2. TECHNICAL ASPECTS

1. CONCEPTUALIZATION BEFORE FIELDWORK
2. PREPARATION FOR FIELDWORK
3. FIELD EXECUTION
4. TREATMENT OF DATA
5. PRESENTATION OF DATA IN TABLES AND MAPS

Some technical challenges faced in the context of forests to be co-managed between government and villages include

- finding ways to incorporate indigenous knowledge into numbers-oriented work,
- raising competence of Forest Department and auxiliary personnel in classical data collection and treatment methods,
- presenting data in ways that are understood by both foresters and villagers, and
- presenting data in ways that are useful to development of the management plan.

The following sections are addressed to the inventory planner of a project who must answer these questions. It is assumed that the planner will be instrumental in getting competent field crews together, but the planner does not need to be present for every field plot as long as the field crew is subjected to periodic quality control.

One of the planner's roles is that of communicator: going between the realities of fieldwork, the village farmer's schedule, and demands made by project deadlines. These considerations have been addressed in the previous chapter. This chapter is a synopsis of more technical issues faced by the planner in the quest to produce useful results in little time.

2.1. CONCEPTUALIZATION BEFORE FIELDWORK

Planning a forest inventory requires thinking about the whole process and where it fits into the whole scheme of forest management and product harvest. This allows appropriate amounts of time and resources to be allocated by everyone from the ministry to the village level. Planning allows sufficient time to arrange logistics, execute fieldwork, analyze data, and present findings back to the participants. In more detail, planning requires deciding on the configuration of plots and formulas, measurement methods, software, training format, and maps. Most importantly, it requires knowing what the data collected will be used for, whether they be for baseline, market study, research, or updating.

"Sampling" refers to measuring a part of the forest so that the whole can be described – since no one has time to measure every tree. An important point is this: it is not necessary to tie an inventory to sampling a percentage of the area of the forest -- 10%, 5%, even 2%. It is more important to sample based on the variability of the forest composition, and on the level of commercial activity that will result from inventory results reported. To this end, it is always best to stratify a forest from photos or imagery as part of the inventory planning.

Recall the objectives of a forest inventory

For "participatory" or "joint" management projects, a forest inventory is nowadays more than just a timber inventory. But it is still geared toward producing estimations of averages, and plus-or-minus estimates around the averages. Why? Because an **average of something per hectare of forest times the number of hectares in the forest tells you how much of value is in that forest.**

> Two elements are needed for ideal management planning: (1) averages per hectare, and (2) number of hectares.

Estimated averages of "trees per hectare" or "product per hectare" must be complementary to information gleaned from a preliminary RESOURCE ASSESSMENT or socio-economic study carried out with participating villages before the actual field work is planned (see section 1.1. above and **Annex 1**). From the resource assessment, important trees and nontree products inside the forest are identified so that the inventory plan can be adjusted to quantify them as much as possible. An example of using the preliminary assessment would be the identification of *Sclerocarya* as an important food crop tree, leading to the physical location of the area in the forest where those trees are located, then mapping the stand in question. Another example is finding out about the importance of bamboo, then seeking a way to quantify bamboo stems at the same time that plots are being sampled. Thus, the inventory really starts with a more subjective assessment before it progresses to the numbers-oriented phase.

GENERAL OBJECTIVES

It is worth recalling the usual purposes of the numbers-oriented forest inventory:

- In a first instance, it can be a baseline study of average values against which to measure changes in quantity or quality of forest resources in the future.
- It can be incorporated with necessary updating old information on roads and villages, such as that typical on topographic maps.
- It produces data in tabular and mappable form that can be used to plan production or conservation activities.
- Depending on the level of detail, it can be used to identify resources that need further precision and quantification.
- It results in knowledge of <u>where</u> resources are located in a forest, <u>how much</u> is out there, and ultimately <u>who</u> is in a better position to manage them.
- This knowledge can be used to calculate financial worth of the forest now and in the future, if sufficient and appropriate auxiliary information is collected.

In the context of African forests and co-managed forests in which Forest Department and other government personnel must work with adjacent village-based forest committees, we can add:

- Suspicions that villagers often hold toward Forest Department personnel, whose main role in the past has been to repress, can be assuaged as they participate in data collection and see how the data are used (this objective was discussed above).

Data collected are not restricted to timber products, thus the information interests everyone involved in the management plan.

SPECIFIC OBJECTIVES

One of the critical steps to take in conceptualizing and planning an inventory is to define what information you are after. Here is some advice for the objectives:

STATE OBJECTIVES IN DETAIL: Before any inventory is undertaken, the specific objectives need to be stated clearly in an INVENTORY PLAN (covered below). It is not enough to say, "The inventory is to fulfill state regulations for management planning", or, "Concerns of the populations must be taken into account." It is more practical to say, "Tables are needed that describe the number of saw and honey trees per hectare by 2-centimeter diameter class and species", or "A list of the geographical coordinates of point resources is to be produced", or again, "The total number of bamboo stems exploitable in the next ten years will be estimated".

It is worth mentioning that a simple basal area calculation is not sufficient for planning specific management actions. Since the village users see a tree as a tree and not as a fraction of a square meter or cubic meter per hectare, it is more useful and easier to explain the number of trees by size class found on a hectare or per unit of land area with which they are familiar.

GET THEM FROM THE SOURCE: It is usually assumed that the forest inventory will include some estimation of sawtimber, whether the data are used to justify an actual sawing operation or to justify not sawing. In addition to the sawtimber, there is going to be a variety of other products, given the diversity and multiple uses of trees in natural forests. As mentioned above, if you begin with a **well-planned** participatory resource assessment or some similar study carried out in a sociological context, you will have already a list of the principal resources that are economically important to the people involved in the management of them. This information should be used to determine what resources to look out for in the more numbers-oriented inventory. Some participatory tools for identifying important resources are included in **Annex 1.**

BE REALISTIC ABOUT WHAT CAN BE ACHIEVED: It is easy to make a wish list of what you would like to have in tables and on maps. In the context of finite projects, however, those deciding on the objectives need to be mindful of time and terrain limitations that set up the inventory for failure when overambitious goals are set. The classic example is the so-called "percentage sampling" in which some named percent of the forest area must be measured at all cost. The inventory crews of rugged forests will attest to the absurdity of this goal in forests with sheer cliff faces on one hand and hundreds of hectares of fields on the other. Cliff faces and fields would be among the lowest-priority areas for plot-based sampling.

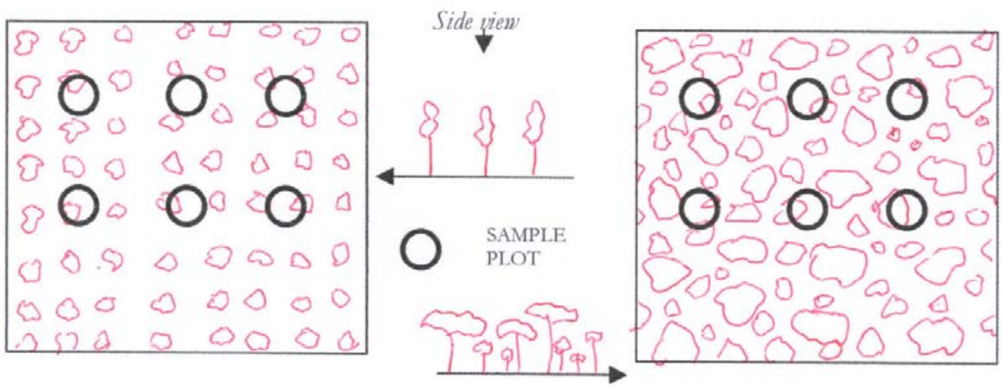
Along the same lines, conceptualization of the measurement process should guard an attitude of getting the necessary and no more. It is tempting to think that as long as you are doing those transects, you might as well collect such-and-such information, when, in the end, that information will not be useful to the management plan. By the same token, time could be used up in the field to collect information in an erroneous fashion that does not lend itself to further estimations of means. To quote from Freese,

> *Collecting data and then asking someone how to use it is a good way to lose friends and waste survey money.*
>
> *- Frank Freese, 1962:*
> *US Forest Service Agricultural Handbook No. 232, page 77*

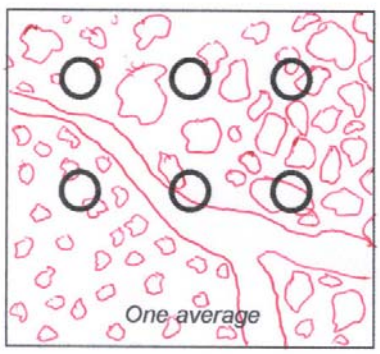
Stratification is a given

NOTE: A statistical sample with plots located randomly or systematically within separate homogeneous (stratified) stands <u>is superior to</u> a blindly systematic sample. When conceptualizing, think that it is necessary to stratify a forest containing more than one vegetation type before inventorying it; this is the only logical way to describe different potential uses of the land according to location.

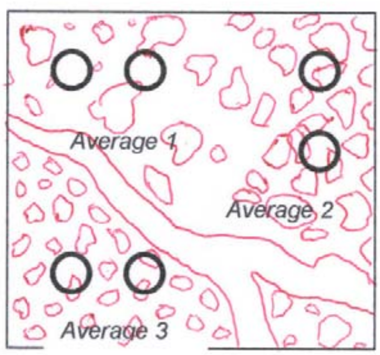
Consider a graduation of increasingly complex forests composed of one to several stands. Placing sample plots in a systematic arrangement is okay as long as the trees in the forest are arranged homogeneously across the landscape: the average of, say, cubic meters per hectare will reflect about the same number no matter where the plots are placed (figures below show tree crowns):



In a non-homogeneous forest:



A bad arrangement of plots



A better arrangement of plots

In sampling, anything that you can do to reduce variability in calculating averages will lend credibility and precision to the results. Prestratifying is the first, most obvious way to reduce variability. The end result is a set of tabular results that applies to a visibly distinct area of the forest. Area-specific tables allow harvest planning based on actual numbers of trees on the ground. **Tables that jumble together trees per hectare for an entire forest of thousands of hectares, without distinguishing densely-stocked areas from fallows from special-use areas, are not ideal for management planning.** The margin of error will be too wide.

You need aerial views of the forest to stratify it. It is practically unheard of to have no access to photography. Even 20-year old photos can (and must) serve if necessary, because there are always certain features that will be unchanging landmarks. But ideally, you will at least have had a chance to order a SPOT image a few months in advance (see following). Even flying over the forest with a video camera to identify where to sample will be better than a strict systematic grid.

If you simply cannot get a photo, you will be obligated to do the systematic sample, so that you can make yourself a stratification of the forest. Then relatively narrow transects (a few hundred meters apart) can be used, but you may still miss important but small forestry formations. This method of mapping and inventory should be avoided if at all possible.

Ordering maps and photography or imagery; desktop GIS

MAPS

From the very beginning, you can be sure that forest management will require information on forest areas (hectares) and village locations (to identify participants). This information is typically gotten from topographic maps and aerial views that facilitate inventory and mapping for the management plan. Chances are that a government survey department has topographic maps at 1:50,000 scale for sale at affordable prices. At least two sets should be ordered, even if they are old: one for carrying in the field, one to keep unfolded and clean for the office and tracing into GIS system.

AERIAL PHOTOGRAPHY

Often the government survey offices also retain old aerial photography negatives that can be re-developed at various prices depending on demand: I have seen prices between $5 each and $25 each for not-so-recent views. This could be the fastest option, depending on the local bureaucracy.

Ordering **new** photography of your forest often requires getting a specialized company to travel from another location and can run into several thousand dollars for a 50 000 hectare forest.
It would be up to the manager and the Forest Department to determine if this cost is justified for the project at hand.

> *The cost of aerial photography or imagery, like the cost of inventory itself, is part of the cost of maintaining a "public good" and should not be expected to "pay for itself" in developing countries any more than it is self-supporting in "developed" countries.*

The resolution of aerial photography, which should be ordered at the scale of **1:25 000** for best economy and for potential overlays with satellite imagery, is good enough even to count homes in villages and see tree crowns with magnification applied. Areas of great interest can be "blown up" to 1:10 000 or even 1:5 000 scale as needed. Each person's house can be seen, and villagers appreciate these views greatly. (However, in places like the U.S., it brings up a privacy issue.)

The other disadvantage with aerial photography besides the cost is that you end up with radial and topographic distortions due to the physical characteristics of the camera lens and terrain. Sometimes, especially on mountaintops, the scale is even twice what it is on surrounding lowlands, so finding your ground location with these photos is error-prone. Photos need to be corrected digitally to eliminate this effect, which is another expense.

The irregularities in interpreting classical aerial photographs can be addressed by drawing watercourse and road templates from the topographic maps (which have geographically correct positions for major landforms), choosing "control points" with known coordinates off these templates, finding the same control points on the photography and on the ground with GPS, then "stretching" tracings off the photography so that the major features and control points overlay onto each other. It is a time-consuming process that requires special software and a lot of computer space and expertise. However, it is not impossible.

SATELLITE IMAGERY

For forest-level management, 30-meter resolution (the LANDSAT standard) does not allow visualization of cut-over areas, roads, and individual fields. It is more appropriate for regional studies and monitoring at scales of 1:100,000 and smaller.

A better option for forest-level inventory is **panchromatic** SPOT imagery at a scale of 1:25,000. Some panchromatic (black and white) imagery has 10-meter resolution, sufficient for tracing encroached fields, wide paths, villages, individual fields, outcrops, and watercourses. It can therefore provide a substitute for aerial photography as long as individual homes and tree crowns do not need to be counted.

SPOT panchromatic imagery with 10-meter resolution and 60-kilometer-square views is large enough to cover forests of several tens of thousands of hectares in size at a relatively affordable price. Multispectral, or color, versions have 20 or 30-meter resolution, not as useful at 1:25 000 scale. Type maps can be drawn around homogenous stands if you use **simple** grey-tone, texture, and landform criteria for differentiation.

One of the best features of this imagery is that you can order it **digitally corrected** to match the local topographic maps by providing them to the supplying outlet company for level 2B processing. The processor uses control points from the topo maps to register features on the image. Then any features traced from the image (new roads and villages, shifted watercourses, field and forest boundaries, vegetation types, land occupation, historic sites) can be added into a GIS file with that same topographic map as the base, and a perfect overlay is achieved.

Another feature is that you can ask SPOT to "**program**" the satellite to record data using your area of interest as the "centerpoint". Satellites circle the globe each few days; when the satellite passes over your area during the next possible clear-weather day, you have a view of the forest that is less than a year old.

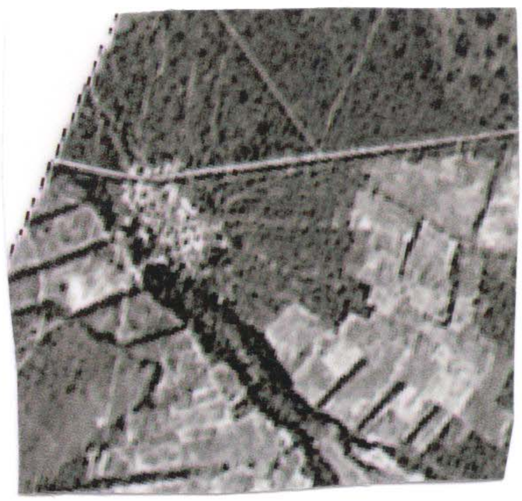
If you order **hard copy** of the image at 1:25 000 scale, it cost around $3500in 2003, plus $500 for a second copy. They arrive laminated with a thick plastic that allows one image to be cut up into pieces suitable for fieldwork, and the other image to remain whole for display in the office. The field copy is rugged enough to **carry** everywhere during the sampling fieldwork.

A **digital version** can be ordered instead at a higher cost, but then you will need a higher level of technical expertise to process it, a huge amount of space on your hard drive, and a printer big enough to cover your forest at the working scale. In addition, it is hard to laminate photography by hand. The advantage would be that you could print out as many copies as you like within the limits of your printer. My view is that **time and trouble can be saved by ordering hard copy at Level 2B processing** and learning to work with that medium.

In summary, LANDSAT color (multispectral) imagery at 30-meter resolution, or SPOT multispectral imagery at 20-meter resolution, is not useful or cost-effective for management **at the forest level**. You only need 30-meter resolution if there is a *landscape-level analysis* component to your project. It has been documented that multispectral images, when classified by vegetation type using spectral signatures, often confuse fallow fields with wooded savannas. Resolution is also insufficient to capture individual fields and smaller roads and villages, which are key elements for making management maps of soil occupation and forest use. The color is a selling point, but it is not as practical as the higher-resolution imagery.

Addresses for image products are given in **Appendix 2**.

1:25 000 aerial photograph…….



and 1:25 000 SPOT image (panchromatic, 10- meter resolution)

GEOGRAPHIC INFORMATION SYSTEM AND CARTOGRAPHER

Desktop mapping is the way to go for these forests if budget can allow the $7000 or so investment in software, large-format printer, modest digitizing pad, and computer (see **Appendix 6 typical costs**). GISs are now much more user-friendly than they used to be, and computer capacities are much bigger, facilitating map file storage at the project or in Forest Department databases. My personal experiences with ArcView and MapInfo have been favorable, and the softwares are widely used in Africa.

A convenient and relatively inexpensive roll-up digitizing pad allows tracing features into the software and is adequate for forest-level work. For longer-term and constant use such as in a Mapping Office, the solid adjustable digitizing table may be more appropriate.

For map production, it will be necessary to hire someone versed in computerized cartography: It doesn't make sense any more to map by hand, and as mentioned, there is a growing body of able nationals in this domain. The cartographer can be made responsible for photo or image procurement, follow-up, and storage.

Ideally, the cartographer will be deeply involved in inventory and in getting referenced points and trails with the Geographic Positioning System receiver. S/he will also be the one to collect field-based GPS units regularly and put them into the individual forests' databases. It should be noted that **the cartographer does not work alone.**

> The essential for the project/ forest planner is to *communicate adequately which features are needed for the management plan* and to *direct the cartographer as to which field activities they should conduct.* It is not the cartographer who dictates the needs of the forester or planner.

Digitizing is a skill that can be learned quickly by interested Forest Department personnel. There will be a certain amount of drudgery involved in tracing features of topographic sheets, but it is worth it to have geographically-referenced features that will tie together road, watercourse, surface feature, village points, and vegetation type overlays. Topographic maps can also be scanned and used as background controls for new field work, which requires linking up with more sophisticated regional mapping offices -- a less rare possibility these days.

GPS VERSUS COMPASS

Both the GPS and the compass can be useful and complementary. You can plan on finding office-located plots with GPS by plugging in coordinates determined from the office or on the ground from known reference points. You can use the compass WITH PROPER DECLINATION to find office-determined plot centers as well, to check on uncertain GPS locations, and to run short distances (which are not reliably tracked with the GPS).

> **COMPASSES MUST BE OF THE "GLOBAL NEEDLE" TYPE, which has a special needle and liquid medium for working outside of temperate zones.** Otherwise, the needle will attempt to pass through the center of the earth to reach north, hanging it up on the compass's plastic surface and threatening to put you seriously off course.

If you plan to use GPS heavily, a careful training program needs to be run for the field personnel operating it; there are several pitfalls. Training should be held contemporarily with instruction on compass use and navigation to plot centers. (See **Appendixes 3 and 4**.)

Sampling scheme based on terrain and time

It is assumed that the object of the inventory involves calculating means from plot data. There are two objective ways to locate plots in nonlinear vegetation formations: randomly and systematically. **Systematic** location takes less thinking in the office and field. However, when the terrain is very rugged, following systematic lines between plot centers may require unnecessary physical hardship and even danger. **Random** location allows more creative solutions for reaching plot centers chosen in the office, and it allows more plots to be measured each day if clustering is used. Either method allows calculation of valid statistical means and standard errors.

For linear vegetation such as riverine or gallery forests or windbreaks, a "subjective" survey will have to be made: either a walkthrough with a list of species and sizes, or a series of cross-strips of predefined widths, depending on the width of the gallery. The gallery will most likely be preserved as wildlife habitat (in which case the list survey is made) or converted to specialized crops requiring nearby water table, such as rice (in which case a 100% census of trees planned for cutting would be made). In some cases there could be a partial harvest, in which case only the **timber marked for cutting** would be censussed.

PLOT LOCATIONS

RANDOM SAMPLING, SIMPLE OR IN CLUSTERS: In forests with poor accessibility due to roadlessness, water, and cliffs, it is expensive to get to some plots. One solution is to **randomly choose "primary" plots in the office and then take several systematically-located "secondary" samples off the primary in the field**, so that a minimum of time is spent traveling to plots. The method is described further in Lund and Thomas (1989), the Mémento Forestier, and Shiver and Borders (1996). The US Forest Service has configured its national inventory in this way for a few decades. It is called cluster or two-stage sampling. Formulas from Shiver and Borders can be used to analyze the data from cluster plots. This method makes a lot more sense than trying to run straight lines through treacherous terrain, often just to end up in a fallow field.

Alternatively, plots can be chosen at random in the office off the stratified vegetation map, then executed directly in the field without adding secondary clusters. The plots are simply chosen with a random number table from numbered intersections of a square grid placed over the forest map. Either way, a GPS, 100-meter tape, and a compass are used to locate the office-selected plots.

SYSTEMATIC SAMPLING: Sometimes there is just no one available who is confident enough with random selection of plots to do a random inventory. If this is the case, it is still okay to do a systematic sample after the forest has been stratified. But **it is not necessary to depend on sampling a certain percentage of the total forest area.** Stratifying will already have helped the variability to be kept to a minimum, and we will see later that a time limitation can be more important than an area limitation.

If a systematic sample is laid out in each homogeneous forest type, it is desirable to

- measure fixed radius plots in shrub-dominated types and for regeneration, and
- use variable-radius or relascope plots (described below) in tree-dominated forest.

The methods can also be combined during inventory, as long as the procedures are decided in advance and adhered to throughout the forest and throughout the inventory.

The advantage of the systematic sample is that you can point your field crew in a pre-measured direction and tell them to go, stopping every so many meters for a sample. Even so, you need to know just where you are in relation to the stratified forest map in order to be able to describe the vegetation reliably. GPS and proper notetaking and compass work help with this.

PLOT MEASUREMENT

VARIABLE PLOT RADIUS METHOD: Another time saver, once the plot center is reached, is the variable plot radius (VPR) method of sampling. This method uses a glass wedge or a Bitterlich relascope or similar instrument to count trees at plot centers by "probability proportional to size": the larger the diameter, the more likely the tree will be counted in the plot, but also the less weight the tree has in the final calculation of average trees per hectare. The method allows calculation of basal area, trees per hectare by diameter class, and volume of sawtimber per hectare.

Although the technology has been in use since the 1950s, many foresters are not comfortable with it because of the need to apply an "expansion factor" to trees counted "in" the plot in order to find the average numbers per hectare. In traditional "fixed-radius" plots, it is obvious that if you use a tenth-hectare plot, the "expansion factor" is 10 for each tree counted. In variable-radius sampling, the expansion factor is equal to (band number used in the relascope) divided by (individual counted tree's basal area). For a two-factor prism or band that registers one 10-centimeter tree "inside" the plot, the 10-centimeter tree represents (2 divided by (pi x $(.05m)^2$) = 255 as one estimate of 10-centimeter trees per hectare. The average number of 10-centimeter trees per plot (the total number of 10cm trees divided by the total number of plots) is then multiplied by 255 to come up with an average number of 10-centimeter trees per hectare in the entire stratum. The standard error of this average is calculated using the usual formula (standard deviation divided by square root of the number of plots), with each plot's represented 10-cm trees as the individual observations.

The band number to use depends on sizes and spacing of trees in the stand being sampled. Practitioners prefer to register a range of 2 to a dozen trees per plot for practical reasons. More is explained on this method in Dilworth (1981) and Avery (1975).

Usually the VPR method is quicker than fixed plot sampling and a crew can complete 8 or 10 of them in a day.

NOTE: In fallow areas of forest, it is more logical to install fixed-radius and regeneration plots only. If the fallow is already beyond head-height, a plot count with relascope band one may be tried.

FIXED PLOT RADIUS OR RECTANGLE METHOD: The more traditional plot measurement is based on a fixed radius usually stretched out with a 30-meter tape. A maximum size in rugged terrain is probably a tenth-hectare plot, which requires stretching the tape out to

17.8 meters around the plot center. A twentieth-hectare has a 12.6-meter radius. If tree spacing is very wide, a larger plot (one-half hectare, or 39.9-meter radius) should yield less variability. However, the larger the plot, the more time it takes to complete the plot and the more important it becomes to adjust correctly for slope distances.

Rectangles that are placed along a walked transect can also be used. Their advantage is that a set distance off the centerline (identified by the already-laid-out 100-meter tape) can be easily measured off by a smaller tape to count all the "in" trees. For a tenth-hectare plot, 100 meters by 5 meters on each side of the centerline is reasonable.

The advantage to seek in either method is to minimize the frequency of stretching out the tape to check whether trees on the limit of the plot are in or out. Time should not be overspent on simply going around obstacles (other trees) while determining "in" trees.

NESTING PLOTS: To measure regeneration – a critical aspect to predicting future crop trees and forest potential – it is common practice to use a smaller, nested plot within the larger one. A convenient measured radius out is probably between 3 and 5 meters. Everything should be counted to a predefined upper limit.

In principle, a minimum-diameter tree will be defined for the large plot, and the regeneration plot will pick up the remaining smaller-diameter trees. *No age class should be omitted from the sampling.*

MEASURING SPECIAL RESOURCES: There could be resources other than woody ones to be measured from the plot center. Some examples:

- For the broom-bush of Zambia: using the regeneration plot, the number of brooms was recorded in classes corresponding to number of live buds on the plant.
- For bamboo: some method of counting stems per tuft of a certain size would be appropriate.
- For wildlife: it is also possible to incorporate a wildlife survey into the tree-oriented survey by using sighting distances to animals or their signs (Buckland et al. 1993).
- For grasses: A pasture study using another nested plot is possible if grasses are in high demand.

For these resources, technical discussions of growth and ecology habits of the resources in question should be held with local users of them. Some sort of sampling idea could come to light that can easily be incorporated into the tree-measure study.

Alternatively, discussions with user groups could lead to the conclusion that a given resource's importance and spatial distribution warrant a separate study.

Calculation of number of plots to sample

There are formulas for calculation of number of plots to sample in a forest of given variability. The formulas are based on (1) the variability measured in some test plots and (2) the error that you are willing to accept in the final estimation of the mean. **They do not depend on the total number of hectares visited in relation to the total area of the forest.**

The formula is typically

$$\text{plots to sample } n = t^2 s^2 / E^2$$

t is an expression of confidence that the true average is within the estimated range;
s is a measure of the variability of the stand; and
E is an expression of the amount off the true average you are willing to be for a given estimation.

In the case of a pre-stratified forest, each homogeneous vegetation type ("stratum") is treated as a separate forest within the whole, getting its own descriptive table. (The stratum might consist of several stands of some type of savanna, of one homogeneous multispecies forest stand, or of a pure stand of some species identified from the photography.) In addition, some strata will be harder to access on the ground than others. Therefore, it is preferable to calculate an allocation of time and personnel that takes into account both variability and cost so that all strata are sampled with an appropriate number of plots. Luckily there are formulas for this as well. The allocation formulas make use of, again, stratum variability measured in some test plots, and of the total number of potential plots that could be selected for measurement if the whole stratum were divided up into sample units.

In some ideal world where funds, time, and personnel are infinite, a forest inventory planner could always depend on these formulas to calculate a number of plots to meet criteria set ahead of time. However, in the context of the constraints of projects and Forest Departments, we need another method to calculate that number. In the very words of the Chef de Section Inventaire of the National Direction of Eaux et Forêts of Republic of Guinea:

> "Inventory is a function of TIME and PERSONNEL… everything depends on the people funding the inventory…."

In the context of the jointly managed forests and of project time constraints, I propose the following method: The total number of plots is to be calculated by the formula

NUMBER OF FIELD TEAMS
X
NUMBER OF PLOTS EACH TEAM CAN DO EACH DAY
X
NUMBER OF DAYS AVAILABLE FOR THE INVENTORY

A reasonable guideline is to use about a month to six weeks of time or 30 field days for a descriptive inventory of 10,000 to 50,000 hectares. Everyone has other work to do in the year, and after a month everyone will be ready to move on to another activity. It will be discovered during this inventory whether more inventory is absolutely necessary in specific areas of interest.

It is reasonable to aim for having around one field team of 4 or 5 persons per 20 000 hectares. You still should have an idea of the variability of each stratum before finalizing the workplan. This can be gathered at the time of plot testing or using some standard method of estimating it from aerial photography or previous inventories. **The variability can be based on the prism**

counts, sample plot trials, or average tree counts in each stratum during a two-day exercise in the forest. Use these averages to calculate a standard deviation. This will provide the basis for your allocation of human resources. Once you have the variability and a rough estimate of number of plots, you can then allocate the plots based on an allocation formula described in **Appendix 5**.

In general, the more variable the stratum, the more plots it should contain; yet the more inaccessible the stratum, the fewer plots it should contain.

An easy way to estimate variability is to walk through each stratum with the relascope or prism and visit several widely-spaced "practice plots". Count and mark down the number of "in" trees for each plot., by stratum. Use the calculated variance (by the standard formula) of the number of "in" trees per plot in each stratum as the measure of its particular variability. For fixed-radius sampling, you can use the numbers of trees counted per plot on several practice plots in each stratum.

Permanent plots

It is advised to establish "permanent" plots that can be remeasured at the least during the life of the project, if not beyond, to get an idea of growth rates in the local area. Data pertaining to 4 or 5 years of growth is like gold in places where no data exist at all.

In any forest with a cutting component to its management, **sustained yield, allowable cut, and regeneration** will necessarily be elements that will have to be either estimated from another source or calculated from the area itself. This can be applied to sawtimber, bamboo, firewood, poles… about any species whose economic importance is based on complete harvest and regrowth. It is not complicated to set aside an area of the forest to revisit, as long as local communities are made part of the decision on location and purposes. Guidelines are available from IUFRO (address in **Appendix 2**). At a minimum, diameters to the tenth-centimeter and heights to the nearest meter should be measured accurately and at the same month each year; and azimuths and distances from plot center to trees should be recorded.

If permanent plots are not feasible, then from the beginning of the project, it is worth the effort to establish a crew of local "monitors" that can record quantities of sawn wood from trees of given diameters at local mills or small enterprises. Monitors could also follow forest users as they harvest bamboo or other products, promising immunity from any perceived illegal action in exchange for yield information.

Getting field crews together

One project person would be the office liaison to the field crew or crews.

An ideal field crew will be composed of

- one or two field-based government foresters to operate equipment and navigate, detached for the entire period of the inventory;
- one project representative if there is a field person available to help navigate, translate, and be a buffer between government and village levels;
- one local sawyer for sawtimber and other product estimates and measurements; and
- one other artisan or forest user to specialize in plant names and uses.
- If necessary, an armed guard can be retained for areas with dangerous wildlife.

Each crew should be kept to a trim size so that logistics of transport, housing , and availability can be minimized and there are no people standing around during plot measurement with nothing to do. At the beginning, however, there may be interested observers who want to verify what sort of work is being done.

The members of the crew originating in local villages (referred to as "resource assistants" or "resource informants") may need to vary according to the area being worked and the resources of interest. Normally, one source of variability in estimations would be changing personnel too often, so it is discouraged. However, it is even more important to ensure representativeness for all the areas around the forest, so it may be a source of variability that is unavoidable. It can be minimized by

(1) having some kind of screening process of potential resource assistants to select only the most consistent and/or accurate on the crews, and

(2) including all selected assistants in the field training.

What will be done with the data

You will accumulate piles of filled-out forms once the fieldwork begins. Besides having in mind some way to get the data into a software program that can calculate averages, you also need to have a way to organize the sheets so that every plot can be uniquely identified and so that no sheets get lost. When the time comes to enter data into a spreadsheet or database, the process will be a smooth continuum. It will still require a certain amount of quality control, however.

Until a more country-specific software is developed, the most universal spreadsheet in use is Excel. It will be important to have someone available to enter data conscientiously who can also put out the tables that are needed for the management plan.

Trying to re-create the field sheet with all its formatting on the spreadsheet screen is to be avoided.

It is reasonable to reproduce one copy of each filled-in sheet with the photocopier. Thereafter, the computerized worksheet should consist simply of **the first row as headings and the remaining rows as data from the field sheets – one row per plot.**

Use these rules:

- No breaks or blanks between entries, between plots, between clusters.
- Use the Forms command under the Data menu heading to enter each plot's data.
- One "worksheet" or "page" should be assigned to each vegetation type (stratum) that was sampled.

General guidelines in conceptualizing forest inventory:

- Use a stratified map of the forest to plan.
- Get material needs (maps, photos, references, equipment) together a year early.
- Hire necessary and technically competent help.
- Get villager input to see which resources to measure besides timber; decide which resources will be estimated per hectare and by vegetation type.
- Treat each homogeneous stand as a separate sampling unit; then plan plot selection in each stand, either random or systematic.
- Allow more total sampling time and/or crews as stands become larger and more variable.
- Concentrate on assessing regeneration potential, rather than fullblown inventory plots, in the fallow areas.
- Think ahead to data collection and analysis methods.
- Think ahead to mapping needs for the management plan.

2.2. PREPARATION FOR FIELDWORK

Write the inventory field plan

The end result of inventory field planning is an INVENTORY FIELD PLAN. Naturally, deadlines and personnel may change over the course of execution, but there need to be some guidelines set up for the field part of the sampling. The inventory field plan is a separate document that names specifically:

- OBJECTIVES (addressed above in the conceptualization stage; what averages are being sought, what values per hectare)
- TYPE OF INVENTORY (random or systematic; method of stratification, addressed above)
- LAYOUT OF FIELD PLOTS (azimuths and distances to get to the plots, use of GPS)
- ITEMS TO BE MEASURED (following a predesigned inventory form)
- FORMULAS TO BE USED IN CALCULATING RESULTS (or a reference thereto)
- EQUIPMENT TO BE USED
- COMPOSITION OF TEAMS
- SPECIFIC OUTPUTS (tables and maps)
- SCHEDULE OF TRAININGS AND FIELDWORK

The plan need not be more than 5 pages long.

Conduct training in consistent map and equipment use

The first training can be carried out months in advance of the fieldwork if necessary, but is more ideally carried out closer to the time that the practice will be used. Equipment and map use should lead right into the testing of the field sheet.

Field training subjects in order of presentation:

1. Maps and Photography or imagery: orienting to the ground, relationship with compass and GPS, declination, major topographic features and forest types
2. Distances on map, photo, ground; scales, pacing, measuring tape
3. Sample plot layout: fixed radius, rectangle, or variable radius
4. Tree identification and measurement: local names, diameter, total height, and saw height
5. Other products' measurements
6. Filling out forms: listening and repeating back, consistency, crosschecking, storage/delivery
7. Navigating to a plot

Three days at minimum should be allowed for equipment training, and three days for practice plots. Teams should work as such toward the end to practice harmonious work patterns.

Quite often the Forest Department personnel have had at least theory relative to the equipment, and many have had practical experience from past projects but do not have a chance to practice frequently. I have found that they catch on very quickly even when not totally familiar with the equipment.

Some principles to follow for the training procedure:

- *Limit the number of trainees to those who must know the material for fieldwork so you can concentrate on those people. Invite higher-level personnel at a later time to see how the plots are done on the ground, once the method is finalized and operational.*

- *One object of the training is to get everyone to measure things in the same way. The method has to be consistently applied by all crew members by the end of the training, especially if you are training two or more crews. There are standard rules for using forestry equipment of various types, and these must be respected if the equipment is to serve its purpose.*

- *Another object is to draw out problems people have with certain equipment either due to physical difficulties or due to personal preferences. Appropriate choices of equipment can be made now.*

A certain amount of theory may be taught in advance of hands-on work, but the emphasis must be on the hands-on part. The training site must therefore be located in a forest somewhere, with "real" trees, even if it is in a forest different from the eventual object of the inventory.

Pretesting a form to fill out

To avoid inconsistencies in data collection, a standardized form should be designed for the crew to fill out in the field. The form should have a place on it for every item to be measured on site, with ample room for comments and for the data. Considering the number of details to remember, the form can include little reminders of, for example, the EXACT distances to plot limits or the position of the plot within a cluster of subplots:

CHIULUKIRE FOREST INVENTORY **DATE** ___________

NOTETAKER ____________ GPS WPT REF _________

SUBPLOT NUMBER: 1 2 3 4

SITE INFORMATION:
Grass type ______________ Soil type _____________

Rocks: gravel __ man-sized __ house-sized ____

Any other species indicators _____________________

MAP

A typical regeneration count table:

REGENERATION INFORMATION *(LESS THAN 7 CM DIAMETER; USE 3 METER RADIUS)*

SPECIES	***COUNT***	***SPECIES***	***COUNT***	***SPECIES***	***COUNT***

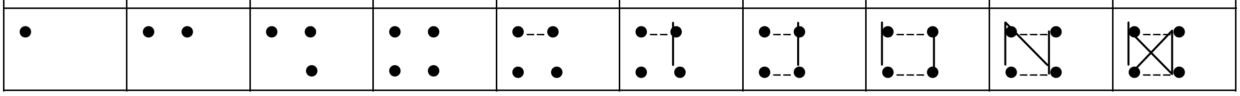
A nontimber resource example, the broom-bush found in Zambia:

SUNDE INFORMATION on 3-meter regeneration plot

	DEAD	*NUMBER OF LIVE BUDS AS BIG AS SMALL FINGER*										TOTAL
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10+*	
COUNT												

The "dot count" method is convenient for many forms:

1	2	3	4	5	6	7	8	9	10



And the typical timber and tree use table:

NO.	SPECIES	DIAM	TOT HT	LENGTH + SAW OR OTHER PRODUCT +DIMENSIONS; LENGTH + ROTTEN; START FROM GROUND ZERO

NOTE: possible methods of recording quantities of other nontimber products and wildlife information should be discussed with local users and experts.

Any product estimated from a plot can be averaged over all the plots for use in a calculation of economic value or potential harvest over a rotation period. We have used this principle to quantify potential sacks of charcoal per hectare, barkhives per hectare, cants per hectare, brooms per hectare, and others.

Each plot should have its own individual form with some indication of where it is located geographically.

The form is designed in the office but then it must be PRETESTED IN THE FIELD before writing up an accompanying TECHNICAL GUIDE TO DATA COLLECTION. Pretesting allows the planner to see many things:

- where inconsistencies are likely to occur so that further training can be given to the crews,
- how much space needs to be allowed for each column of data,
- how the crew works together, and
- useful versus less useful data that could be eliminated from the sampling procedure.

Following several actual plot executions, adjustments to the form should be made and one final practice plot tried out.

Logistics

It seems obvious, but still must be addressed: there must be food and water and beds and transportation for the inventory crews. In some cases there must also be security from carnivores and rebels residing in the forest . **Nights in hotels have to be avoided** unless the hotels are within a half hour of the inventory sites. Traveling by car for an hour before fieldwork begins is to be avoided as much as possible; it starts a physically demanding day off on a tired foot. Tents and other camping gear should be used.

Schedules work best when a very early start is maintained (0700 hours at latest), a short break for food is taken after 3 or 4 hours, and then another 3 or 4 hours is spent on plots. A day of rest during the week may be prescribed, unless the crew is anxious to finish the work. The crew will have to see what works best for them.

Project personnel, government Forest Department personnel, and village informants must remain available for the entire period programmed for inventory. Since everyone has other work to do in the course of a year, it is all the more reason to keep the inventory time down to a month or 6 weeks at the most. Once momentum is lost, it can be difficult to pick up again.

2.3. FIELD EXECUTION

By the time you have done all this conceptualization and planning, the fieldwork itself almost seems moot. In effect, once the fieldwork begins, the field crews turn into smooth-running data-generating machines with a personal touch. Yet, the planner still needs to remain on their toes, to watch out for glitches in the operation and adapt the plan as necessary. There are some pitfalls for which to watch out.

Quality control

At least once a week, the inventory planner needs to be in the field with the crews to assure a **proper** and **consistent** collection of information is taking place.

Typical things to watch out for in quality control

- Proper adjustment of slope distances to match planned horizontal distances (take the horizontal distance and divide by the cosine of the slope angle; often it makes little difference unless on a slope greater than 10%)
- Correct use of measuring tapes (diameter and 100-meter), clinometer or other height instrument, relascope or prism, compass, GPS
- **Consistent** filling out of the data collection sheet
- **Consistent** placing of diameters in the proper classes (if that method is used; the diameter classes should be defined by *the minimum and maximum to the nearest tenth-centimeter*)
- Team conflicts
- Personal biases, especially in compass readings (many people have a tendency to always veer to the left or to the right)
- Consistency from team to team

It bears repeating: if the sample is set up to measure tree diameters at a height of 1.3 meters off the ground on the uphill side, the person doing the quality control must watch to see that all crew members are measuring diameters in that position on all the counted trees. The quality control person should take a compass and check the azimuths of transects walked by the head compass person on the crew. The quality control person should observe how distances are measured and how forms are filled out. The sooner mistakes are found and corrected, the less chance that some data will become unusable, and the less variability that will be introduced into the statistics unnecessarily.

Variability in sampling is normal, but at every possible chance it should be controlled and reduced so that credibility and accuracy of results are maximized. Quality control checks are one way to assure this.

Data verification and organization

- Forms should be collected at the end of each week so that they do not get lost or damaged. There must be a protected place in the office for the data sheets to accumulate before data entry begins.

- If data are missing, they need to be recuperated immediately before the field crews forget what they saw.

- Plot locations need to be verified as well. If the plot data will be used to describe the stratum in which the plot fell, the plot must be either georeferenced or the procedure used to reach it must be explained satisfactorily. Magnetic variation must be accounted for when using azimuths drawn on maps in the office. Otherwise, plot locations in the field will not be correct, even if they are said to be based on directions from the office.

  Compass use is actually an important aspect of training: in large forests, it is not amusing to become lost, although in principle at least one of the resource assistants will always know where you are in relation to a village. To accompany the compass, verify actual plot center locations, and facilitate plotting inventory and updated points, it is wise to spend the money required on GPS units that eliminate the need to correct for magnetic variation. Most forest agents pick up very quickly on the use of the GPS. Software that comes with the newer units enables automatic download of plot center data for the easiest verification between planned and actual locations. The model currently used (mainly because it is the only unit to claim operability even under forest cover) is Garmin 12XL.

2.4. DATA ENTRY

The biggest issue when it comes time to enter the data collected is how to set up the spreadsheet or database.   Since most people are familiar with Excel or QuattroPro, the following discussion supposes that the data will be entered there. Its format is such that you can work on several custom-named pages ("worksheets") of data within one file. Ideally, the worksheet is named after the vegetation type (stratum) that is being described, and all the plot information for that vegetation type is entered on that one page, even if there are hundreds of observations.

In conformity to typical spreadsheet formats, and for each table to be produced, there must be a section on each worksheet where **the only entry appearing in each cell of the first line (line 1) is the name given to the data contained in the column of cells below it.** Otherwise, it will be difficult or impossible to calculate means and standard deviations and perform extractions from the data.

For these first inventories, there will most likely be at least three forestry tables to produce for each stratum:

(1) Estimate of trees per hectare per diameter class for each species
(2) Estimate of sawtimber per hectare in each stratum
(3) Estimate of regeneration abundance by species

For (1), the spreadsheet could look like this:

1	PLOT NO.	SPECIES	DIAM 1 - 5CM	DIAM 6-10CM	DIAM 11-15CM	DIAM…
2			*PLOT VALUES PLACED HERE*			
3						

For (2), the spreadsheet could look like this:

1	PLOT NO.	SPECIES	MADRIERS-3m	MADRIERS-4m	MADRIERS-5m	TRESSES-3m...
2			*PLOT VALUES PLACED HERE*			
3						

For (3), the spreadsheet could look like this:

1	PLOT NO.	SPECIES	COUNT	AverageAFZEL	AveragePTERO	Average…
2	*PLOT VALUES PLACED HERE*			*STAND AVERAGES CALCULATED HERE*		
3						

In addition, it will be possible to pull out other information that was taken on the plots, for example:

(4) Number of bark hives that can be made from trees in the stratum
(5) Number of mature bamboo stems per hectare
(6) Incidences of animal sign by species and by stratum
(7) Number of productive karité trees per hectare in the karité stratum, plus the number of trees in each diameter class (to monitor upcoming crop trees)

Such estimations will follow the procedure of

- recording counts per plot, then
- averaging the count per plot throughout the vegetation type, then
- applying the "expansion factor" depending on the size of the plot or whether "in" trees were determined by relascope.

Some information will be more aptly presented on maps than in tables, to whit:

- Sites for mining certain products
- Hydrological information
- Watercourse crops
- Fishing sites
- Grazing areas
- Sacred forests

When location information is taken by GPS, such points are downloaded into a point file or else entered manually into a spreadsheet table saved in text format. The points are then projected onto the GIS-traced vegetation type map using instructions specific to the software.

Alternatively, points can be drawn onto topographic sheets using scale and calculator, and then transferred to the forest map using identifiable control points.

2.5. PRESENTATION OF RESULTS

We must consider that there are three audiences for the results of the inventory: the management plan writers, the technical forest agents who will have to implement actions resulting from available numbers, and the forest user groups who want to know how foresters see the resource they see and how much they will be able to use each year.

Tables and graphs; statistics

For forestry persons, it is normal to put results in readable tables and graphs whose titles match those mentioned in the data entry section above.

As for statistics, the following are usual:

- **Averages** (trees per hectare, basal area per hectare, charcoal cords per hectare, …) are always reported.
- Upper level foresters always want to see an inclusion of **standard errors** as an expression of confidence in the resulting averages.
- **Totals** for the entire forest can be reported, but it is more interesting to have those broken down by management unit so that area-specific annual planning may by done.
- The **coefficient of variation** is a good way to compare your different areas inside the forest for degree of variability, justifying more or fewer inventory plots in areas of higher variability. You can also compare variability of different forests.

> *West African foresters have concluded that a typical COEFFICIENT OF VARIATION (s as a percentage of the average) for natural forest is around 60%; this can be a measure of proof of proper stratification, at least when comparing basal area variability to the mean.*

Some steps that are helpful in Excel:

(1) First, under DATA, a "SUMMARY TABLE" is made. You give instructions to SUM the number of occurrences of a diameter class per plot, specifying to add the sum AT EACH CHANGE IN PLOT to the diameter class in the heading.

(2) Then you instruct the software to calculate the AVERAGE stems per plot in each size class, simply by dividing the sums of the plot occurrences by the number of plots. Further division into size classes BY SPECIES simply requires more organization and more summing operations,

and remembering to still divide by the total number of plots to get the average, even if some plots had zero values.

(3) The standard error is calculated by the usual formula (s/√n) for each population of trees that has been averaged. This could be all 15-centimeter trees, all Afzelias in the 35-cm class, the basal area per plot, or any population of variables you are interested in. Again, values of zero on plots still count as members of the population.

A typical table format is:

TABLE X. Number of stems per hectare in the savane arborée dense stratum

	DIAMETER CLASS (cm)			
SPECIES	***15***	***25***	***35***	...
Afzelia africana	55	35	12	...
Burkea africana	108	55	10	...
...	...	...	...	...
TOTAL	(SUM +- 2 x standard error)	(SUM +- 2 x standard error)	(SUM +- 2 x standard error)	...

Or again,

TABLE Y. Number of bark hives per hectare available in all the forest's vegetation types, based on the (number of trees in beehive size class per hectare of species xyz) multiplied by (total hectares with this number per hectare)

FORET CLAIRE	SAVANE ARBOREE	SAVANE ARBUSTIVE	FORET DENSE HUMIDE	.....
28 +- 2x standard error	55 +- 2x standard error	2 +- 2x standard error	0	....

The latter table would be derived from a combination of what village informants said on each inventory plot and the number of trees per hectare from the previous table. One could then make an annual plan of exploitation of bark hive trees (assuming that the tree dies once its bark is harvested) by estimating how many of the younger trees will move up into the exploitable size class in the next 10 years and dividing by 10. A specific example is worked out in Section 2.6 below.

One can also record the estimations of each species by average plus or minus the confidence interval, and one can divide the table in two or more sections to treat sawtimber and wood that is used for other purposes. Then a **graph** of the simplified results is a convenient way to show the information: