files will be copied to their corresponding subdirectories as well as the main project-file: PLOT.APP.

2 User`s Guide

There is no difference in the operation of the new version of PLOT compared to the previous versions. For data input, management and analsysis the „User`s Manual of the <PLOT> System“ should be consulted.

For the analysis of a RFI the system parameters have to be set as follows:

Relascope Sample: Y
Cluster Sample: Y
Size Major Plot (ha): 0.000
Totals for conifers reported? Y
Site & Stand recorded? Y
- heights recorded? Y
- crown class recorded? N
- timber potential recorded? N
- radial increment recorded? N
- permanent plots recorded? N
- line description recorded? N
- height of codominants reported? N
- new landuse codes used? Y or N

Basal Area Factor: 4
Number of plots per cluster: 3
Size Minor Plot (ha): 0.000
Totals for broadleaves reported? Y
Wildlife recorded? Y
- special recorded? N
- log grades recorded? N
Regeneration recorded? N
- bark thickness recorded? N

During data input all variables which are not included in the RFI should be left blank.

Non accessible clusters and plots, however, should be treated as zero plots and included in the analysis. The reason for it is, that the result should represent the potential production area and capacity. If the plot is not accessible, this part of the forest is not a potential timber production site. If the plot would be excluded from the analysis the average „usuable“ standing volume of the corresponding stratum would be overestimated.

Volume calculations can be based on local volume functions as height measurements were taken.

3 Documentation of Changes

NOTE: Only the DOS-Version was changed!

To add the option for relascope sampling and the calculation of cluster samples, the PLOT-Program had to be changed as follows:

3.1 Change of Database Files

The folowing 4 new data fields including standard values had to be added :

RELASCOPE	*(N)*
RELFACTOR	*(4)*
CLUSTER	*(N)*
CLUSTNUMB	*(1)*

to the following files:

subdirectory C:\PLOT\SYSTEM\
SYSTEM.DBF
D_SYSTEM.DBF

subdirectory C:\PLOT\STORE\
SYSTEM.DBF
$SYSTEM.DBF
$_SYSTEM.DBF
D_SYSTEM.DBF
$D_SYSTEM.DBF

The following files have not been changed so far (they are either used for the WINDOWS Version or are of no importance for data analysis).

subdirectory C:\PLOT\MENUS\
SYSTEM.SPR

subdirectory C:\PLOT\REPORTS\
SYSTEM.FRT
SYSTEM.FRX
D_SYSTEM.FRT
D_SYSTEM.FRX

subdirectory C:\PLOT\SCREENS\
SYSTEM:SCT
SYSTEM.SCX
SYSTEM.SPR

3.2 Change of Program Files

The changes made in the program files are documented in the Annex of „Documentation of Changes and User's Guide for Updated Plot-Version).

All program files are stored in subdirectory C:\PLOT\PRGS

3.2.1 Adjustment of System Programs

The new system variables:

s_relascop
s_relfact
s_cluster
s_clustnum

had to be added to the following programs:

TESTINIT.PRG
SYSPARMS.PRG

3.2.2 Change of Calculation Programs

3.2.2.1 QUATTRO.PRG procedure EXPANSION

The calculation of the number of trees per ha had to be adjusted. In case of relascope sampling the reference number of trees per ha (*mult*) which are represented by the sample tree will be calculated <u>for all trees of dbh 10+ cm</u> as follows:

N/ha = basal area factor / basal area of sample tree
(mult = s-relfact/BASALAREA)

To change the diameter limit of 10 cm for relascope sampling would require additional changes in:

QUATTRO.PRG, function fromDbhc

For cluster sampling the number of trees per ha *(mult)* will be devided by the number of sample plots per cluster (*s_clustnum*).

(*mult = mult/s_clustnum*)

3.2.2.2 REG_CALC.PRG

In case of cluster sampling the N/ha of the regeneration (*multre*) has to be devided by the number of sample plots per cluster (*s_clustnum*).
(*multre = multre / s_clustnum*)

3.2.2.3 RECALCST.PRG

This program had to be changed in order to enable a correct calculation of the variables *plotsize, nr_p_plots, sample_int* and *fpc* in the program STRATUM.PRG which are stored under the same field name in the following data files:

STRATUM.DBF, ISTRATUM.DBF, CSTRATA.DBF, ICSTRATA.DBF.

For relascope sampling the variable s_maplotsize (which is in fact 0 in case of relascope sampling) had to be set to a dummy value of 0.05, otherwise the the program would stop because of an internal system error (division by = 0). The correct calculation is then done in STRATUM.PRG (see below).

3.2.2.4 STRATUM.PRG

A new subroutine had to be added for the calculation of *plotsize, nr_p_plots, sample_int* and *fpc (see excerpt of STRATUM:PRG).*

4 Notes

This PLOT-Version, if fully tested, can be used for the calculation of all different type of designs (fixed sample plots, relascope samples, cluster and satellite sampling, etc.). However the following has to be observed:

- For relascope sampling, the dbh limit is 10 cm, there are no minor plots. To combine relascope sampling with minor plots (eg. relascope for trees dbh>30cm, minor plot for dbh 10-30 cm) would require adjustment of the function „fromDbhc“ in QUATTRO.PRG. To incorporate a user input for the dbh limits requires too many changes in the program and databank files.

- For cluster sampling, the regeneration plots are also devided by the number of plots per cluster. If, for example, only major plots or relascope samples should be combined as clusters, but not the regeneration, the REG_CALC:PRG had to be changed again (delete changes done by WS).

- PLOT accepts only plot numbers of a particular standard eg. AA01 ... ZZ99. This makes numbering of linear distributed nested cluster samples a little bit difficult. It is proposed to use the last figure always for the specification of the basic calculation unit (eg. the cluster). The other figures can be freely used.

In order to use the new PLOT-Version for the recalculation of old inventories, the SYSTEM.MEM file in the corresponding subdirectory has to be deleted and the system variables has to be set-up again .

There are still some mistakes in the PLOT-Program. For example the option „restore of back-up data“ only accepts the reading of data from drive b: not from drive a:.

If restratification is done, it has to be observed, that the stratum numbers have to be serially arranged. If one number is missing in between (eg. 1,2,3,6,8), PLOT gets mixed up and will finally brake down because of „internal system error“.

Finally it should be mentioned, that the PLOT-System as such is not suitable to calculate forest management inventories which should provide results on stand or subcompartment level. It is advised, that in case the management planning system is revised, a new tailor-made program should be developed which can be based on some of the components of PLOT. To change or adjust PLOT itself for this purpose is because of it`s complexity almost impossible.