Report on a consultancy to the EC Natural Forest Management and Conservation Project

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Summary

This report covers permanent sample plot work, stock survey methods, forest inventory and growth modelling. It makes recommendations based on a review of current practices in the Uganda Forestry Department. For PSPs it is noted that trees should be marked with yellow paint, that measurements of heights, crown diameters, and tree position should be discontinued. Future work should aim to establish 100 PSPs well-distributed by reserves at a density of about 0.08%. Software will need to be developed to process data from these plots, including production of a growth model. Examples of the latter, notably PINFORM from Papua New Guinea were demonstrated.

Stock survey methods are efficient but could be improved and better related to silviculture and management inventory. The consultant suggests adoption of a 15-year polycyclic system using low intensities of felling (typically 5-6 trees/ha) . Stock survey should include circular 0.05 ha inventory plots on a 200 x 200 m grid, measuring trees down to 20 cm, and 10 cm on one quadrant (5% and 1.25% sample respectively). All trees over 50 cm should be numbered with blue paint 30 cm above ground, but only some of these (20-40%) would normally be selected for felling. Software is needed to process stock surveys, draw maps, prepare schedules of trees to fell by blocks, and guide silvicultural decisions and planning.

Exploratory forest inventory methods established in 1989-90 are still in use. These methods could be improved by using circular plots on a 1-km tract system within a stratified random sample. Existing software needs upgrading for millennium and Windows compliance or it will become obsolete.

It is suggested that in the next phase of the EC forestry support, some 8 months specialist consultancy over a 5-year horizon are needed to assist the Uganda Forestry Department with these issues. This would cover stock survey software, PSP analysis and growth modelling, and updated forest inventory software.

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1 Introduction

1.1 Terms of reference

The terms of reference (TOR) for the consultancy described in this report are set out in Appendix A (see page 20).

1.2 Work programme

The consultant arrived in Uganda on 8th September and departed on the 19th September. The following programme of field visits was undertaken during the mission

- *8th-10th September* Arrival from United Kingdom. Visit to Budongo Forest Reserve to view permanent sample plot (PSP) operations in compartments N8, N10, and N11. In the latter, exploitation was in progress by licensed pit sawyers. Forest trails at an eco-tourism site in compartments S8 and B1 were also visited. In compartment N15, the results of enrichment plantings established in 1963 were seen. Although recently destroyed by recent illegal pitsawing, this showed the substantial results that could be achieved through this silvicultural system.
- *11th September* Stock survey by the block method was demonstrated at compartment 230 in Mabira Forest Reserve.
- *12th September* Discussions and report writing in Kampala.
- *13th-15th September* Visit to Kasyoha-Kitomi Forest Reserve to view forest inventory operations.
- *16th-17th September* Discussions and report writing in Kampala.
- *18th September* Presentation of draft report to Forestry Department with discussions. Demonstration of PINFORM tropical forest growth model.
- *19th September* Completion of final report incorporating comments and observations from the presentation. Departure for United Kingdom.

2 Permanent sample plot procedures

2.1 Current practices

The Department Standing Orders (DSO) as recently revised include a substantial section on PSPs which are based closely on sections extracted from Alder & Synnott (1992). These have been selected as a basis for re-establishing old plots which have been largely unmeasured since 1973.

These old plots include 120 PSPs in Budongo Forest Reserve. These were established according to standards described in Dawkins (1958). They were 1-ha plots, 100 m square, subdivided into 25 quadrats each 20 m square. On each quadrat two trees were selected for measurement and permanently marked with tags and paint. Trees were selected as Leading Desirables (LDs), and were restricted to a limited group of species.

The old PSPs were well mapped and it appears can mostly be relocated. Trenches marked the access lines, plot corners and edge quadrats; these have proved a useful aid in relocating the plots. Paint marks for the point of measurement on the old LD trees are mostly visible in spite of the lapse of some 25 years. Numbered tags have however typically disappeared, so that identifying the original number requires reference to species and size from the last measurement. Because there were only two trees per quadrat it is likely that there will not often be ambiguity about which tree is which.

The author visited four of these recovered plots, of which one had been demarcated to the new standards. These require that all trees down to 20 cm dbh be marked and numbered for measurement. This operation is however at an early stage and this consultancy is timely in allowing some of the procedures in the DSO to be fine tuned as discussed in the following section.

2.2 Recommended modifications

2.2.1 Sampling intensity, number and location of plots

The DSO recommend that PSPs are established at an intensity of one per 125 ha of forest (0.8%). The EC Forestry Project plans to target some 141,000 ha of production high forest for management over the next five years (see page 20). This would imply establishing some 1128 PSPs.

This is too large a number to consider. In reality, 100 PSPs of 1-ha well distributed by site and forest type are fully adequate for constructing growth models suitable for informing current standards of forest management. It is also important within the context of a 5-year project to try to achieve two biannual measurements. This will allow the procedures, training programmes, and data processing methods to be fully tested and evolved. A useful growth model can also be produced within the life span of the project.

Re-demarcating all the old Budongo PSPs (some 120 plots) is also not especially desirable. This would lead to a biased sample that focuses entirely on one geographical area. The author suggests the following procedures to determine the numbers of plots by forest reserves:

- The goal should be to locate and establish 100 PSPs within the first 12 months of the EC Forestry Project.
- Only the more productive forest types should be sampled. Areas which are degraded, or have high concentrations of non-commercial species (*eg.* pure *Cynometra* stands) should be avoided.
- Small, fragmentary reserves, or localities under intense population pressure should be avoided (the PSPs are unlikely to survive for a long period).
- Likewise, areas within 500 m of public roads, external forest boundaries or settlements should be avoided.
- Subject to the above constraints, some plots should be located in each of following the forest reserves: Budongo, Bugoma, Kalinzu, Kayoha-Kitomi and Mabira.
- In Budongo (and elsewhere if applicable) use should be made of old PSPs to locate the new plots, subject to the above constraints.
- Plots established in each forest should not be unduly concentrated in any one compartment or locality.

Application of the above rules is likely to lead to some 30 plots being established within Budongo using old PSP sites, with the remaining 70 being in other forests.

The sampling intensity proposed (100 plots on approximately 125,000 ha of productive forest) is an average percentage of 0.08%. The DSO should be amended in due course to reflect the above constraints and an average sampling intensity of 0.08% (1 new PSP per 1,250 ha).

These guidelines are based on the consultant's experience of PSP data analysis and growth model development in Costa Rica, Brazil, Papua New Guinea and Ghana. It provides for sufficient plots for a solid base of growth and yield estimation without loading the forest management budget with excessive recurrent costs for PSP maintenance.

2.2.2 Selection of trees

The consultant agrees with the DSO regarding the selection of trees. All trees irrespective of species, form or quality which are greater than 20 cm dbh (or above buttress) should be included for measurement. This should include palms if applicable.

Trees which are totally dead and clearly decaying but retain a standing bole may be omitted. However, any tree which shows any signs of life, including those with broken tops, should be included. Large stranglers which have assumed tree form should also be included.

Where a tree forks at or below 1.3 m, it should be treated as two separate stems, with each individual stem included or excluded from measurement on the basis of the 20 cm criteria.

2.2.3 Quadrat numbering

The DSO recommends a system of quadrat numbering derived from Alder & Synnott (1992). However, old PSPs use a system of spiral quadrat numbers. It is recommended that to avoid confusion, and because it has some inherent advantages, that this system of spiral numbering is retained, as shown in Figure 1 below.

1	2	3	4	5
16	17	18	19	6
15	24	25	20	7
14	23	22	21	8
13	12	11	10	9

Figure 1 Spiral system of quadrat numbering

2.2.4 Quadrat codes

It is useful to assign site codes for quadrats which indicate edaphic factors (rock outcrops, swamps, etc), human disturbance of various kinds, fire, or natural tree fall gaps. Roads, streams and rivers can also be indicated. Appendix B (page 24) gives a suitable form and list of codes that are recommended. The codes given are compatible with those suggested for inventory and diagnostic sampling. This list can be added to if required.

2.2.5 Variables to be measured

During the field visits, the consultant discussed with the Forestry Department personnel the relevance and usefulness of different measurements. It is recommended that the following measurements are made on each tree over 20 cm dbh:

- <u>Diameter</u>. Tree diameter is normally measured at 1.3 m height (dbh). When the tree has buttresses, stilt roots, is forked close to 1.3 m, then it is measured 1 m above the base of the main stem. Diameter measurement should be made as accurately as possible using diameter tape graduated in millimetres. In rare cases, it will not be possible to reach high enough up the tree, even with a 4-m ladder, to measure the tree. In such cases, a wide-angle relascope should be used.
- <u>Alternate diameter</u>. This is not normally used. However, exceptionally, when a plot is re-measured the root system ,buttress, or some abnormality will have

developed at the original point of measurement. In this case, the original diameter should be re-measured as well as possible and recorded. A new point of measurement well above the old one (at least 1.5 m) should then be established and measured as the alternate diameter. At subsequent measurements, the original diameter is no longer measured, and only the alternate diameter used, but now recorded under the main diameter field.

- Height of point of measurement (POM). This only need be recorded when the stem is not measured at 1.3 m. Otherwise the field can be left blank on the form (see Appendix B, page 24). If an alternate diameter has been established, then the POM recorded is for the alternate measurement, not the original.
- Crown illumination. This is scored from 1 (completely shaded) to 5 (emergent) using the well-known Dawkins system.
- Tree condition codes. These are a series of 2-letter codes for qualitative factors. They indicate mensurational problems (fluted trees, stranglers or buttresses that are too large), indicators of tree health, natural or logging damage, phenological information, or site influences such as fire. The DSO gives a list of codes in alphabetical order in Appendix V.27E. Appendix B gives a revised list of codes classified into groups in a format intended to be used for quick reference in the field.

A number of factors that have been previously suggested in the DSO for measurement are excluded and need not be measured. The following remarks gives the consultant's justifications for these exclusions:

- *Tree position*. Tree co-ordinates are of very little practical value. Plot maps based on them are of little use. Competition indices based on relative positions do not work well in natural forest. Mistakes in recording co-ordinates (X-Y trans-positions or measurement from the wrong side of the quadrat) are frequent. The measurement process is slow and expensive. It is recommended accordingly that tree co-ordinates are not recorded.
- *Crown radius*. Crown radius is slow to measure and not appropriately collected on PSPs. It is much better to conduct an independent sampling exercise to determine crown-tree diameter relationships. The information is not needed for natural forest growth projection.
- *Tree total or merchantable height*. It is extremely difficult to measure total height in natural tropical forests. The consultant has also found little practical use for this data. Merchantable height is easier to measure, but also quite slow. Height data contributes little useful information or relevance to growth studies.
- *Crown form*. Although crown form (on the Dawkins scale 1-5) is sometimes a useful indicator of health and shows some correlation with increment, this is basically only in relation to factors such as dieback or broken branches which can be better covered in coded notes. The shape of the crown *per se* is mainly a species characteristic. It is again recommended that this is not measured separately, but sufficiently accounted for through coded notes.
- *Tree form*. Stem straightness is conventionally recorded in forest inventories on a numerical scale. It is principally either a species characteristic or sufficiently covered by the various coded notes for gross defects. It need not be recorded on PSPs.

The objective of these recommendations is to focus effort on factors that are important to the analysis of growth, and avoid spending time on measurements that are slow to make and irrelevant to the analysis.

2.2.6 Method of tree marking

Discussions were held in the field on the relative merits of paint and metal tags for numbering trees. It was concluded that paint has fewer problems than metal tags. On the old PSPs, which have not been maintained for some 25 years, painted marks for the POM remained clearly visible, whereas the metal tags had completely disappeared. This conforms to the author's experience under a variety of situations.

It is accordingly recommended that yellow oil-based paint of good quality is used to paint numbers on trees and mark rings at the point of measurement. The paint should not be thinned, and a 1" brush should be used in the field. Paint should be applied after measuring the tree. The measurement team should use chalk to mark the POM and tree number clearly.

2.2.7 Sub-sampling methods

In the field, a sub-sampling method was discussed based on enumeration of trees of valuable species down to 2 m height. However, in reality such a procedure will not be very useful due to changes over time in the list of appropriate species, and the difficulty of analysing such data without individual tree identification.

The consultant recommends instead a system of sub-sampling. On the central quadrats (18, 20, 22, 24, 25) shown in grey in Figure 1 on page 4, trees should be permanently marked and measured down to a minimum diameter of 10 cm. All species should be included, as for the 20 cm plus trees, and exactly the same criteria of assessment applied, using the same plot record form.

The consultant does not recommend any system of regeneration sampling on permanent plots. Investigation of the dynamics of regeneration is more suited to a research framework than as part of a routine forest management process. He has found from past work that recruitment to a 10-cm minimum diameter has sufficiently close linkage with prior forest operations to be useful for management projections. The sub-sampling recommendations made here adequately fulfil this objective.

3 Stock survey, inventory, and diagnostic sampling

3.1 Stock survey methods

3.1.1 Current practices

There are two closely related methods of stock survey that have been re-introduced to Uganda forestry practice in recent years. These are described in the DSO, and are termed the Block method and Budongo method respectively. The consultant visited Mabira Forest Reserve to see the application the Block method.

Both methods involve cutting lines on a N-S and E-W orientation to form a 200 m grid. Within each 200 x 200 m block formed by this process, guidelines are cut at 50 m intervals. Each 200 x 50 m strip formed by this process is walked by tree spotters who identify and record and trees above 50 cm dbh that are found. Mahoganies (*Khaya*, *Entandophragma* species) are only recorded over 70 cm.

In the Budongo method, the co-ordinates of the tree are estimated, so that a complete stock map can later be plotted. In the Block method, only total counts of commercial trees are calculated by blocks.

Each tree located is marked with a sequential stock number using a metal hammer.

Some trees from the mahogany group are supposed to be reserved as mother trees. The exact procedure for doing this in the field was not completely clear to the consultant, and the explanations of the process appeared a little uncertain.

Costs were stated to be around shs.30,000-40,000 per ha (around $20-30/ha), but no formal study of this has yet been made. These figures were estimated from the overall expenditure for the compartment visited.

The consultant came to the following conclusions about these operations:

- Logistically and operationally the stock survey is well-conducted. Personnel appeared efficient and well-organised.
- Estimation of co-ordinates would be simpler of 20 m guide strips were used.
- Co-ordinates should be estimated relative to the SW corner of each block.
- Stock trees should be numbered using blue painted figures 30 cm above ground level, preferably on the northern side of each tree for consistency. This would give more legible and durable markings than hammers. For reasons discussed below, no marking need be made at dbh. The essential point is to number the stump of the tree.

3.1.2 Stock survey and selection silviculture

The consultant did however feel that the silvicultural components and objectives of stock survey had been omitted from the operation. As used on other countries and in earlier times, stock survey is a preliminary to the selection of trees for felling. Present prescriptions in Ghana and Costa Rica, for example, combine several concepts of forest protection and conservation with the stock survey, so that valued trees are protected. Areas of forest with low stocking are not harvested, and a certain number of trees above commercial size are retained in order to maintain the integrity of the forest ecosystem.

The consultant felt that these components should be included in Uganda's stock survey process. Under this approach, all trees over 50 cm are assigned a stock number (including mahoganies). However, not all will be scheduled for felling. When the survey is mapped and analysed, decisions are made in the office as to which trees should be retained and which felled. This then results in lists of tree numbers for felling (the *yield*, to borrow a term from the Ghana Selection System) which are given to the contractor as approved for felling.

In section 3.4 below, some proposed procedures are discussed in more detail in the context of an integrated selection management system for Uganda.

3.2 Forest inventory

3.2.1 The FRP inventory method

The method of forest inventory developed under the World Bank-sponsored Forest Rehabilitation Project in 1989 continues as the basic method of inventory in Uganda. The consultant visited operations of this type in Kasyoha-Kitomi Forest Reserve during the present mission. He also developed the software and analysed the results for the FRP inventories (principally in Budongo FR) conducted in 1990-91 using this method.

As a system of exploratory inventory, to provide information for provisional management plans, it appears quite suitable. A base point is established by reference to readily identifiable features on the ground, and lines are cut on randomly located bearings. Along each line, sample plots of 0.5 ha are placed at 400 m intervals.

The sample plot used is 100 x 50 m on which trees over 50 cm are sampled. This is sub-divided into 100 x 10 m strips for control purposes. On the first strip, trees over 20 cm are measured (0.1 ha). On the first 50 m of this strip, trees over 10 cm are measured. The trees larger than 50 cm are measured for upper stem diameter and merchantable height with a relascope to calculate volumes.

Associated with each plot are two 5 x 5 m regeneration quadrats on which all trees are counted down to seedling size.

3.2.2 Some shortcomings of the FRP method

The author has never been particularly enamoured of this method of inventory. It has several weak points:

- Sampling probabilities of plots are unequal. Forest near a base point is more likely to be sampled than that remote from it.
- A relatively disproportionate amount of time is spent establishing the sample plot.
- The thin strip used to sub-sample (100 x 10 m) is not laid out accurately enough given the small trees sampled and the high perimeter to area ratio.
- Relascope sampling for volumes is notoriously slow and inaccurate. Two phase sampling using an accurate tool to measure upper stem diameters and heights,

with the construction of volume equations, is standard inventory operating procedure.

3.2.3 Forest inventory objectives

To consider improvements to the FRP method, inventory objectives require some clarification. Basically, three situations probably exist in the high forest zone of Uganda :

- *Exploratory inventories of forest reserves*. These require low intensity inventories (0.5-1%) using stratified random sampling. The FRP method is serving this role at present, but the design could be improved in efficiency. The information from these inventories is used to develop provisional management plans and to help define potential wood supply for strategic planning.
- *Management inventories within forest reserves*. These guide silvicultural decisions and forest management and control at the compartment level. Systematic sampling using small plots and a 5% typical coverage is normally required. In section 3.4, proposals are made to combine this inventory with the stock survey process.
- *Low-intensity inventories outside forest reserves*. These will rely primarily on remote sensing and photogrammetry, but will use small randomly located plots established in clusters to develop mean stand tables for each stratum. The NFS-sponsored Biomass survey substantially corresponds to this type of inventory, but for forestry purposes, some supplementary plots or re-analysis may be required. The objective is usually strategic, to determine the potential wood resource to meet rural demand, deforestation rates, and related questions.

3.2.4 Improvements to the FRP method

It should be an objective within the next phase of the EC Forest Project to upgrade inventory methods. The present consultancy does not offer sufficient time to consider possibilities in depth, but the following changes are likely to be important elements:

- *Adoption of a tract system*, using 0.05 ha circular plots laid along 1-km square tracts for exploratory inventories. Typically, two tracts would be randomly located in each compartment or stratum of about 500 ha. There would be 20 plots per tract, established at 200 m intervals. Measurements within plots would correspond to those for the management inventory. Field procedures would be accordingly standardised at the plot level. Sampling intensity would be 0.4%.

- *Separate volume equations* would be constructed based on accurate measurements. Field sampling would require only diameter measurement and species identification and would be considerably more rapid. The volume sampling would used felled samples in operational areas, supplemented by some smaller trees measured standing with a Wheeler Pentaprism.

- *Checking of a sub-set of inventory plots* would be made a standard operation for quality control, with appropriate software developed to highlight differences between original and check samples.

3.3 Diagnostic sampling

3.3.1 Current practice

The proposals for diagnostic sampling contained in the SFO are essentially those of HC Dawkins 1958 paper on the management of natural high forest, which were enshrined in the Uganda Forestry Department standing orders of that time.

In fact Diagnostic Sampling (DS) is a term normally employed for a rather subjective type of inventory, in which presumed future crop trees (Leading Desirables, LDs) are selected to obtain an estimate of advance growth. There is also normally provision for some sort of regeneration sampling.

3.3.2 Objectives of diagnostic sampling

The fundamental objective of DS is to trigger some types of silvicultural treatment when certain criteria are met. These may include:

- Liberation thinning if LDs present are subject to certain levels of competition.
- Enrichment planting or conversion to plantations if sufficient regeneration is absent.

The consultant believes that the originally defined type of DS proposed by HC Dawkins in 1958 and now included in the DSO is of little relevance or value for forest management. However, the central objective of silvicultural decision-making can be achieved within the context of a combined management inventory/stock survey operation, as discussed in the next section.

3.4 Proposals for an integrated selection management system

3.4.1 Forest management objectives

Based on the various growth models the author has developed in several countries, and experience in rainforest management in Queensland over some 40 years, short-cycle logging with low-intensity felling represents perhaps the optimum solution for selection management in the tropics. Such a system is also supported in Costa Rica for the management of internationally-certified natural forests.

This system allows the operations of management inventory, stock survey, and diagnostic sampling to be carried out as an integrated operation, reducing costs and double sampling. The short felling cycle (15 years is proposed) implies that the 200 x 200 m block lines cut for stock survey become a semi-permanent infrastructure for forest control.

Figure 2 shows the principal features of this 15-year silvicultural cycle. The forest is brought under management through initial inventory and a provisional management plan, including demarcation of the main working circles, and compartment boundary demarcation within the timber production areas. This is the present situation. Subsequently, the cyclic operations start with a stock survey combined with management inventory. This leads to detailed silvicultural planning using the sub-compartment blocks as the basic unit. Trees are allocated by stock number to pit-sawyers and other small-scale operators.

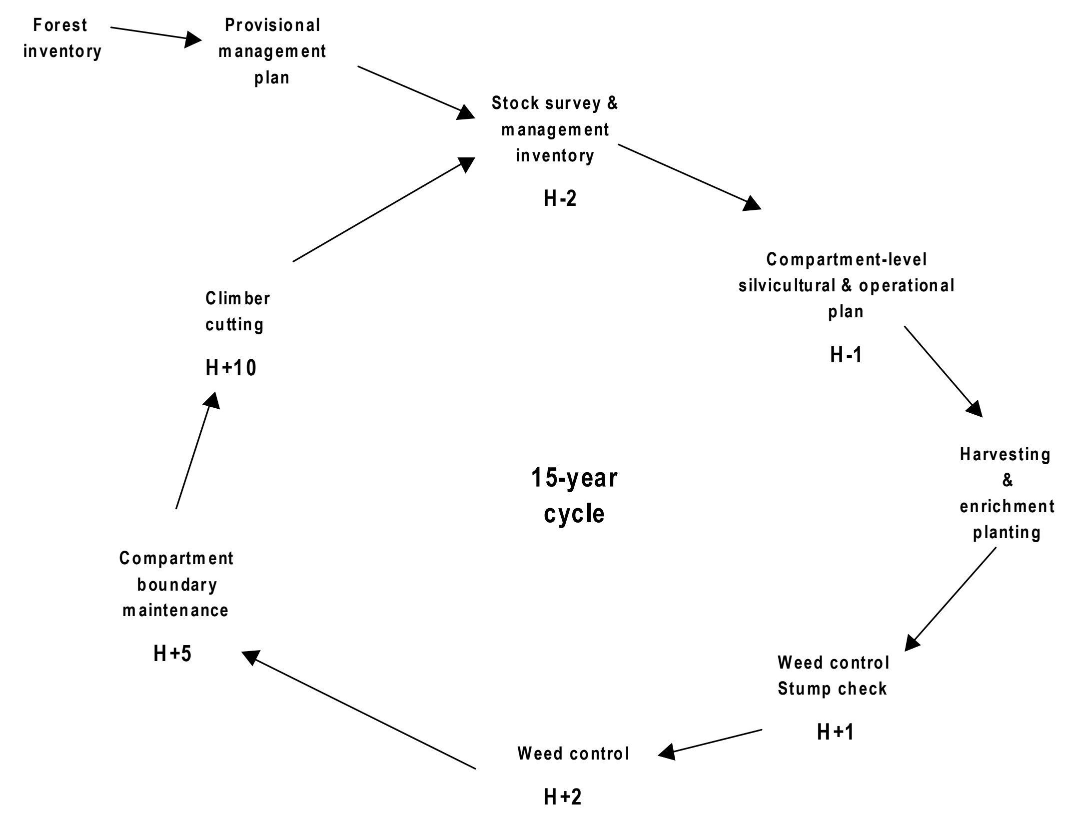

Figure 2 Operations within the 15-year silvicultural cycle

Harvesting, as at present, includes stump control, volume measurement, and collection of royalty fees. Immediately after harvesting, enrichment planting is done in areas identified under the silvicultural plan as having inadequate regeneration.

In the subsequent two years, the enrichment plantings are tended and weeded. Felling damage repair is also done where appropriate. A random selection of felling blocks are subject to a stump inventory. This is compared in the office with allocated yields and royalties collected. It is a control on possible collusion at the time of felling between forest rangers and pit-sawyers. Throughout this period the 200 x 200 m block lines are kept open and used to control operations.

In about the fifth year after felling, compartment boundaries are renewed. In the tenth year, climber cutting is undertaken as a preliminary to the following harvest. This involves a re-opening of the 200 m lines as a control operation. The cycle then repeats with the stock survey/inventory in about the 12^{th} to 13^{th} year.

In order for this type of system to work, the polycyclic fellings must be seen within the context of the regeneration cycle. Typically within natural forest, it may take 50-100 years for trees to grow from seedling to 50 cm diameter. The forest can be operated with four polycyclic fellings per regeneration cycle.

There are two key requirements for success:

- The polycyclic fellings must be light and tightly controlled. Typically, about 15 m3/ha in bole volume, or 5-6 trees per ha, is the maximum that may be removed.

- Logging must be restricted to low damage systems. The largest machinery permitted in the forest should be agricultural tractors or light skidders. Skid trails should be carefully planned. In this regard, pit-sawing and the use of mobile circular saws are ideal systems due to the minimal extraction damage.

This system requires detailed planning and supervision in the forest. It is a true selection system, corresponding to that successfully applied in Australian rainforests for many years, and in the temperate region selection forests of Europe and North America.

3.4.2 Stock survey/inventory sampling design

The present method of stock survey appears efficient, and would be the basis for a combined management inventory. As shown in Figure 3, at each 200 m grid intersection, a circular plot of 12.6 m radius is established (0.05 ha). On this plot, trees down to 20 cm dbh are measured. A sub-plot is formed by the NE quadrant of this circle, on which trees down to 10 cm dbh are recorded. For each circular plot, a site assessment is also made using the same codes as for PSP quadrats (see page 24). This gives a 5% systematic sample of trees 20-50 cm, and 1.25% for poles 10-20 cm dbh.

The stock survey process is similar to the present method except that:

- Guidelines within blocks are 20 m instead of 50 m apart for better control.
- Tree co-ordinates are recorded as guidelines are cut. E-W distances are estimated visually within guidelines.
- Distance measurements are always relative to the SW corner of the block.
- Stock numbers start at 1 for each new block. The block number is prefixed to the stock number in printed reports and control forms.
- Short trenches (60 cm) are dug at each 200 x 200 intersection and a stout numbered post used at the centre. This provides a semi-permanent infrastructure for forest monitoring.
- Stock numbers are painted in blue oil-paint at 30 cm above ground using 1” brush.
- Mahoganies are given stock numbers above 50 cm.
- If it has not been done in a preceding operation, climbers are cut on all stock trees.
- Each stock tree is scored with a silvicultural condition code as shown in Table 1.

An important difference between this operation and current stock survey is that the numbered stock trees will not automatically be harvested. After analysis of the stock map and block averages, a list of stock tree numbers for felling is prepared which can be used for allocation of trees and control in the field.

1	Tree severely damaged, crooked or rotten, with no possible commercial log.
2	A severely defective tree, but probably containing ½ -1 log of 3-5 m.
3	A defective tree, but containing 7 m or more (1½ logs) of straight bole above buttress.
4	A basically sound tree, with minor defect, and at least 2 logs in the bole of 4.3 m each.
5	A completely healthy tree with completely straight bole and no sign of decay or damage and a clear bole of at least 9 m length (2 logs).

Table 1 Silvicultural condition codes for stock survey (trees 50 cm+)

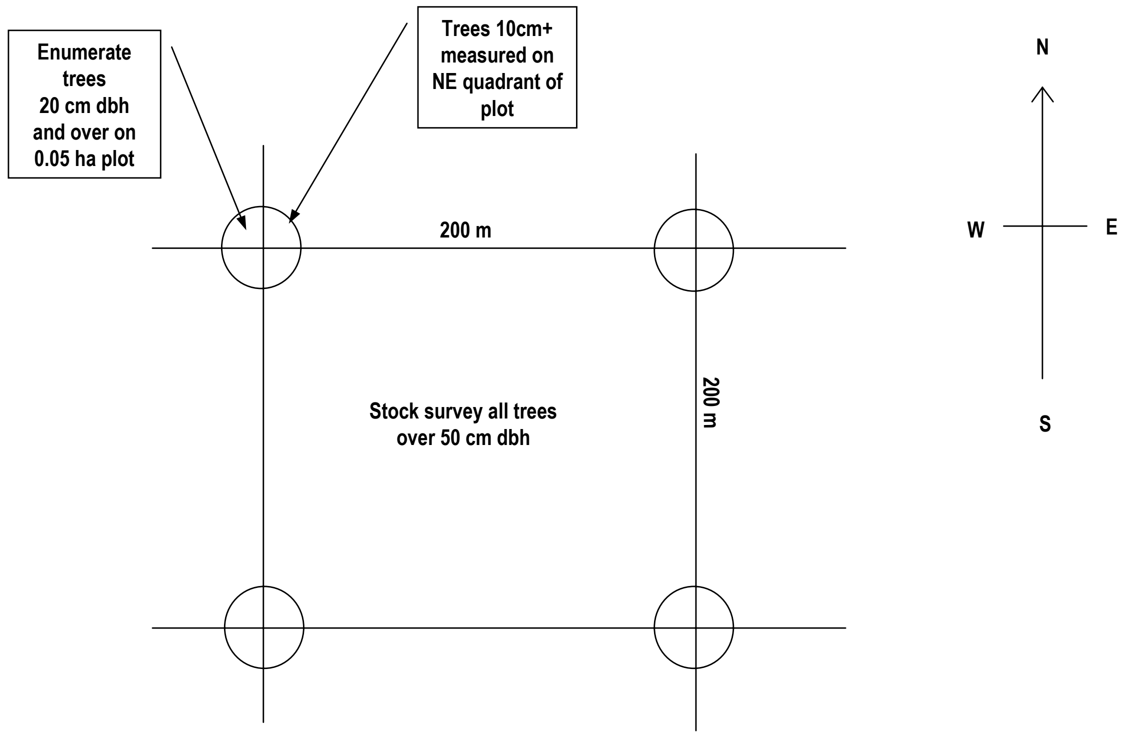

Figure 3 Layout of management inventory plots with stock survey lines

3.4.3 Analysis and silvicultural decision-making

A series of decision rules should be applied to select the number, species and location of trees to be harvested, and to specify other silvicultural operations including the felling of useless and severely defective trees (relict trees), and designation of blocks where enrichment planting is needed.

These decision rules will require to be fine tuned and given a logical form that can be applied automatically by a computer program. The following are the general criteria:

- Gaps created by felling should not exceed 30 m across with a matrix of undisturbed forest between. Trees to be cut should be spaced out to avoid this.
- Total harvest should be limited to about 15 m3/ha bole volume (3 m^2/ha basal area)..
- Poorer quality trees should be given priority for selection. Better quality trees should be retained.
- Where inventory plots indicate insufficient advance growth, harvesting intensity may be reduced or enrichment planting specified.

Results from the PSPs and growth modelling studies are required to fine-tune these rules. However, there is sufficient data from modelling studies elsewhere for provisional guidelines to be developed. There is also a need to keep records and make surveys of felling damage in order to develop functions appropriate for pit-sawing and use of mobile sawmills.

It is suggested that computer software should be commissioned early in the next phase of the EC Forestry Project which would process the stock surveys and inventories and provide the following facilities and outputs:

- Stock maps on various scales (from block to compartment per A3 sheet) directly from field data forms.
- Block summaries in thematic form at the compartment level, showing stock density, species distribution, and codes for harvesting, culling and enrichment planting recommendations.
- A user-definable and modifiable set of decision rules that would allow constraints and silvicultural practices to be easily changed without programming knowledge.

The consultant would think that developing this software, testing it against field operations, and undertaking training and documentation would require 3 months by a suitably experienced specialist.

4 Silvicultural observations

4.1 Enrichment planting

Although the consultant has hitherto tended to be sceptical about the merits of enrichment planting, various cases have been cited to him of successful examples. In Budongo, he was shown plantings of *Khaya antotheca* in 1963 which were of the order of 60-70 dbh. Unfortunately these had been destroyed by illegal pit-sawing in 1997, but the stumps and residual logs were apparent from numerous trees of the group.

Enrichment planting is not bound to succeed. It requires good quality growing stock, appropriate nursery and planting methods, establishment in large gaps, and tending for 2 years or more to remove weeds, competing re-growth, and climbers. However, where it does succeed, the results can be spectacular and transform the economic prospects of the natural forest.

The integrated management system (ISM) described in section 3.4 above would identify sites for potential recruitment planting as areas of low advance growth stocking and the absence of valuable mother trees. The management inventory would also in future indicate the presence of successful plantings and conserve them by diminishing or prohibiting felling in immediate vicinity. The mapping of plantings would facilitate the logistics of tending operations.

4.2 Forest stand improvement

Forest stand improvement implies measures to improve the size-class distribution, species composition and genetic population of the forest to enhance future productivity. Conventional tropical selection logging by size class alone tends to cream the most valuable trees, is indifferent to variations in forest structure, and is strongly dysgenic (*ie*. leads to rapid deterioration of the gene pool by continually culling the best elements of the population).

The proposed ISM would be set up to counter these tendencies. Felling would select the poorer stems and less valuable species except in areas where there were sufficient good quality advance growth. In areas of low density or inadequate regeneration, felling would be reduced and enrichment planting recommended.

Relict trees (Silvicultural condition code 1 in Table 1) would normally be recommended for culling, of felling to waste.

The application of these measures over several cycles would lead to a continuous improvement in the appearance, productivity and genetic quality of the forest.

5 Growth modelling

5.1 Objectives: Analysis of management options

Because forestry is a long-term activity, models are needed to indicate the results decades hence of current actions. This is routinely undertaken in forestry using a variety of graphical and computer-based methods. However, tropical forests represent a special challenge because of the complexity of the ecosystem, the measurement difficulties involved, and the wide variety of management choices.

Typically, a tropical forest model (TFM) should allow choices to be made about felling cycles, species selection, and size limits. It should show the results of these choices, in terms of the future growing stock, 100 to 200 years hence in order to indicate the sustainability of any given silvicultural system.

5.2 Methods of constructing models

It is not possible in this short report to explain all the possible approaches to TFM development. Most published work is more or less academic in nature and of little value for management purposes. The outstanding exception are the various publications by JK Vanclay regarding the Queensland rainforest model NORM.

The consultant has adapted Vanclay's work through several models for different countries: CAFOGROM for the Brazilian Amazon, SIRENA for Costa Rica, MOSQIRO for Quintana Roo, Mexico, and PINFORM for Papua New Guinea.

These models are written in Visual Basic using Microsoft Excel, versions 5 or higher. They incorporate species mean growth and mortality rates, and stand level functions for recruitment rates and density factors to limit growth. The many species in the forest are grouped into growth classes using a simple ordination method. Logging damage functions are incorporated based mainly on empirical studies in Costa Rica, Surinam and Brazil.

The basic requirement is a minimum 3-5 years good quality PSP data from 50-100 sampled hectares. This data must be complete in its coverage of species, and should sample all trees down to 10 cm dbh. Good quality control and data entry standards are essential as otherwise the data may be unusable.

The analysis and model development and testing process typically requires about 3 months work

5.3 Demonstration of the PINFORM model

The PINFORM model was developed in early 1998 for the Papua New Guinea Forest Authority. It is based on 72 PSPs established and re-measured between 1991 and 1997 with a wide geographical coverage of the lowland natural forests. Data analysis and model development required some 4 months. The entire project was sponsored by ITTO and executed by the PNG Forest Research Institute in Lae.

A demonstration of this model is scheduled for 18th September as part of this consultancy.

5.4 Recommended work under the EC Forestry Project

As has been noted earlier in this report, 100 PSPs should be established to gather data over the 5-year period of the forthcoming EC Project. This work can largely proceed without external specialist inputs. However, the following key stages will require some assistance:

- As soon as practical, development of basic data entry routines including data checking. This process should be combined with a fine tuning of the field operations and forms. Two to three weeks should be sufficient for this work.
- In the second year of the project, 4 weeks should be allocated to design forms, software and procedures for re-measurement. This will include a review and check of the data gathered to date and should occur when the re-measurement process is about to start.
- In the third and fourth years, 2 weeks each should be scheduled to review the data acquired.
- Early in the final year, subject to sufficient PSPs having been re-measured, the analysis and growth modelling proper should be undertaken. Three months should be allowed for this work.

6 Conclusions

6.1 General assessment of operations

The consultant found that the various operations seen in the field, for PSP establishment, stock survey, and forest inventory, were being performed effectively and thoughtfully. Although he recommends some changes, these are mainly in the nature of improvements to systems that are already reasonably functional.

He was particularly impressed by the synthesis of these methods to an effective whole for forest management and conservation. This includes a thorough planning process, boundary demarcation and survey operations on the ground, and an evolving but clearly useful method for controlling pit-sawing and expanding the use of hitherto little-known timber species.

His main concerns related to the lack of a silvicultural element in the stock survey process, and the absence of any strong scheduling or control of felling series (*ie*. The sequence by years over which compartments should be worked).

6.2 Immediate recommendations

The recommendations summarised in this section can be implemented directly, and do not assume future consultancy or material inputs, or adoption of procedural changes in forest management.

1. PSP work should be simplified as discussed in section 2.2, page 2.
2. On the stock survey, blue painted number should be used (page 7 *ff*).
3. For inventories, the measurement of upper stem diameters with the Relascope should be discontinued. The program will automatically apply suitable volume equations based on earlier sampling.

6.3 Recommendations in the context of a future project

The remaining recommendations in this report require some additional material or technical assistance resources, and need to be set in the context of the forthcoming EC Forestry Project.

The following are key points in this report::

- For PSPs, software will be needed for data entry, checking and analysis. This should be developed in phases as required.
- Once re-measurement data is available, a growth model applicable to Uganda's natural forests can be constructed. This will require some 3 months work late in the project life.
- Early in the life of the new project (or as soon as possible) work is required on software and procedures for stock survey mapping and analysis according to silvicultural rules to allocate yields. This includes participating in field trials of the new methods. Some 3 months work is required.

- The software and field procedures for exploratory forest inventories should also be revised, requiring an estimated 2 months in conjunction with field work. This may not be on the critical path of the new project.

Altogether, the consultant sees some 6-8 months of forest biometric consultancy being desirable in the new project, mostly divided between the first and last year, but with some short visits in between.

6.4 Conclusion

This short assignment has been assisted greatly by the discussions with EC Project Forest Management Specialist Steve Nsita and Forestry Department Biometrician David Elungat. District and local forest officers including DFO Masindi Martin Alomu, FO Budongo Stephen Khaukha, DFO Busyeni Levi Etwodu also provided useful advice. The recommendations made remain the personal opinions of the consultant, but have been modified or adapted on the basis of these discussions.

It is hoped that the suggestions may be regarded as useful and a contribution to improving natural forest management in Uganda. The consultant believes that the key recommendations regarding PSP procedures, stock survey and silvicultural management, if implemented, would like to significant improvements in future.

Denis Alder
Kampala
18th September 1998

Appendix A

TERMS OF REFERENCE
FOR A CONSULTANCY ON NATURAL FOREST STOCK SURVEY AND ASSESSMENT

Background

The Tropical High Forest (THF) in Uganda's Protected Areas (PAs) covers about 738,000 ha. About 400,000 ha of this are Forest Reserves managed by the Forest Department (FD). In addition, there is ca 200,000 ha of THF outside PAs.

The Forest Reserves in Uganda have been zoned into production and biodiversity conservation areas on a ratio of 50:50. Whereas biodiversity inventories were carried out in some of these reserves recently (1994-1996), inventories for purposes of timber production and regeneration were last done in 1992 under the Forest Rehabilitation Project (FRP). Even then, few of the forest reserves under natural forests were covered. There is an urgent need to update those inventories as well as have the other areas covered for the first time.

Between 1989-1995, the FD went through a process of re-establishing the boundaries of the most important forest reserves in Uganda, including those with tropical high forest vegetation. This was done through the Natural Forest Management and Conservation Project. Since July 1995 to date, the Project has been going through a bridging period between the old and proposed new projects. During this period, the project has been supporting work in:-

- writing Forest Management Plans (FMPs) for the important Forest Reserves and the corresponding Annual Work Programmes (AWP);
- resumption of silvicultural and other technical operations based on recently revised Departmental Standing Orders (DSO);
- stockmapping in the production zones of natural forests; and
- exploratory sampling in production zones of selected Forest Reserves.

In order to plan and execute operations in respect of this work, information regarding existing volumes, regeneration trends, etc. needs to be gathered. This type of information can be generated through inventories and regular assessment of Permanent Sample Plots (PSP). The last assessment of PSPs was done during the early 1970s. Although work on stockmapping is now going on (over 2,000 ha in 3 forest reserves todate), the cost effectiveness of operational procedures needs to be assessed and improvements introduced if it is to become financially sustainable by the FD.

Over the next 5 years, the new EC-Forestry Project will target the following THF reserves:

Production Areas in Forest Reserves (TRF) of the new EC-Forestry Project

District	Forest Reserve	Area (ha)
1. Masindi	Budongo	24,000
2. Hoima	Bugoma	26,000
3. Bushenyi	Kalinzu	14,000
	Kasyoha-Kitomi	23,000
4. Mukono	Mabira	21,000
5. Kabarole	Itwara	5,000
	Matiri	5,000
	Kitechura	2,000
	Muhangi	2,000
6. Kalangala	5 Forest Reserves	5,000
7. Mpigi	6 Forest Reserves	14,000
Total		**141,000**

Objectives and Tasks of the Consultancy

It is envisaged that the new EC-supported project on Natural Forest Management and Conservation is going to emphasize sound technical operations at the Management Unit level. This will be based on resource assessment practices that the FD can sustain. In this connection, this consultancy will:-

1. Update the FD practices of natural forest resource assessment within the context of Sustainable Forest Management (by the FD).

2. Assist the Project to programme forest resource assessment activities that will be included in the new EC- supported Forestry Project which is expected to last 5 years.

More specifically, the Consultant will:-

- Review the present procedures of the FD (as documented in the DSO and practiced in the field) in relation to stock-survey in the natural forests.

- Recommend simple and cost effective ways of carrying out stock survey/assessment for routine management work in natural forests. Emphasis should be placed on surveys and assessments that aim at improving the economic worth of the timber production zones in terms of species, stem count and quality.

- Recommend where appropriate revisions to procedures and practices within the relevant sections of the DSO.

- Propose ways in which the natural forest timber stocks outside the Permanent Forest Estate can best be surveyed and regularly assessed.

- Suggest and demonstrate appropriate growth modelling methods that the Project should adopt given the data available from past PSP assessments and the new work you are able to propose for the next 5 years.

Appendix B

Permanent sample plot form and notes

The complete form and notes are given on the following page. The notes should preferably be copied on the back of the form upside down, to facilitate reference on a clipboard.

The DSO should be amended to include this form as Appendix V27 in place of the current forms FD54 and FD 55.

Permanent sample plot enumeration form

Sheet of

PSP No.	Forest	Block	Compartment	Enumeration date

OIC enumeration team	General observations	Last meas. year (Old PSPs only)

(1) Quad No.	(2) Tree No.	(3) Diam	(4) Alt. Diam	(5) POM	(6) Crown Illum.	(7) Coded notes/remarks	(8) Old No.	(9) Old Diam

Notes for PSP enumeration form

Notes for main columns

(1)
- For a new quadrat, put the quadrat number on an line that is blank except for coded notes.
- Fill in the coded notes for the quadrat site factors .
- Start a new sheet if only2-3 lines left on form.

(2) Number trees sequentially on each quadrat from the NW to SE corner in a W-E zigzag

(3) Diameter at 1.3 m or above buttress. POM must be painted on tree. Record to nearest mm.

(4) When POM must be moved due to buttress etc., record diam at new POM here after measuring diam at old POM in column (3). When POM is not changed leave this column blank.

(5) Record height of POM to nearest dm except when 1.3 m.

(6) Dawkins crown illumination score on scale (1) fully shaded to (5) emergent tree.

(7) Use tree condition codes as below. Enter long-hand remarks only when no suitable code.

(8) For re-established plots only, original tree number for old LD trees.

(9) For re-established plots only, diameter at last recorded date (year to be entered above cols. 8-9).

Coded notes for quadrat site factors

AG	Agriculture (current or recent)
CT	Climber tangle impeding regeneration
FI	Forest fire indicators (burnt bark etc.)
GA	Gap from natural tree fall
GF	Gap caused by recent felling
LG	Mechanised logging
PL	Plantation or enrichment planting
RK	Rock outcrop
RS	River, stream or lake
SW	Pitsawing or mobile sawmills
UN	Unstocked – no measurable trees. This code must be present for empty quadrats.

Coded notes for tree condition.
To use these codes properly, the booker must examine each tree as it is measured and run down the list for applicable codes.

BS	Broken stump (apparently natural tree fall)
BT	Broken top
CD	Crown damage – major branches broken
CI	Climber infestation – competing with tree crown
DB	Dead bark – areas of bark loss exposing dead cambium
DC	Diameter change – new POM adopted
DF	Defoliation – tree has little or no foliage
DT	Dead tree – tree clearly dead, but standing
DU	Diameter measurement unreliable (due to heavy climbers, very high buttresses etc.).
EX	Excrescences – large wood growths from bole of tree.
FB	Fluted bole – bole is fluted and cannot be well measured.
FD	Fire damage – charred wood or bark.
FU	Fungi – fruiting bodies of fungi on stem or buttress.
FW	Flowering – tree is in flower
IN	Ingrowth – a recruit tree not previously measured.
LD	Logging damage – tree has been damaged during logging.
LS	Logged stump – sawn or axe-cut stump
LT	Leaning tree – tree partially uprooted
NT	No tree – Tree completely missing
OD	Optical diameter measurement – large high buttress trees measured by Relascope
RB	Rotten buttress – Base of tree largely rotten
RT	Rotten timber – rotten branches, hollows, etc. on main bole.
ST	Strangled tree – Tree largely dominated by strangler
TF	Tree fallen and on ground.
US	Uncertain species – identification given is best guess.