*Double sampling for stratification* or *two-phase sampling* is similar to stratified random sampling except that the strata sizes are not known if optimal allocation is used. This method is often used for extensive forest surveys. First a large number of samples are classified into strata, typically on aerial photographs. Second, the inventory designer draws a random sample from each stratum for ground observation. Because one does not know the strata sizes, the uncertainty of the size is incorporated into the variability of the resulting sample estimates (Cochran 1977). If samples are distributed proportional to the size of the strata (which is the case if a systematic grid is used for the entire second phase), the sample size is known in advance.

With systematic sampling or random sampling, there is no guarantee that all classes of lands will be sampled. Both designs may miss small or irregular classes. Stratified random sampling (pre-stratified) is the only one that samples all classes because classes are identified *a priori* and samples are allocated to each.

*Unequal probability sampling* is a general design-based method of selecting plots which allows plots to be included into the sample with unequal probabilities of selection (Cochran 1977). Typically, the probabilities of selection are proportional to size (PPS sampling), because this selects plots with higher values of the attributes of interest which are usually the ones which contribute most to the variability. This selection rule lowers the resulting sampling errors. This method requires that some easy-to-observe attribute, X, which is related to the attribute of interest be observed on all possible samples, as in double sampling for stratification or model-based sampling. One caution is that the probabilities of selection are related to the value of X at time 1. If X changes over time, then the efficiency of the design may decrease. Stratification has much the same problem. Note also that while PPS is efficient for attributes that are highly correlated with X, it is much less efficient for those that are not.

Unequal or variable probability sampling designs can be used to improve efficiency in inventories. These designs, also called probability proportional to prediction (PPP) or proportional to size (PPS) focus the sampling effort on sampling units that are more likely to be important in obtaining a precise estimate of the population. However, these designs can only be utilised when the objectives of the inventory are clearly specified and prioritised and some auxiliary (additional) information on size or prediction is available. PPP and PPS sampling designs will improve the precision of the most important parameter chosen in the inventory, but a the cost of potential loss of precision for other parameters. The auxiliary information is needed to determine the probability that any element has of being sampled. Bitterlich (1947) first demonstrated the PPS design for efficient estimation of forest stand basal area.

*Model-based sampling* is a method that utilises the prior knowledge of a relationship (in the form of a model) between easily measured attributes and attributes of interest. It has long been known that if the relationship between X and Y is known, then the model parameters are best estimated by observing Y at the extremes of X. Because the mean of X is known, then the mean of Y is efficiently estimated using the model. The key is the validity of the model, otherwise model-based estimators can be very biased. Schreuder, Gregoire, and Wood (1993) discuss the advantages and disadvantages of model-based versus design-based inference.

Sophisticated inventory systems may use a combination of designs (Department of Natural Resources and Environment 1997). However, one should keep the estimation simplified so that local detail can be extracted by resource managers, clerks, and other users on an intuitive basis without a Ph. D. in statistics (Furnival 1979).

☺ When conducting multipurpose resource inventories, use a common sample design that permits reorganisation of sample unit information to describe the land base for each resource and that permits relationships between resources to be analysed.

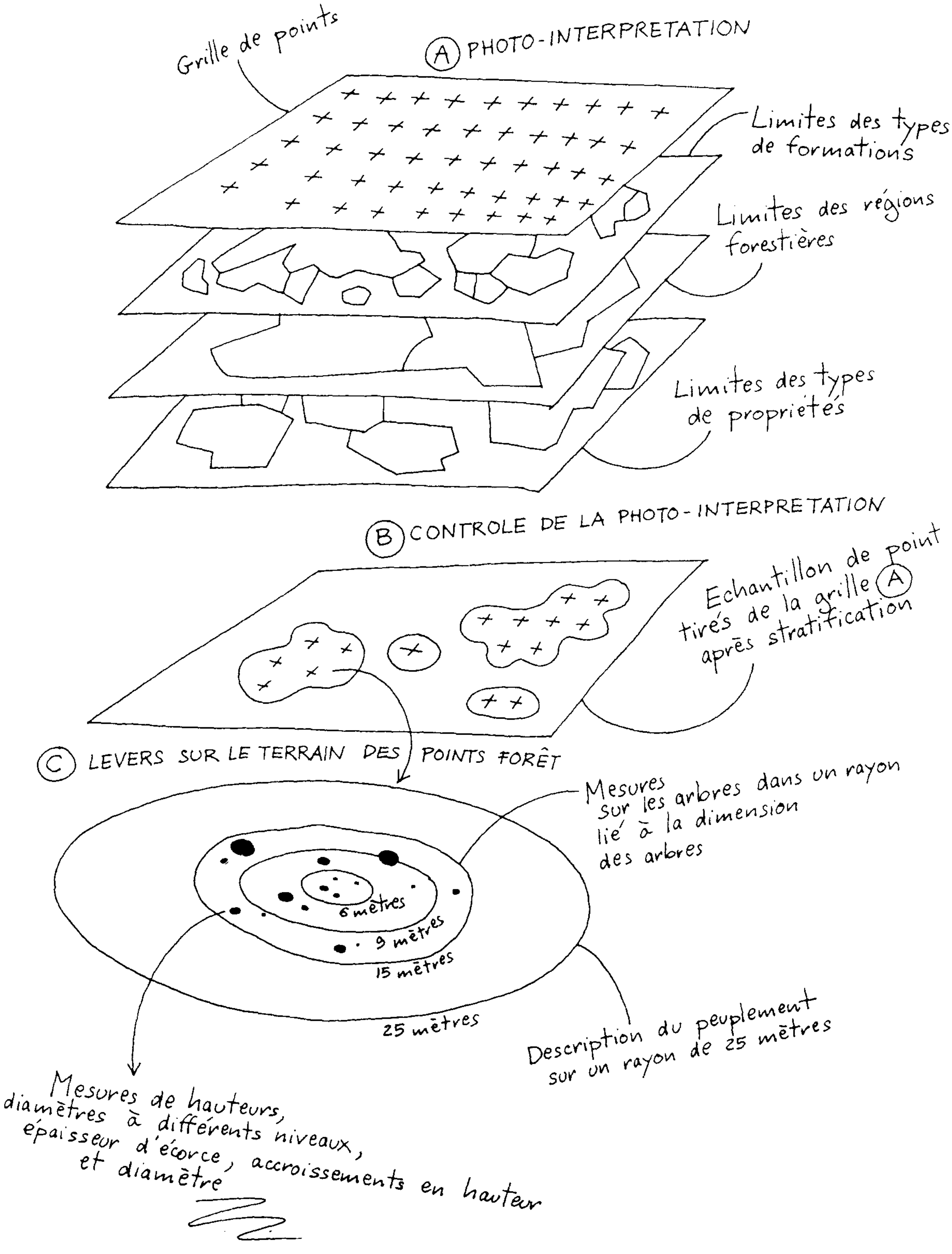



**Figure 2-9:** Example of an MRI inventory design. Even though it is in French, it may be easily understood. Having a simple and effective design that all partners can understand is fundamental for developing a successful MRI. Source: Inventaire Forestier National 1995.

| Continent/Country | Sample design | Remote sensing | Plot configuration | Source |
|---|---|---|---|---|
| AFRICA | | | | |
| Guinea | Stratified | Satellite and aerial photographs | Circular 17.84 m radius | Goussard 1997a |
| Malawi | Area Sample Frame | Landsat, Aerial Photographs | Rectangular | Wigton 1997a |
| Mali | Grid | Landsat , 35 mm aerial photos | | Treadwell and Buursink 1981 |
| Morocco | Not specified | | | Kerrouani 1997 |
| Mozambique | Mapping | | | Cruz 1997 |
| Rwanda | Stratified, Systematic | Aerial Photography, SPOT | Varies. Circular 17.84 m radius | Mushinzimana 1997 |
| South Africa | Systematic, Stratified | Aerial Photography , Landsat | Varies, both circular and rectangular | du Plessis 1997 |
| South Africa | Stratified, Random and Enumeration | | Varies. Variable radius and fixed area. | Hattingh 1997 |
| South Africa | Stratified and Enumeration | | Varies | Morley 1997 |
| Sudan | Systematic | Landsat TM | Rectangular 20 m x 100 m 3 plot | Obeid and Hassan 1992 |
| Tanzania | Systematic, Stratification | | Circular | Haule 1997 |
| Uganda | Systematic/Random. Double sample | SPOT Imagery, B&W Photography | 50 m x 50 m permanent plot | Hedberg 1993, Drichi 1993 |
| Zimbabwe | Systematic, Mapped Based | Landsat TM | Circular nested 1, 2 and 5 m | Mkosana 1997 |
| ASIA/OCEANIA | | | | |
| Australia | Mapped-Based | | | Rumba 1997 |
| Indonesia | Strip | | | Stockdale and Corbett 1997 |
| Malaysia | Stratified Random | Landsat TM | Circular 0.05 ha - cluster of plots. 240 m x 240 m | Yuan 1997, Salleh and Musa 1994 |
| Nepal | Mapped based, Stratified | Aerial Photography | | Jordan 1997 |
| Nepal | Systematic | Satellite images, Aerial Photography | Circular 18 m radius. Cluster, and strip | Pikkarainen 1997, Kleinn *et al.* 1996, Laamanen *et al.* 1994 |
| Philippines | Systematic | | Strips and sample plots | Rosario 1996 |
| Philippines | Systematic Grid | | Circular | Villanueva 1996 |

Table 2-9: Listing of sampling designs, remote sensing use, and plot configurations by countries based on MRI questionnaire survey and literature review (Lund 1997b).

**Table 2-9: Listing of sampling designs, remote sensing use, and plot configurations by countries based on MRI questionnaire survey and literature review (Lund 1997b).**

| Continent/Country | Sample design | Remote sensing | Plot configuration | Source |
|---|---|---|---|---|
| EUROPE | | | | |
| Austria | Systematic | | Circular 300 sq. meters. 9.77 m radius. | Schieler 1997, Winkler 1997 |
| Belgium | Systematic | | Circular, variable radius. | Rondeux 1997, Lecomte *et al* 1997 |
| Denmark | Systematic | | Rectangular 5m x 5m for trees, line transect for birds | Skov 1997, Plum 1997 |
| Finland | Systematic | Satellite Imagery | Circular | Tomppo *et al.* 1997 |
| France | Stratified | Aerial Photography | Nested circular plots. 6,9, and 15 m radius. | Valdenaire 1997, Lagarde 1997 |
| Germany | Systematic | | Circular | Schmitz 1997, Kleinn *et al.* 1997 |
| Italy | Systematic | Aerial Photography | Circular | Tosi and Marchetti 1997 |
| Italy | Questionnaire | | Circular | Tosi 1997 |
| Latvia | Mapped based | | | Vazdikis 1997 |
| Netherlands | Integral Survey | Aerial Photography | | Daamen and Stolp 1997 |
| Norway | Systematic | | Circular, fixed area 250 m sq. | Tomter 1997a, 1997b |
| Norway | Stratified Random Sample | Colour Aerial Photography | Square, 1 m sq. | Dramstad 1997 |
| Norway | Mapping , Literature | | | Elgersma 1997 |
| Russian Federation | Mapped Based | Satellite and airborne imagery | Varies | Filiptchouk 1997 |
| Slovenia | Systematic | Aerial photography sometimes | Circular, fixed area | Kovac 1997 |
| Spain | Directed sample | | Circular, variable radius | Garcia-Guemes 1997, Martinez-Millan, Condes 1997. Pita 1996 |
| Sweden | Systematic | Aerial Photography | Circular | Söderberg 1997 |
| Sweden | Stratified | Satellite Imagery | Rectangular 25 x 25 m, nested 1 x 1 m | Persson 1997, Merkell 1997 |
| Sweden | Mapped Based | CIR Aerial Photography | | Rudqvist 1997, Merkell 1997 |
| Sweden | Mapped Based | CIR Aerial Photography | | Merkell 1997, Noren 1997 |
| Switzerland | Systematic | Aerial Photography | Circular | Brassel 1997, Köhl and Brassel 1997, Brassel 1995 |
| United Kingdom | Systematic, Random | Aerial Photography | Rectangular | Dewar 1997, Jordan P. 1997 |
| LATIN AMERICA | | | | |
| Mexico | Stratified Systematic | Landsat TM | Nested circular plots, 3.92 m | Varela-Hernandez 1997 |

| Table 2-9: Listing of sampling designs, remote sensing use, and plot configurations by countries based on MRI questionnaire survey and literature review (Lund 1997b). | | | | |
|---|---|---|---|---|
| **Continent/Country** | **Sample design** | **Remote sensing** | **Plot configuration** | **Source** |
| | Sample | | radius and 17.84 m radius. | |
| Peru | Stratified | Aerial Photography | Quadrants, questionnaires | Goussard 1997b |
| MIDDLE EAST | | | | |
| Israel | Systematic - Mapped Based | Aerial Photography | Variable and Fixed Area | Sachs 1997 |
| Turkey | Systematic | Aerial Photography | Circular variable radius. | Çaliskan 1997 |
| NORTH AMERICA | | | | |
| Canada | Stratified | | | Rennie 1997 |
| Canada | Systematic | | | Omule *et al.* 1996 |
| United States | Random | | Circular | Gee and Forbes 1997 |
| United States | Stratified random | | Circular nested | Fimbel 1997, Fimbel and Fimbel 1997 |
| United States | Systematic, Double Sample | Aerial Photos., Landsat TM | Circular plot cluster | Smith 1997 |
| United States | Systematic, Double Sample | | Circular plot cluster | Buck 1987 |

### 2.5.3.2.3 Stratification

Nearly all MRI designs require some form of stratification. Stratification is the process of dividing an inventory unit into relatively homogeneous areas, usually based on what can be interpreted from imagery or maps. If stratification is done before sample selection (pre-stratification), it will reduce the number of field plots that would have been needed had stratification not been used. If stratification is done after sample selection and establishment (post-stratification), it will reduce the sampling error compared to that achieved had stratification not been used.

*Pre-stratification* requires that strata be defined before sample selection. Thus some type of classification, and often mapping, system has to be developed in the early stages of the MRI. Pre-stratification may best be used in the following instances:

- If the classes or strata show extreme differences, such as croplands versus forest land or if the decision-makers or partners need different information for each class.
- If the classes, strata, or mapped polygons are fairly large so that they can be easily distinguished both on the ground and on imagery (that is, the strata are not intermixed giving a mottled appearance).
- If the field sampling or data collection processes in several of the strata are considerably different from what one would collect in other strata. Vegetation data one normally collects on croplands, for example, are intuitively different from those one generally collects on forest or rangeland.
- If data are needed for every stratum.
- If strata are relatively homogenous with respect to key attributes, resulting in more precise estimates, or lowered costs.

All strata should be sampled – otherwise any misclassification errors (or changes since imagery interpretation or mapping) cannot be incorporated into the estimates. In addition, the estimation of variance is affected. When observations are not taken for a particular stratum, they are assumed to be zero when computing overall means and variances.

When using pre-stratification, one has the choice of proportional allocation versus optimum allocation for the distribution of field plots. With proportional allocation, the strata having the largest area will receive the most plots and the stratum having the smallest area will receive the least. The advantage of proportional allocation is that the field plots have nearly the same weight. The impact of errors or changes in classifications will not be so great as through optimum allocation. Proportional allocation should be used, if:

- There are more than one attribute of interest, that is it is not clear with respect to which attribute the optimal allocation should be obtained. The optimal allocation for one attribute may be a disaster for another attribute!.
- The units of reference should be flexible in the analysis of the inventory results. The user should be able to do analyses on the bases of political boundaries, vegetation units, etc.
- If a permanent inventory system is to be installed, the plots may change their stratum (such as stage of forest development, age class, etc.), which requires the assignment of a new stratum (changes) if the distribution of plots is not proportional.
- If there is a small chance that the attributes of interest and the information needs will change in the future (and who doubts that?) only proportional allocation will satisfy the future user needs and maintain the time series of plot data.

Under optimum allocation, the most field plots are assigned to the stratum in which the variance is highest (or cost the most). Thus strata that are relatively small but very heterogeneous internally could require more plots. Here, errors or changes in the classification of field plots could have large impacts on the results of the inventory. On the positive side, optimum allocation will result in the fewest numbers of field plots for a given precision requirement if variances are used to determine allocations.

*Post-stratification* is generally used following a systematic sample where strata are not identified in advance. A systematic sample with post-stratification is generally used:

- If a permanent systematic grid or random sample was chosen initially.
- If mapping or imagery is not available in time for the MRI.
- If the mapping is so interspersed that development of a stratified sampling frame ranges from cumbersome to impossible.
- If the strata are apt to change over time.
- If it is more important to have data on all lands than to have information on specific classes of land.

☺ Systematic sampling with post-stratification is also used for long-term monitoring. This is generally because boundaries of vegetation types can change over time. This can raise havoc with plot weights if pre-stratification, and especially with optimum allocation, was used. A systematic sample with post-stratification will also generally result in a sampling of strata proportional to size.

☹ A disadvantage of systematic sampling with post-stratification is the possibility that a certain stratum may not be sampled. This often occurs when there are very small strata or when the distributions of the polygons or mapped units are such that they fall between the systematic sample.

😐 In summary, pre-stratification is more efficient for a set of specific goals. If the MRI objectives become moving targets, as they are now in many countries, a systematic sample of permanent plots with post-stratification may be the best design over the long term.

### 2.5.3.2.4 Sampling Units

Conceptually, the population is divided into all possible sampling units. In order to make comparisons and to estimate precision, sampling units must be of fixed size and shape. The sampling design is used to select a probabilistic sample of the sampling units. Sampling units must either fall completely within the inventory unit or use boundary correction methods (Gregoire and Scott 1990).

As a result, statistical estimates of population attributes can be produced with an estimate of their reliability. If the sampling units are located subjectively, or the size of the sampling units is altered by the field crews, then no estimates of precision can be produced. Estimates of unknown reliability are of little value.

Different sampling units or *field plot designs* are often used for different ecosystem components (Figure 2-10). One can sample most components with plots that cover a fixed area of ground. When possible, they are co-located at a single plot centre. This makes the field work easier and more efficient but what is more important, it means that the relationships between ecosystem components can be explored. Some attributes are most efficiently sampled as a cluster of subplots, such as four understory subplots within a larger overstory plot. Other ecosystem components are linear features, such as edges or streams, and can be measured with line transects or other means.

Field crews often use nested fixed-area plots for tallying multiple resource data – a large-area plot for tallying big trees, a mid-size plot for saplings and poles, and a very small plot for tallying seedlings and other vegetation. Using different plots for different resource components affords the opportunity to attempt to balance (optimise) the amount of information taken on each (Scott 1993). A nested plot may be particularly useful in the moist tropics where there are large numbers of plant species. Over half the respondents to the MRI questionnaire indicated that they used some form of nested circular plots in collecting data for their MRIs.

Some prefer rectangular plots, as a crew can stake out corners, then look along the lines of the plot to see what vegetation is in or out. Others prefer circular plots, particularly if they are relatively small as a crew member can walk out to the end of the radius, and swing the line around to determine tally trees. Circular plots have less 'edge' than rectangular plots, but rectangular plots may be better for sampling 'clumped' vegetation. Field plots can be different among the components. However, these plots for each component should not vary among the sample units (that is, locations) or between strata. See Figure 2-10 and Case Study 3.4, Chapter 3 for a examples of plot layouts.

Establish permanent plots and re-measure over time. Permanent plots are those one establishes in such a manner so that crews can easily relocate the plots exactly and remeasure the vegetation within their boundaries at a later time. Permanent plots are essential for determining change and predicting trends. Päivinen *et al.* (1994) provide guidance on establishing permanent plots for monitoring forest conditions.

People observe vegetation in sampling units using a variety of methods. One determines *density* (number of individuals per unit area) by counting the number of individuals within the plot or by using a distance method, such as the point-centred quarter method. One assesses *cover* (proportion of the plot covered) using a series of points or lines, ocular estimation, quadrats, line transects, or photography. Ocular (visual) estimates, although very time-efficient, should be avoided in favour of measured observations .

We generally assess *frequency* (proportion of plots on which something occurs) using plots or nested plots. One assesses *biomass* using clipped plots or through the use of biomass equations or tables that relate the biomass to more easily measured attributes, such as tree diameters. Inventory specialists assess *spatial patterns* of populations and communities by mapping individual or community locations using compass and tape, global positioning systems (GPS), or by remote sensing imagery. Chambers and Brown (1983) give a good overview of all these methods.

☺ Consider using permanent plots for monitoring changes or for establishing trends in the vegetation resource base. Establish and document permanent plots or transects so as to permit repeated measurements of the same variables at the same exact places. Remeasure a sufficient number of samples often enough (for example, ten-year cycle) to establish trend analyses and projections. Integrate previously established permanent samples into subsequent resurveys where an adequate sample is available and where trend or monitoring information is necessary. See Alder and Synnott (1992).

### 2.5.3.2.5 Sample Size

Sampling intensity will vary by the objectives of the MRI, the precision the decision-makers require, the anticipated variation within the target population, the sample design the inventory specialist uses, and the time and funding available. A certain sample size may be adequate for some variables of interest, but not others. Statisticians base the specified reliability of the estimates on two factors. First is $\alpha$-level which specifies the probability of detecting a difference when no difference exists (also known as a Type I error or false positive).

Second is the power ($1-\beta$) of the design (see 2.5.3.2.6 Power) which is a measure of the ability to detect real changes. Decision-makers have to decide on what is an acceptable $\alpha$-level and $\beta$-level.

☹ Individual components will have different variation and precision requirements. As such, desirable sample sizes will vary among components. The sample design should be able to accommodate their differing needs (for example, field plots for different components can be adjusted in size or uncoupled). However, where the decision-makers desire both types of information, collect the information on a common sample point.

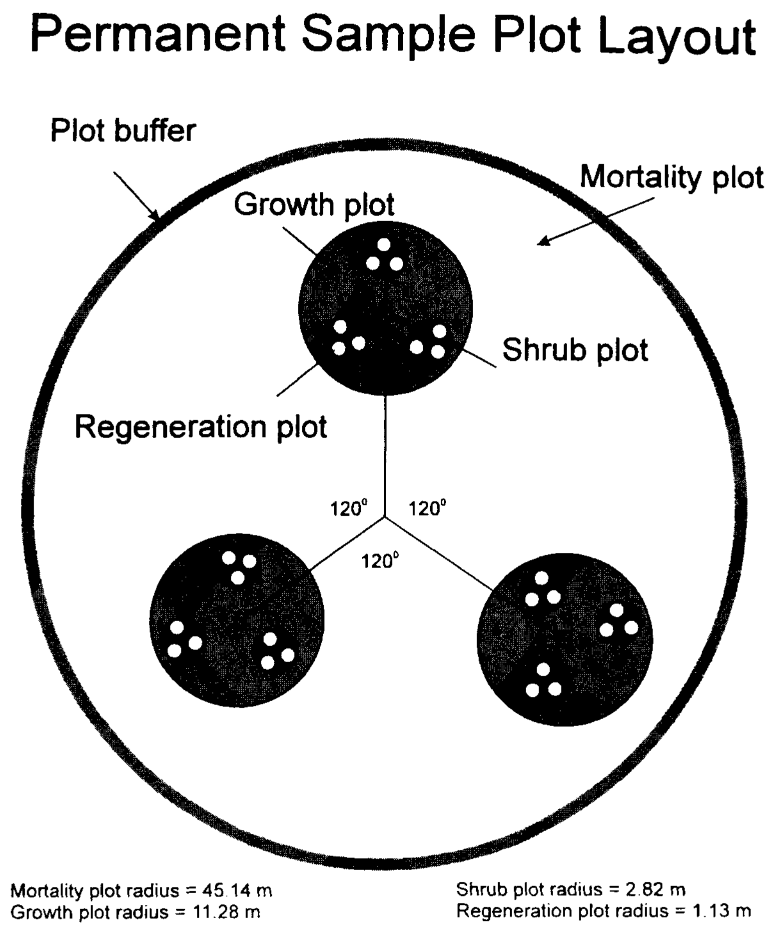



**Figure 2-10:** A plot design useful for measuring and monitoring vegetation for multiple purposes. Source: Hayden *et al.* 1995.

Based on the sampling unit and the sampling design, the statistician or inventory specialist computes the sample sizes to achieve the desired precision level or the specified cost. Sample size computations depend on the attribute's variability for the given plot design, $s^2$, the confidence interval half width (expressed as r% of the mean, $\overline{Y}$), the confidence level (1-α), and the sampling design itself. Assuming simple random sampling, the required sample size, n, is based on the precision requirement for the confidence interval:

$$width = 2r\overline{Y} = 2t_{\alpha/2,n-1}\frac{s}{\sqrt{n}}$$

thus,

$$n = \frac{t^2_{\alpha/2,n-1}s^2}{\left(r\overline{Y}\right)^2}$$

Where t is the Student's t-value that can be obtained from most statistics texts. Scott and K`hl (1993) describe a program for computing sample size for stratified and permanent designs.

The sampling errors are computed for categorical data, such as forest/nonforest, in much the same way as for measured attributes. If the interest is in the area of forest, then each observation that is forested has a value of 1, otherwise it is 0.

One value in gathering existing information for the area or similar areas is in providing information on the expected mean, $\bar{Y}$, and its standard error, $s/\sqrt{n}$. If no data are available, then it may be advisable to conduct a pilot study to provide estimates of the expected variability.

Rather than specifying the allowable sampling error, we often constrain sample sizes based on time, funding, and available personnel. These three factors dictate sampling intensity more often than anything else. Sampling intensity, coupled with terrain, vegetation, and size of crews may dictate the plot configuration.

☺ Design inventories to meet the precision requirements for international needs, the national assessments or for resource planning as appropriate. Supplement these to meet local issues and concerns. When feasible, derive area estimates from known mapped areas to eliminate area sampling errors

☺ Based on the sample size calculations, revisit the survey cost constraints. If necessary, adjust the objectives, constraints, or the precision objectives.

### *2.5.4 Plan Field Work*

Planning field work involves considering required skills, land ownership and access. Plans should be reviewed daily as field work is implemented (Figure 2-11).

**Figure 2-11:** Planning the day's field activities for an MRI in Sudan. See Chapter 3.4.

### *2.5.4.1 Skills*

Due to an MRI's multipurpose nature, its implementation requires a range of data collection skills. An integrated team of highly trained resource personnel is necessary to assure accurate data. One may find, for example, that a forester may not be qualified to collect data about range, wildlife habitat, water quality or biodiversity. Similarly, ecologists may not be experienced in collecting data on timber defect or agricultural production. Species identification in some parts of the world such as the Tropics may be extremely difficult requiring a taxonomist to be on the crew (Gillespie 1992).

> An MRI requires a field team of professionals representing the variety of disciplines to collect quality data.
>
> Building this type of co-operative team of individuals with specific expertise presents a challenge.
>
> Seek to enlist people familiar with the local area.

### *2.5.4.2 Land Ownership*

If the lands are generally public, then carrying out an MRI is relatively easy as the lands come under the Head of State. When most of the lands are in private ownership, an MRI may be difficult to carry out. Local people may not be co-operative because of fear of repeated measurements on their land. They may be suspicious of the inventory teams interest in that particular area. The fear of losing one's land or rights is understandable (Drichi 1993).

Permission to enter private lands may require adding an extension, training, or publicity component to the MRI. We want people to want and use the inventory. We do not want them to resent it by being inconvenienced for having the inventory done in their local area. It is important that those responsible for the inventory keep all affected people informed of the MRI efforts.

> Brief local people and organizations on objectives, advantages and use of the MRI. Enlist their support in carrying out the MRI through employment, training and education (Figure 2-12) .
>
> Ensure privacy of data collected on local landowners' holdings.

Always obtain permission prior to entering private property. Brief the land owner on the intention of the inventory and how data collected on his or her land will be used. If granted access ask about the easiest way to get to the plot location (Wright and Gilbert 1996).

### *2.5.4.3 Access, Logistical Supply, and Replacement*

Many forest areas lack road and transportation networks. Getting into these areas and maintaining supplies can be a problem. Poor access increases the costs of inventory. Access also affects security of personnel and equipment. Inventory equipment can be a temptation.

> Use remote sensing to its fullest to reduce the amount of field locations that crews need to visit. Consider a wide range of rempte sensing options including satellite imagery, aerial photography and airborne videography. If necessary, stratify by accessibility and take fewer samples in difficult areas.
>
> Choose equipment that is rugged and for which repair is available locally. Take steps to secure equipment when not in use with locks, guards, etc.

If access is denied or if the location is inaccessible, then record the location as such, rather than attempting to replace the plot. This method simply results in estimates of the area denied access and inaccessible areas, and does not bias the results.

**Figure 2-12:** Use of local people helps bring support for the MRI. The MRI in Sudan used local people to help define the inventory objectives, assist in data collection, and provided logistical support in camp. See Chapter 3.4.

### *2.5.4.3 Access, Logistical Supply, and Replacement*

Many forest areas lack road and transportation networks. Getting into these areas and maintaining supplies can be a problem. Poor access increases the costs of inventory. Access also affects security of personnel and equipment. Inventory equipment can be a temptation.

Use remote sensing to its fullest to reduce the amount of field locations that crews need to visit. Consider a wide range of remote sensing options including satellite imagery, aerial photography and airborne videography. If necessary, stratify by accessibility and take fewer samples in difficult areas.

Choose equipment that is rugged and for which repair is available locally. Take steps to secure equipment when not in use with locks, guards, etc.

If access is denied or if the location is inaccessible, then record the location as such, rather than attempting to replace the plot. This method simply results in estimates of the area denied access and inaccessible areas, and does not bias the results.

### 2.5.5 Test Field Procedures

Testing, before implementation, is an important step in designing any inventory (Figure 2-13). One U.S. federal agency designed a near-perfect MRI system that would provide statistically-valid estimates for range, wildlife, and forestry needs for every stand or vegetation polygon that the agency administered. The system developed was technically and scientifically sound. The agency approved the design for implementation. Unfortunately the agency did not test the system under actual field conditions to see how much it would cost or how long it would take to complete. As a result, after the expenditure of several millions of dollars, the agency abandoned the system for a less ambitious inventory method (Lund 1984).

**Figure 2-13:** Review and briefing of inventory specialists on an MRI project in Switzerland. Such a review is beneficial to all parties involved.

| ☺ Test any new system to see if it is economically, technically, and environmentally feasible. Make sure the system is practical, socially and politically acceptable, and that it provides the results desired (Rudqvist 1997). |
|---|

In many cases, there will be pioneering elements in the MRI project. Many of the methodologies and techniques may be either new or adapted. Prototype your system. Initially, most users may not have a clear and detailed picture of what they want and sometimes not even in principle. Prototyping provides partners with time and an opportunity to learn and participate.

Start in a quite small scale and test the methods very intensively before introducing the project on a large scale. Especially test the programs and routines for computers well before implementation of the MRI (Rudqvist 1997). One important aspect of testing or of prototyping is that you expect to make mistakes, and may even welcome their discovery. Mistakes and or emerging conflicts often lead to significant progress and better understanding of the situation (Hedberg 1993).

Test the proposed MRI design against the objectives and goals. It is important to carry out the test as collecting data may be the easiest step of the program. Regard the test as a probationary period. Determine if the data are providing the information required. Is the MRI proving too time-consuming. Are more resources necessary? If the test reveals that the MRI does not meet the goals, redesign the MRI or reconsider the objectives with the end users. Look for ways to streamline the process (Shopland 1992).

Every planned inventory should receive interdisciplinary review before being officially implemented to maximise efficiency and avoid duplication. Field testing the survey methodology as crews gather data is also important. Take the statistician, computer programmer, decision-maker, resource administrator and potential critics to the field and measure a demonstration plot. They may help point out flaws in the data collection procedures and they also may prove to be allies of the MRI in the future. Build quality assurance and control into the process. Include training standards, consistency checks, and close supervision.

## 2.6 ESTABLISH THE INFORMATION SYSTEM AND PROVIDE FOR ACCESS

Build the information system at the same time as the team develops the MRI. Have a 'draft' or 'dummy' system in place that the team can use to demonstrate the proposed resulting information and its availability to the end users. With a draft system in place, the end user will be better able to evaluate the data and procedures from pilot surveys effectively.

### *2.6.1 Develop Information Structure*

A key is understanding the relationship between MRI system(s) and information structure(s). Regardless of the number of inventory systems used, the data must go into one information structure with one set of standards. Failure to require this means splintered and often duplicated information throughout all levels. Recognise the difference between one information structure and the availability of many user interfaces. The end user needs to provide input as to how the information they will be using will be available to them.

Of equal importance is the relationship between MRI for local planning and organizational agency needs, and MRI for project (local) level. The information structure must be flexible enough to handle both local planning and agency level data, as well as larger scale, project level information. Flexibility also must take into account the variability of information needs that occurs throughout the agency.

Considering the above, develop a common database and record keeping system. As an example, soils scientists need to collect ground cover information during soil surveys. Fire specialists also use the cover data to analyse fuel loading and wildlife biologists use it for their analyses. The database system should present information in a format that all users readily understand. Include measures of data quality in the presentation of the results.

### *2.6.2 Decide Access to MRI Results*

A willingness to share information may lead to more support for the project. Such was the case in Uganda where they have experienced a skyrocketing interest in their National Biomass Study (Hedberg 1993). Make data and information – both analogue and digital – as easily accessible as possible. A basic principle is that all data are available to anybody on an incremental cost-recovery basis (for example, the user pays for paper, ink, diskettes, computer time to down-load, etc.). On the other hand, inventories are resource-intensive activities and at times may become very sensitive. The team should develop a clear policy right from the start as to who will have access to the inventory data and what restrictions the partners may place on its use. This is generally not a problem in cases where, for example, a government forest service inventories national forests or a community or private individual inventories a forest over which they have uncontested jurisdiction. Nevertheless, even in such seemingly clear-cut situations, difficulties may arise if, for example, an MRI of public forests reveals information about rare species which the government forest service is not in a position to protect against illegal harvesting or other damage (such as tourist viewing). See Table 2-10. A similar situation could arise if an inventory crew found valuable resources on private land leading to illegal exploitation by outsiders.

Another difficult scenario that is likely to become increasingly common in the future is one in which MRI data collected by private owners (whether individuals or communities) are used by government organisations to monitor changes in biodiversity. Where such monitoring leads to restrictions being imposed on the owner's use of their resource, it may be necessary to compensate them for any loss of income.

Perhaps the most problematic situation for any MRI is one in which tenure of the resource is uncertain or where access and use of the resource are not necessarily linked to legal ownership. A local community may, for example, be using a public forest for collecting construction timber, fuelwood and other non-timber forest products. If the government forest service carries out an MRI which reveals a high density of a particularly valuable resource (e.g. certain timber species or medicinal herbs), outsiders may attempt to exploit the resource resulting in a loss of income (or amenity value) for local people. The government could also decide to capitalise on its own valuable resources by making concessions available to companies thus again endangering local people's access to and use of the forest and rangelands.

**Table 2-10:** Some issues to consider relating to access to MRI results

| Who owns/uses forest or rangeland? | Who carries out MRI? | Information risks | Possible action |
|---|---|---|---|
| Government lands under tight control, e.g. national forests | Government forest service or contractor | Data about valuable species may lead to poaching, illegal exploitation | Requires measures to ensure protection of the vulnerable species or the whole area |
| Government lands widely used by local people for subsistence and/or income-generation | Government forest service or contractor | High density of timber or other valuable species may lead to<br>1. Government takes decision to sell concessions, etc.;<br>2. Outsiders move in to exploit resource resulting in loss of income or amenity value to local people | Objectives and risks of MRI need to be discussed with local users in advance, possibly leading to their involvement in carrying out the MRI, analysing the results and participating in decision-making about further management of the resource |
| Private or community forest or rangelands | Government forest service or contractor | Two risks may arise:<br>1. Data about valuable species lead to illegal use by outsiders;<br>2. Imposition by the government of certain management regulations, e.g. to maintain biodiversity levels, which may result in loss of local income | 1. Requires improved protection, possibly with government help<br>2. May require some training in improved management and/or compensation for loss of income |
| Private or community forest or rangelands | Owner(s) or contractor | 1. If information can be kept out of the public domain, the main risk is that multiple owners may disagree about how to manage the resource;<br>2. If information is made public, see risks in the above box. | 1. Requires in-depth discussion about potential options in advance of carrying out MRI, and possible conflict resolution<br><br>2. See actions in the box above. |

Another example is the disclosing of plot location information. Some partners may wish to keep plot locations secret. They may have a fear that disclosure of the plot location may lead to people treating the area differently or that others will come on to the land and use destructive sampling techniques. In either case, the plot may be biased and unsuitable for further monitoring programs.

From these few examples it is clear that inventory information must be handled with care. In cases in which an MRI is carried out by an organisation (such as the USDA Forest Service) on land that is owned or used by other people, the latter need to be involved in discussions about the MRI and its objectives early on in the planning process. Where inventories are carried out together with, or at the request of, local people, it is important to discuss why each piece of information is being collected and what the possible implications of certain results might be. This could lead to an agreement that certain MRI information will not be made public, although in practice it may be difficult to prevent a determined person from gaining access to it. If local people are fully aware of these risks, however, they can prepare to deal with such an eventuality. It may also be necessary for the government to provide assurances that it will uphold and help enforce local peoples' rights to use a particular resource if conflicts do arise as a result of MRI information being made public.

## 2.7 PROVIDE FOR QUALITY ASSURANCE AND COLLECT DATA

Quality assurances (QA) are those activities one performs to ensure that the final product will meet the desired level of accuracy and precision. In this case, the final product is data and information from multipurpose resource inventories to answer questions about available resources and support conclusions drawn from that information. Integrate the quality assurance program with the entire measurement process. QA ensures that operations and procedures requiring controls are identified and that appropriate control protocols are defined, documented, and implemented. Quality control procedures are specific actions designed to maintain data quality within an acceptable range.

The implementation of a quality assurance program is vital to any inventory or monitoring program. The goal of any quality assurance program is to continually improve the data quality from year-to-year. The collected quality assurance information is essential for interpreting and evaluating MRI results. In addition, the MRI team uses the information to:

- Develop actual, realistic measurement quality objectives;
- Revise methodology to reduce errors;
- Improve the effectiveness of the training sessions; and
- Revise the remeasurement program (for collection of quality control data) for subsequent field seasons to be more cost-effective and efficient.

☺ Develop quality and quantity control standards for contractors, co-operators, co-ordinators, crew leaders, and crew members. Inspect inventories as specified in the inventory work schedule. Emphasise accuracy, objectivity, and efficiency. Make quality assurance/quality control visits to a sample of the plots. Use a different crew for comparison with the initial crew's data.

☹ Do not correct data at this step. We use the data simply to assess the data quality. The Quality Assurance report should accompany the inventory and monitoring report, thus allowing the decision-makers to draw their own conclusions about how reliable are the results.

We use various measures to interpret the level of data quality – accuracy, precision, completeness, and comparability. There are three basic aspects of any quality assurance program: prevention, assessment and appraisal, and correction.

### *2.7.1 Error Prevention*

Prevention is the major activity that attempts to ensure that we collect "good" data prior to any data collection. In addition to development of standard definitions and documentation specific prevention activities are:

- Develop standardised methods
- Establish measurement quality objectives and data quality standards
- Apply calibration techniques and training

#### *2.7.1.1 Methods*

Development of standardised methods is the basis of this entire document on multipurpose resource inventories. After standardised definitions are finalised, the next step is the adoption of or the adaptation of existing methodology or the development of a new method if no appropriate procedures exist. The adoption of a method usually occurs after testing under actual field conditions of the inventory area. Testing is necessary to ensure that the selected method meets the data quality and cost limitations of the particular inventory. Sometimes this requires a modification of the existing procedure.

Occasionally, multiple procedures exist which will meet the needs of the particular inventory. In this case, base the decision upon a logistics and cost efficiency study or examination. In other cases, the MRI design team may find the method that produces the desired level of data quality is not cost effective under the conditions of the particular inventory. These situations require that a different method be selected and/or that the desired level of data quality be changed to meet these situations. As can be seen, the selection of a standardised method is usually an iterative process and with many of these activities occurring simultaneously.

#### *2.7.1.2 Establish Measurement Quality Objectives*

We base measurement quality objectives on the criteria of data quality. Within biological measurements, accuracy is difficult to determine because it is almost impossible to determine the "true" value. Experience from the U.S. Forest Health Monitoring Program has shown that the primary data quality attribute is precision (Stolte 1994). Additionally, researchers have shown that with plot measurements, within-crew precision errors are very small compared to between-crew comparability. This does not imply that precision is the only data quality attribute. Include other measures of data quality where and when appropriate.

The measurement quality objectives are specific goals that clearly define the precision for the measurement process. For example in Forest Health Monitoring, the USDA Forest Service rates crown condition in 5% classes from 0% to 100%. The measurement quality objective is that 90% of the values are classified within two classes ($\pm$10%) of their true value for the data to be acceptable. The USDA Forest Service developed and refined these measurement quality objectives after years of use. Where one does not know the achievable levels of data quality, use a target set of values. After several field seasons determine whether the measurement quality objectives are appropriate for the measurement systems and the intended use of the data. Modify the values if needed.

#### *2.7.1.3 Calibration*

The final activity under prevention is calibration. The major activity in calibration is training of field crews, although equipment calibration is also important. Equipment calibration is important to ensure that all field equipment is providing comparable results. For example, compasses all have some variation in values along the same heading. It is critical that crews check the comparability between various compasses and document the results in the inventory program records. Compass declination should be determined annually and compasses should be re-set.

Training is the most important aspect of calibration (Figure 2-14). The objectives of training are to:

- Ensure that observers have the required basic skills and meet the quality standards for the survey,
- Provide information about survey design and data collection, including changes as they occur, and
- Incorporate feedback from observers into the survey design, execution, and reporting of results.

**Figure 2-14:** Field training in habitat identification in Colorado, USA.

Train the data collectors in the specifics of the MRI methods. Training is another step that inventory planners often overlook in the interest of saving time and due to the false impression that crews do not need training. Even experienced crews refine their skills with each training session, and it helps ensure that data are collected consistently between crews. It also provides an opportunity to raise questions and to provide feedback to the survey planner. Carefully plan the training session. This increases the likelihood that crews will collect the data properly.

Initiate training early in the program rather than towards the end. Training should overlap the design and the operational phases and probably last as long as the inventory occurs. For an MRI, it is unlikely that current field personnel will have all the skills for all the types of measurements. For larger inventories there may be the need to have more crews or contract out the work. All these require training to ensure quality. There is also a need to extend training to the end-users so that they utilise the information correctly. It may also be important to have specialists who continue to 'sell' the process as it is being developed.

For field work, it is important that the training session cover the objectives of the survey. Crews must understand the 'why' before they understand the 'how.' The inventory methods, attributes, and measurement techniques must all be described until all crews have a clear and common understanding. As a tool to ensure consistent results, each resource expert should lead a session where all crews independently assess the same attributes. Share and discuss the results. Repeat this process until crews achieve consistency. Finally, the trainer(s) should visit each crew during the first few days or weeks of field work to answer questions and to ensure that the crews are following the MRI methods.

As part of ensuring that all observers have the required basic skills, each method may have some minimum level of qualifications or skills needed by personnel. For example, if the methodology requires identification of tree species on the inventory plots, crew personnel may be required to be able to identify the expected range of species in the MRI. The steps in training are:

- Instruct personnel on the specific methodology,
- Practice the methodology, and
- Evaluate and document (certify) field crew performance.

Base the training session on the flowchart shown in Figure 2-15.

```
New observer → Does not have basic skills → Provide skills training
|                                                  ↓
|
→ Has basic skills → Provide information about survey methods/objectives
                                                   ↓
Experienced observer → Does not meet measurement → Train and certify in
(Update changes)        quality objectives          critical measures
|                                                  ↓
|
→ Meets measurement quality objectives →          Qualified observer
```

**Figure 2-15:** Structure for determining training needs

Evaluation of field crew personnel (certification) should be part of every training session. The training session should include all aspects of the measurement processes that are possible at the training session location. For every major area of training, simulate some level of testing under field conditions. Use this information to immediately evaluate the effectiveness of training and to identify individuals who may need additional training. Use the measurement quality objectives as a basis to determine whether or not to certify an individual.

The last aspect of training should be an evaluation by personnel on the effectiveness of the training session. Use a discussion session or a questionnaire covering the training session (both classroom and field), the instructors, organization of the training session, and training evaluation procedures. Finally, use this information to improve the effectiveness of future training sessions.

Document all aspects of training including:

- who was trained and certified,
- where and when training occurred,
- a list of trainers,
- a short description of the training,
- any problems/questions encountered (and how they were resolved),
- field personnel feedback, and
- certification results.

## *2.7.2 Collect Data*

The next step is to locate and establish the sampling units in the field and to collect the data (Figure 2-16). Temu (1993) suggests some field techniques to measure timber, fodder, and some community products in a multi-resource situation. See Chapter 3 for case studies giving specific examples of data collection and Appendix 1 for listing of recommended references. Case studies 3.2, 3.3, and 3.4 (Chapter 3), provide example data collection forms. Case study 3.6 provides excellent examples of techniques for collecting flora and fauna data for ecological studies.

Fully document the collection process in a set of field instructions. The survey planner must ensure that the timing of the fieldwork matches with the crews' availability and the seasonal patterns of the ecosystem components. Often crews are over-committed during the growing season. Look for tasks crews can complete more efficiently during the dormant season, such as plot establishment and tree diameter measurements.

Collect quantitative, continuous data rather than subjective, categorical data. For example, measure and express forage production in weight per unit area rather than reporting the forage production to be low, medium, or high. Use classes if they are defined by specific quantitative minimum and maximum values.

**Figure 2-16:** Top: Collecting forest habitat information in a MRI in Montana, USA. Bottom: Laying out an MRI plot in Sudan (see Chapter 3.4).

The survey planner must also provide for the collection of sample material, such as soils, vegetation, and insects. Where appropriate, provide collection bags to the crews and appropriate storage locations back at the office. Some samples, like soils, may require refrigeration or immediate analysis. Use a clear labelling system so that one can track the material and relate it back to the site from which the crews collected it. When species identification is a problem, collect samples for later classification. Ground photographs also may assist with interpretation of local situations for which expertise is scarce.

### *2.7.3 Assessment and Appraisal*

Assessment and appraisals are activities done during the data collection (measurement) process. The specific activities include:

- Audits
- Remeasurement program for quality control data collection
- Debriefings and field personnel feedback
- Data validation and verification

Audits by trainers or field visits with crews are an important technique to qualitatively evaluate method implementation. The visits also provide an opportunity for field crew feedback about the MRI project and methodology. Use this information to evaluate the effectiveness of the training session, to identify logistical problems, and to correct problems with the interpretation and application of methodology.

Develop a short report from each audit. Include the name of the auditor, personnel audited, location, problems encountered, questions (including resolutions and answers), and any follow-up action item(s). File this information with the other MRI documentation

At a minimum the MRI design team should implement some type of quality control (plot remeasurement) program. Use this program to quantify comparability and develop precision estimates (quality control data). The target remeasurement intensity at a minimum should be approximately 5-10 % of the total number of measurement units in the system. For example, if there are 300 plots in the inventory then 15 should be remeasured to document the data quality. Conduct the remeasurement without knowledge of the original measurement values. This type of remeasurement provides an unbiased estimate of measurement error or precision.

Use the remeasurement values as a point of comparison. Calculate deviations or differences by subtracting the remeasurement value from the original value. Compare the measurement precision values with target measurement quality objectives to identify problem areas in methods, training, or implementation. Use the precision estimates to develop realistic measurement quality objectives for subsequent field seasons.

After the field season ends, have all of the field crews' personnel complete a questionnaire or participate in a debriefing about the MRI program. Cover all areas including the training session, data collection and recording techniques, logistics, methodology problems, and encoding problems. This provides additional qualitative information and can be done during audits or after the completion of the field data collection activities.

Data validation is the process of determining that crews record the appropriate codes. Data verification is the process for determining that crews record data accurately. An example of the difference between the two terms is a situation where field crews recorded the code for loblolly pine in the State of Maine on an inventory plot (USDA Forest Service n.d.). In this case, the code is correct (valid data) but it is unlikely that a field crew would find loblolly pine in Maine (unverified data).

The MRI design team can carry out both validation and verification during the data collection process through the use of electronic data recorders with programs that determine the range (validation) and logic (verification) checks. A range check is a comparison of recorded values with appropriate codes, whereas a logic check is a comparison of two entries in two different data fields. For example, if the previous d.b.h. recorded five years ago was 8 cm, it is logical to assume that today the d.b.h. on that same tree would NOT be 6 cm.

Usually one completes these steps in the office after the field plot has been measured during the data entry, editing, and processing steps. However, if one discovers errors at this point, it is very costly to go back to the field to determine if the codes are actually errors or real. This is a big advantage of electronic data recorders. They allow for verification, changes and corrections in the data where they should occur – in the field during data collection.

### *2.7.4 Correction*

Correction is the last aspect of the quality assurance program. The purpose of correction is to use all of the information from the prevention and assessment and appraisal systems to make improvements where needed in the measurement system. This assessment is useful in documenting problems with the current data collection system and making improvements for the next field season. These activities are usually done after the completion of the field season, although the MRI design team can make some changes during the field season.

The requirement for this activity is that information collected during the assessment and appraisal steps be available for analysis and review. This requires good documentation of all these activities – audit reports, training certification results, field crew debriefings, etc.

The analysis of remeasurement (quality control) data is the primary activity. This can be simple or complex, but should relate to the measurement quality objectives. Summarise this information and include it as part of the meta data for the database.

The process to handle errors and how to quantify their influence on the survey results are important. Error budgets (Gertner and Köhl 1992) can help to allocate the most important error sources and guide the design evaluation process and the preparation of field instructions. An error budget displays the effects of individual errors and groups of errors on the accuracy of estimates.

Use extreme caution when modifying any methodology. Such changes affect the ability to accurately describe trend information from the database. As a rule, change methods if one can predict the impact of the change with a degree of certainty. Carefully organise and plan any changes to the quality assurance program. Such changes may affect any part of the measurement process. Experience in Forest Health Monitoring has shown that changes to methodology have generally been minor and a majority of changes have had a positive on the training sessions by improving their effectiveness.

## 2.8 ENTER, MAINTAIN, AND ANALYSE DATA

Once data are observed, they must be entered, verified, and stored. Once the data are "clean", then they can be shared with collaborators who then summarise and analyse the data for their own purposes. When performing larger scale assessments, then the data may need to be updated to a common year. Once the analysis is completed, then the MRI protocols can be assessed to determine if the processes need to be modified. Finally, the data and MRI system must be maintained over time to ensure that trends can be detected and interpreted.

### *2.8.1 Enter and Store Data*

As part of the data collection step, the data are written on either tally forms, entered into a data recorder, or a combination of both. Except for sketch maps, use a data recorder if possible. One can program the recorder to check the validity of the data at the time and place that they are easiest to correct. In addition, one does not need to re-enter the data in the office reducing the possibility of additional errors and the analysis team has the data ready for study much sooner – even the same day.

If a crew uses a data recorder, then someone must transfer the data to a personal computer or workstation for loading into a database for further analysis. If the crew uses tally sheets, then someone must enter the data onto a computer, preferably directly into a database application. Often the process of loading the data will reveal some inconsistencies or duplication of data. Time spent cleaning up the data at this point is very worthwhile. However, permanently store original (raw) copies of the data files. Keep backup copies of the clean database files off site. It is advisable to keep copies of sketch maps and tally sheets off site as well.

Store information in at least two separate locations for security and on at least two media. Select widely-used media (for example, common removable-media drives) for storage. Archive data collected in the survey separate from the operational database. The operational database will contain compiled information as well as the original information. Follow a strict procedure for updating "errors" in the archived data.

### *2.8.2 Assess and Interpret Data*

The next step is to analyse the data and to interpret the results. Analysing the data involves summarising the large volumes of data into meaningful statistics for interpretation. The tendency is to develop all possible statistics, but then the interpretation becomes an overwhelming task. Instead, return to the objectives and determine the attributes or measures that are key to the decisions being made. Remember to isolate these attributes by removing other sources of variation, such as soil and site conditions.

Many software packages are available to perform the analyses. Generally, database software provides only the estimates and not their variability. If, however, compilation (for example, of indices or summary statistics) is an appropriate output, use the database software and place in the appropriate output.

People familiar with statistical analysis should perform the analysis in collaboration with the survey planner(s). This provides the planner with the information needed to perform the interpretation of the results. It is this step where one draws conclusions regarding the MRI objectives. Also, data may be available to indicate the drivers or causes of any changes. Finally, present the results in tables and in graphs in such a way that others can draw their own conclusions from the data.

> 😐 Use and interpret MRIs in a manner consistent with the design, sampling intensity, and nature of the data collected. In the traditional organization, we often leave the interpretation of data to the experts. Most often we present data as objective, which they may not be, and complete, which is often an impossibility (Wheatley 1993).

We usually express data representing one sample as single numbers or subjective values, with associated error estimates. For data representing more than one sample (by replication or aggregation), the analyst must decide how to display the data. First, consider whether to represent the data as a sum, range of values, average (mean), mode, median, extreme values, or some combination of these. The analyst can display some variables as a range (elevation, for example), others as an average (soil pH), and others as a sum (timber volume). Still others, typically the subjective variables, should be displayed as a concatenation of all states found (landform, soil series). Use caution in displaying such data as the typical or modal expression. Base this decision on the goals of the MRI as stated. Again, much of how the data are going to be analysed should have been determined in advance.

Of course, there will be a need to do different and not previously thought of analyses. It is important at this stage, however, to demonstrate that the MRI was successful. The MRI design team should show that an initial product was identified and that they designed a process to quickly produce this product once the initial data collection had occurred.

### *2.8.3 Update as Necessary*

An MRI of a large land base may take many years but it is desirable that all reported values be for the same time period. Similarly, the MRI partners may use the inventory results for many years after completion of the data collection but they may also desire summaries for the present. In these situations, it is necessary to update inventory records to the desired standard period. To reflect changes in trends and conditions, updates may reflect known changes documented from other sources or by the use of models specifically developed for projecting the data.

If it is necessary to revise the international assessment, national assessments or resource management plan before the completion of the next scheduled MRI, update the inventory records to reflect changes in trends and conditions. Base MRI adjustments on the following:

- Availability of field examinations with unbiased allocation of plots and statistically valid designs.
- Changes resulting from treatments reported to database information systems.
- Natural catastrophes of sufficient severity to change the inventory classification of the affected attributes
- Natural changes since the previous MRI.
- Growth models and other simulated projections.
- Co-ordination or integration of several inventories.
- Mid-cycle updating (Scott 1979).

## 2.9 EVALUATE AND SHARE RESULTS

The final steps are to re-evaluate the MRI protocol to see if changes need to be made and then to share the MRI results (Figure 2-17).

**Figure 2-17:** Reviewing inventory processes and results. Finland.

## *2.9.1 Evaluate the Results*

The surveys and resulting analyses should (Nossin 1982):

- Reveal the availability of resources – dependent on the phase and scale of the survey – and identify their character, location, and potential.
- Identify the requirements for reaching a land management objective, pre-established or formulated or modified on the basis of the survey results.
- Identify limiting factors and constraints for land management objectives and eliminate impossibilities.
- Assess the balance of resource potentials and management requirements with consideration of the constraints
- Place before the decision-maker a choice of alternatives for land management objectives
- Consider the side effects of implementation, both the desired ones and the detrimental ones. Seek feedback from the end-users about the information provided. What are the likes and dislikes, problems, or further needs?

The data may clearly address the questions raised. However, if the data do not, either the MRI team needs to modify the inventory protocol to provide more precise results, or the MRI partners need to modify the management or objectives. Failure to answer the questions may mean something as simple as taking more plots or extending the time frame one or two more years for monitoring so that the ecosystem response will be more apparent. Alternatively, the MRI design team, in collaboration with the decision-makers and partners, may modify the precision levels. Other possibilities are to restate the management and/or monitoring objectives to reflect the new information. Other possibilities are that the measures (indicators) did not address the problem, or that the monitoring assumptions may not have been valid.

This process provides feedback for both the database and the MRI plan and on the original management plan. The assessment of the MRI system is necessary to ensure that it is providing the appropriate kind of information at the right level of detail. If not, then modify the MRI protocol and continue the project. If the MRI meets the management objectives, then make no changes. If not met, then either modify the management activities to meet the objectives or modify the objectives themselves.

## *2.9.2 Share Information*

As we construct and travel down the information highway, we need:

- A broad distribution of information, viewpoints, and interpretations,
- Organizational designs that foster multiple interpretations of the data, and
- Systems that do not restrict information access.

☺ Note that the MRI partners should decide the format and process for sharing the information and formats of initial summaries in advance of data collection. Test these formats during the pilot studies. It is important to ensure the end-users are going to be satisfied with what they get.

### *2.9.2.1 Present Results*

We should present solutions that transcend current organizational structures. Integration needs to go beyond the survey phase. We must also include integration into the analysis stage. To share information:

- Present information in a form that the partners, decision-makers, and other users easily understand. Include the use of graphs, charts, computer "maps", and simulation and visualisation techniques. In addition, close the information loop. Present the data in such a form so that the data collectors comprehend their importance. This is a final ratification and tells the MRI team that the data they collect have meaning.

- Provide unpublished raw data to anyone that requests it.

- Encourage diversity in resource analysts through additional training and recruitment in non-timber specialities. Involve the public and especially special interest groups in the analysis of the data. Such groups generally have the skills needed to do an adequate job and by having them involved at the outset could avoid some surprises later.

- Use common work stations so the people who are gathering data and the people using the resulting information are in the same area. Use a common work room to promote team building. People can easily discuss how they will use the MRI data.

- Fund worthy research proposals that make use of the MRI data and sample design through co-operative arrangements.

- Encourage multi-disciplinary interaction in resource publications, survey plans, sampling designs, E-mail postings, etc.

- Formally keep track of what uses decision-makers and administrators make of the MRI data especially in non-traditional disciplines. This is an essential part of any pioneering research activity such as that by Rudis (1991 and 1993a).

#### *2.9.2.2 Consider Placing your Data on the Internet*

MRI databases should be easy to find, access, and download by the partners and anyone else that may have an interest. Someone may find your online MRI and use it as a model for their own survey. The best inventory files should require no explanation. In other words they should be stand alone files. They should not require any special codes, encryptions, compressions, documentation, special third-party software applications (which excludes many smaller computers), and stringent format standards

If used properly, the text based World Wide Web (WWW) will offer inventories of all kinds in simple column forms. In other words, anyone should be able to print to the screen buffer or to disk what is seen on the screen. The MRI data should be in tab delineated format (or some other type of columns) with as much information as possible regarding each species in columns in a form that is not cryptic: make it something like one would see in an atlas or almanac. One might call this summarised data. Any of your partners or people looking at the WWW page of your inventory database should find the source information in the title of each file. If your MRI is listed on a Web HTML (hypertext mark-up language) page make sure that it includes these tags:

- Title tag: Multipurpose Resource Inventory (MRI) for a place, by some organization (or person), and on some date. In other words who, what, where, when and why.

- Meta tag: meta name="keywords" content="multipurpose resource inventory, multiple, resource, inventory, ..."

If your MRI is a text document (NOT ending in htm or html) it will not have a title tag or meta tag. This text document needs to have a paragraph at the top which contains the name and a description of the inventory. Web search engines will look for keyword in the text if there are no HTML tags.

For each and every page there should be a title providing: who, what, where, when, and why on the same bookmark title line.

Here is an example of a inventory file, selected at random, that contains essential title information (note the critical information can be in any order).

Good: "Michigan's 1992 Forest Economy: Data By County" (http://www.for.msu.edu/~kpw/cntymain.htm).

What...... forest
Why....... economy data (by county)
Where..... Michigan, ??
When...... 1992
Who....... ?, ??

Any MRI-like data can be more easily found on the Internetby slight modification of the html title as follows.

Better: "1992 Forest Inventory of Alcona County, Michigan, US, Michigan State U., US" (http://www.for.msu.edu/~kpw/alcona2.htm).

What...... forest resource inventory
Why....... economic
Where..... Alcona county, Michigan, US
When...... 1992
Who....... Michigan State University's Department of Forestry and Cooperative Extension Service, US

If a file is a true Multipurpose Resource Inventory than the URL (Unique Resource Locator) would include "MRI" on the title line and any search engine would find the MRI easily.

Best: "Multipurpose Resource Inventory (MRI) of Alcona County, 1992, Michigan, US, Michigan State U., US" (Note, this MRI inventory title does not exist and is used here as a model only).

What...... resource inventory
Why....... multipurpose (MRI)
Where..... Alcona county, Michigan, US
When...... 1992
Who....... Michigan State University's Department of Forestry and Cooperative Extension Service, US

Note that all six parts of the title are included between the title.

The two letter international nation code (for example, Australia=AU), http://leonard.anu.edu.au/email/international.email, should be used (1) on the title line, (2) in the file names (such as forestau.html), (3) in the directory path (such as .../mri/au/...), and (4) in database search indexes (WAIS - Wide Area Information Service). If your MRI database follows the WAIS standard for files then your file can be searched from the Internet and it will can be combined with other WAIS databases.

Providing a full title (title.../title) for each item on a single title line is a courtesy to others outside of your discipline. In addition you can still have the same title information formatted with graphics on the title page as historically is done.

One of the most important pieces of information resulting from an MRI is a listing of the species (flora and fauna) present. This is something that every forest and rangeland has and the public wants to know. If there is no common name of a species group show a common name of the next highest group, taxa, clade, etc.

☺ Register your MRI with several of the Search-The-Web robotics searches once your local Web expert has placed it on the WWW. Submit email to organizations, online mailing lists, and otherwise electronically announce it to the world. The most important thing is to offer the inventory to your partners and others.

## 2.10 DOCUMENT PROCESSES

Documentation of current and previous inventory procedures is an important aspect of quality assurance. We need records of current procedures because it is difficult to design an effective and efficient quality assurance system without a complete understanding of the measurement processes in place (Figure 2-18). These procedures are the basis for the second component of quality assurance, assessment and appraisal. These procedures are also the basis of calibration techniques and field personnel use them as a reference document during data collection.

In addition, documentation of procedures is critical for data analysts to ensure a correct interpretation of the information in the database. This documentation is very important if modifications of procedures or codes have occurred throughout the life of the MRI. These are the meta data for the database. Keep all previous procedures used (if any) on file so that the analysis team interprets data from previous years with the appropriate method. This historical record is also necessary because there may be a change in personnel between years.

When data collection methods change, not only is it important to document when the change occurred, but also to conduct a comparison study between both procedures. This comparison study should allow for trend and change interpretations in the MRI information.

Documentation of data collection, methodology, and standards is essential for verification and monitoring changes in the MRI. Document the organization and progress of inventories by preparing an MRI work schedule and storing the resulting information in the inventory files. The MRI design team must also document proposed future changes. Partners will generate considerable paper during the design and implementation of an MRI. The team(s) ease this process if they agree upon procedures for filing, distribution, review, and formats (for example, for describing variables to be measured, minutes, decisions, reports).

### *2.10.1 Include Inventory Work Schedule*

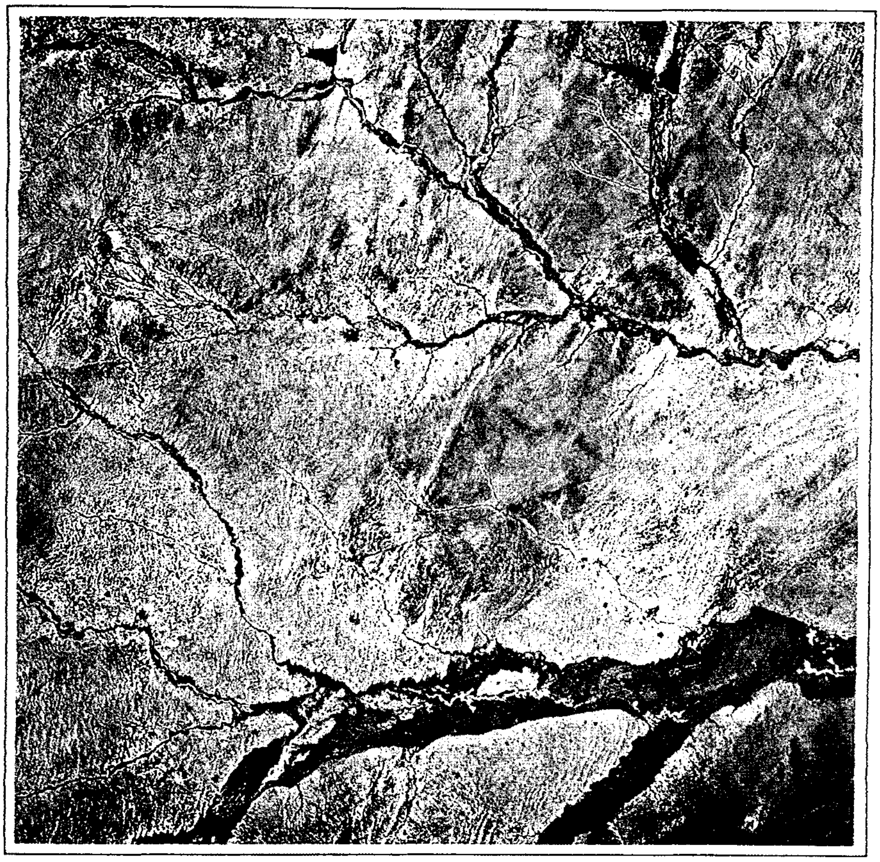
Inventory schedules address how data are to be collected, compiled, and used and how the results are to be documented, disseminated, and maintained. The schedule should cover inventory development through reporting that includes:

- A description of the MRI objectives.
- A list of expected results.
- A determination of how existing data may be combined with the proposed inventory.
- A list of co-operators, including the responsibilities of each.
- The time schedule and resource and budget assignments, including personnel and equipment.
- Classification, stratification, and sampling procedures to be used and sampling intensity required. If appropriate, include the statistical design, precision of required measurements, and precision and accuracy of derived data.
- A set of local field instructions describing field forms, measurement techniques, and codes. Use standard codes where appropriate.
- A review of existing measured and derived data.
- Requirements for training, quality control, and inspections.
- A time frame for tracking and reporting accomplishments within the established procedures.

- Analysis and reporting procedures.
- Data compilation methods.
- Specifications for the storage of the field data files, including paper files, microfilm, and computer databases.

**Sudan**
**Reforestation and Antidesertification**
**(SRAAD)**
**Pilot Project**

**Procedures Handbook**



Prepared for the Forests National Corporation, Khartoum, Sudan
by the U.S. Geological Survey, U.S.D.A. Forest Service, and Sudan Survey Department,
sponsored by the United States Agency for International Development

**FEBRUARY 1990**

**Figure 2-18:** Documentation of the Sudan MRI. See Chapter 3.4.

### *2.10.2 Retain Inventory Files*

Prepare and maintain the inventory documentation and resulting data in accordance with established direction and include:

- A copy of the inventory work schedule
- Accomplishments using established procedures.
- Identification of items such as field samples not measured or established.
- Substitute samples.
- Production rates.
- Unusual situations that affect the MRI results or costs.
- Inspection reports evaluating measurement errors.
- Tabular results of the inventories, including statements of attained sampling errors
- Maps of the inventory unit. All MRI sample and map data, where applicable, should be geographically referenced to primary base series maps for future geographic information system applications. Establish a minimum of three geographic reference points per graphic layer. Maps should show the following minimum information:
    - Land status (title, encumbrances, partial interest, and use restrictions).
    - Location of sampling units and their identification number.
    - Extent of the resources, using established mapping standards. Provide appropriate stipulations regarding information reliability.
- Aerial photographs or imagery used. Stereo pairs of each field location sampled. These are desirable for relocation and remeasurements in subsequent inventories and for monitoring changes.
- Cost summaries.
- Information on schedules, specific objectives, and summary findings.
- Data files. MRI databases and plot records provide the basic source for compiling Forest, State, Regional, national, and international summaries.

## 2.11 SUMMARY AND CONCLUSIONS

The world's human population is growing and the biosphere (the land area per person) is shrinking (Figure 2-19). Within the past 50 years, human population has more than doubled and the available "living space" per person has more than halved.

With the reductions in 'living space,' the competition for land and land use increases. Figure 2-20 shows the changes in land use from 6000 BCE and projected to 2010 CE (Bryant *et al.* 1997, FAOSTAT 1997, Population Reference Bureau 1994, Solberg 1996, FAO 1997b, Lund 1997b). Agricultural lands increase as human populations increase. Forest (including other wooded lands) and Other Lands (lands not qualifying as agricultural or forest lands) decrease as crop lands expand. The source of croplands is, of course, the conversion of forests and other lands.

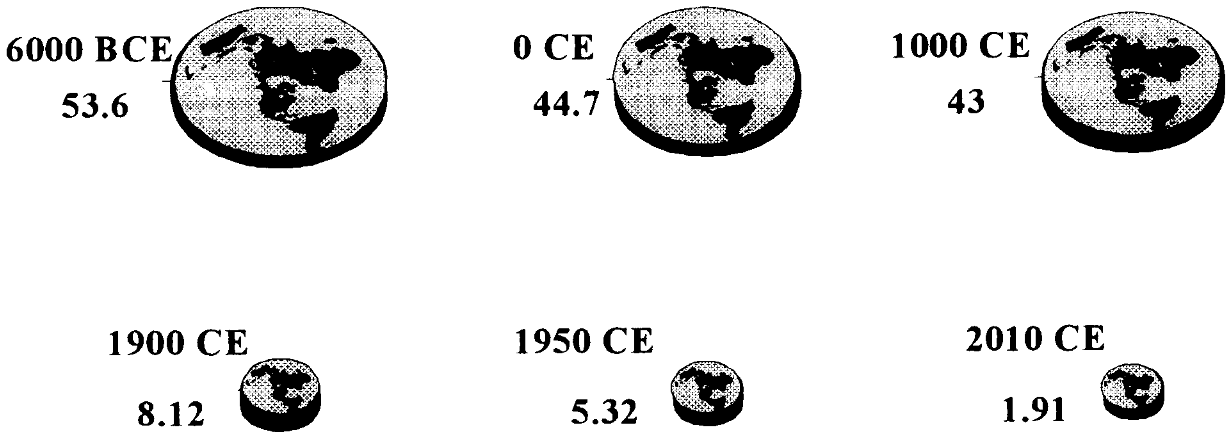



**Figure 2-19:** Shrinking biosphere (land area - ha per person) for selected years. Source: Lund 1997b.

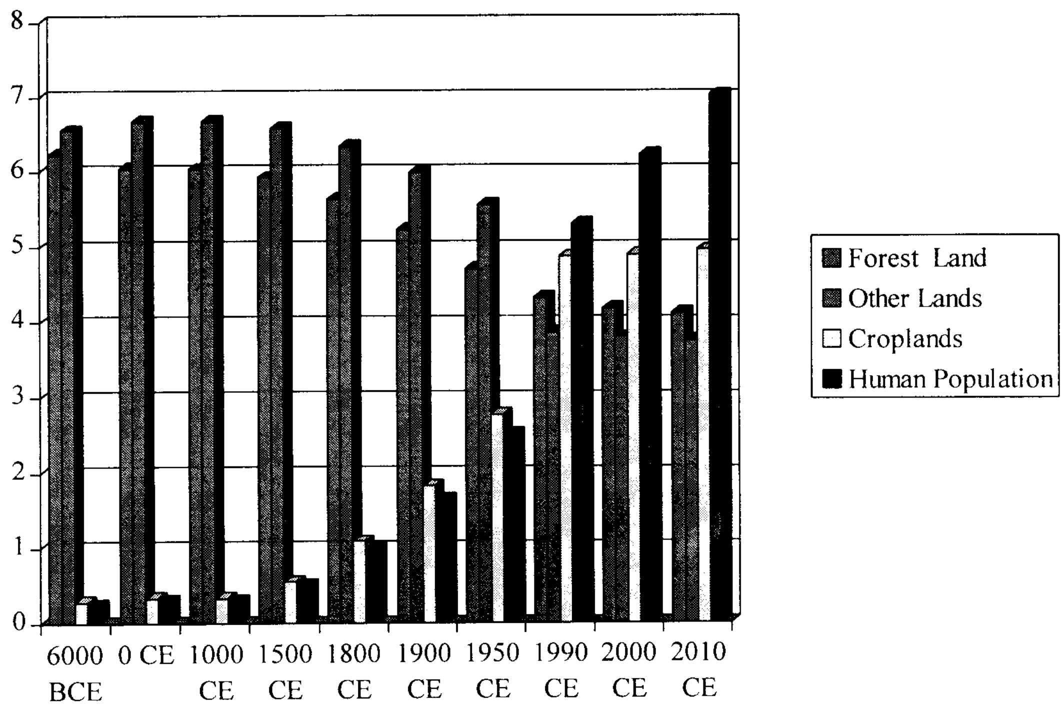



**Figure 2-20:** Changes in land use with increase in human population over time. Source: Lund 1997b.

The numbers are not as important as are the trends. The bottom line is that there will be increasing conflicts between the need for development and for preservation, lands and land use at the global, regional, national, and local levels. With the increasing conflicts there will be more demand for good information from well-designed resource inventories at reasonable costs.

Given the international mandates and local environmental concerns and needs there is no doubt that new resource inventories should not be limited to the study of forest resources leaving out the inter-relationships with other environmental resources and other uses of the land in general. We may say the same of the inventory and monitoring of agricultural lands. It is therefore necessary to widen the scope of information gathered, examining forests, pastures, alpine meadows, uncultivated lands and formations which are not forests, and, on the other hand, to evaluate the natural environment with respect to the whole of its resources.

The effectiveness of any inventory or monitoring program can only be determined by how well the resulting information meets the objectives or the needs of the decision-maker. The authors made the following points in this report:

- Multipurpose resource inventories are designed around the need for information about two or more resources, services or functions. They differ from 'normal' or single purpose inventories in that they are more complex and involve working with people with whom one may not be accustomed to dealing with.

- The attributes selected for inclusion need not be related. Questionable support, however, will exist for an inventory of resource attributes when the attributes have no link to resources of interest to the inventory's stakeholders.

- Data needed in a multipurpose resource inventory (MRI), and the analyses drawn from them, are moving targets. Those targets are time, scale, resource, and discipline dependent (see below). Perspectives and priorities about needed data attributes, even resources, will change over time and with the people who finance data collection and analysis tasks.

- Time dependence means we select attributes referenced to one point in time, or that account for fixed intervals that we perceive to be reasonable. Unlike trees, mobile resources, such as animal species, require more than one measurement. Point-in-time measures may be too variable to draw conclusions about their population numbers. Inventories of even some fixed resources are influenced by processes that occur within a season (disturbances to timber resources by catastrophic events like hurricanes), within a year (ephemeral occurrence of resources like valued medicinal herbs), or within a few years (tree seedling and plantation establishment, or a region's harvesting cycles).

- Spatial dependence means we select attributes suited to selected spatial resolutions. Optimal samples of multiple resource attributes, on the other hand, are categorised at different scales of resolution. Examples include: small sample areas for small species and small-scale processes like forest canopy gap dynamics; large sample areas for larger species and large-scale processes like forest fragmentation. We use one of two approaches: nested sampling or overlays of data from other sampling schemes. Nested sampling often conserves travel time and data management, but increases the cost of logistics and time spent in the field. The overlay of data from other sources is another common approach. However, without adequate spatial registration of sample locations, overlays introduce interpolation error. An optimal MRI most often has one large sample unit for large-scale processes and species, and several small sample units nested within the larger sample for smaller-scale attributes and processes.

- Resource dependence means we primarily select inventory attributes
  - that are directly relevant to supply information (such as to provide a base of information for resource-extractive industries),
  - that are likely to satisfy trend modelling efforts (to predict future resource supplies), and
  - that cost little or augment non-target resources and non-resource data gathering efforts.

- Discipline dependence means we select attributes that reflect sometimes focused views and often limited perspectives. Resource attributes selected and the design of the MRI will be influenced by the discipline(s) involved. Inadvertent, and sometimes purposive agendas, favour one resource over another. These dependencies will cloud data selection and subsequent analysis.

- No MRI will satisfy all data needs. An example below combines timber and wildlife resource inventories. Apart from statistical correlations, there is little data to characterise and validate wildlife population resource estimates without measuring wildlife populations resources directly. The optimal wildlife resource approach is to estimate seasonal populations for several years. Such attributes require both seasonal measures and extensive area sampling. By contrast, the optimal timber resource inventory approach requires far fewer samples in time or space. Timber and wildlife resources are related, but the sampling frame chosen will frequently be suboptimal for satisfying both resource information needs. Perception and control of a MRI's primary and secondary goals will ultimately affect results.

- A consequence of the "moving target" condition is the need to thoroughly document, archive, distribute, and make user-friendly all the data collected. The more open and democratic the data and their analysis, the more likely it is that they will reflect public concerns. This is a key to reducing dependence on narrow points-of-view. Dissemination of the data permits a broadened audience to interpret results, thereby increasing support for conclusions drawn from the data. This is particularly critical when inventory data and analyses guide trade-offs among alternative resource policy options.

- Records of frequently-asked-questions, measures, and analyses provide needed responses to stakeholders and inventory designers about the relative importance of inventoried items. Such records have their limits for new or redesigned resource inventories, as responses (feedback) come primarily from prior survey designs and results. Still, we achieve no progress without an account of past mistakes and accomplishments.

Opportunities for integration include: (1) the use of common definitions, (2) noting and storing location of where data are collected, by whom, when, and for what purpose, and (3) objective sampling methods. Surveys which collect data on existing vegetation offer particular opportunities for integration.

Obstacles to achieving integration include individuals, organizations, and existing designs. Success may be achieved by working with diverse people and groups, establishing a vision, establishing an information system, developing and testing a data collection system, seeking funding and support, creating an MRI organization, and sharing resulting information.

Realise that no single inventory answers all questions for a large agency or nation. It is neither possible nor necessary to develop a "ONE-POINT IN TIME AT THE SAME PLACE" field inventory to cover all resource needs. Some data may have to be collected on the same piece of ground by the same people but for different purposes. For example, some collection efforts are seasonal or cyclic in nature. A range specialist may conduct a vegetation inventory on a piece of terrain in the summer and a snow survey at the same location in the winter. It would be impossible to combine both surveys.

Some data need to be collected at specific locations, such as water quality data at spring seeps, while other data need collecting throughout the landscape (such as soils, vegetation). Some surveys, such as those of wildlife, may have narrow time windows for collecting data or require staying in one place and observing animals over long periods. Many types of data collection require special skills that are in scarce supply or would be too costly to include on all inventory crews. Except for using common codes, definitions, and standards, these data collection efforts may not be integratable with other inventories.

On the other hand, resource inventories that feed agriculture, forest, and range management plans and national assessments could be co-ordinated and in many situations, integrated into a cohesive data collection strategy. For example, many sectors make use of existing vegetation data, such as forestry, wildlife, agriculture, range, and recreation. These interest groups may collect similar information in the same areas. In many instances, these data collection efforts can be co-ordinated or integrated.

Team work and commitment at all levels in the MRI organization are key to the success of a multipurpose resource inventory. Vanclay (1990). Do not be deterred by the fact that MRI cannot be set up overnight. Start with what can be effectively assessed now but set up the frame-work for what should come later.

Having knowledge of the resources, however, is just one step in the process of successful resource management. Plans for land use have to be worked out in concert among the various sectors. Holistic assessments followed by integrated and co-ordinated planning and implementation is the only hope for determining the optimum use of Earth's limited resources.

# 3 CASE STUDIES

Following are six case studies from very different parts of the world. The first three studies are situations where many resource inventories were already ongoing, but actions had to be taken to reduce costs and unnecessary duplication of effort. The first is from the United States showing how the U.S.D.A. Forest Service developed its inventory information needs. The second is from the province of British Columbia, Canada and illustrates how various disciplines organised to develop procedures for conducting MRIs. The third is from the Siskiyou National Forest in the United States showing integration at the very local level.

The next three studies focus on areas where there were no ongoing inventories. The first is an example from Sudan where partners used the latest technologies in a simplified manner to provide multiple resource inventory data. The second case deals with the development of methodologies and participatory involvement of villagers in Indonesia for the inventory of forests and non-wood goods. The last case addresses ecological data collection in the Adirondack Park, New York state. Methods for sampling flora and fauna are presented.

## 3.1 INFORMATION NEEDS ASSESSMENT – USDA FOREST SERVICE

**Case Study Synopsis**

**Area of Concern:** National Forest Land of the United States

**Problem:** Numerous resource inventories conducted on National Forest Land lead to unnecessary duplication of effort and information gaps.

**Organization/Infrastructure Created:** USDA Forest Service National Headquarters. An interdisciplinary task group composed of representatives from the following Forest Service Staffs: Research (Forest Inventory), Timber Management, Range Management, Wildlife Management, Geology and Minerals Management, Recreation, Lands, Watershed Management, and Information Systems.

**Vision/Objectives:** To review existing Forest Service inventory mandates and directives and to establish a core set of data needs and instructions for the agency as a step towards developing an integrated system of resource inventories.

**Methods:** The team reviewed existing direction, used brainstorming and consensus building methods. The team documented each meeting and provided the results to the field offices for verification and suggested changes.

**Results:** The team identified the core data elements and developed definitions and standards for each. They are provided in USDA Forest Service (1989). Direction for the USFS to implement integrated inventories may be found in USDA Forest Service (1990). The USFS is now working to design the actual system or systems to collect the data.

In a review of existing inventory direction for the USDA Forest Service, the agency found 14 Laws, 57 Manual Sections, and 20 national handbooks providing national direction (Lund 1987). Table 3-1 lists some inventories the USDA Forest Service conducted on National Forest System (NFS) lands to meet those requirements.

Details of some of the above inventories are found in USDA Forest Service (1992). They were independent of one another, even though they often covered the same ground and collected the same kinds of information. This resulted in duplication of efforts, wasted time and expenditures, and inconsistent and incompatible data. One forest district reported having to memorise as many as 28 different codes for recording of the same plant species for the various reports and forms the field people had to complete.

As a result, the USFS initiated direction to start using integrated or multiple resource inventories to minimise field data collection effort and to maximise their uses. The agency formed an interdisciplinary team (the Resource Inventory Co-ordination Task Group or RICTG) to determine the USFS national needs and to develop direction for creating integrated resource inventories (Lund 1987).

**Table 3-1: USDA Forest Service Resource Inventories (Lund 1987)**

| Inventory Subject | Major Uses | Responsible Staff |
|---|---|---|
| State-wide Forest Surveys | National Assessments/State Survey Reports | Forest Research |
| Forest-wide Surveys | National Assessments/State Survey Reports/Forest Plans | Timber Management |
| Silvicultural Examinations | Forest/Project Plans | Timber Management |
| Timber Cruises | Project Plans | Timber Management |
| Regeneration Surveys | Project Plans | Timber Management |
| Range Analysis | National Assessments/Forest/Project Plans | Range Management |
| Noxious Weed Surveys | As above | Range Management |
| Water Quality | As above | Watershed & Air Management |
| Air Quality | As above | Watershed & Air Management |
| Soil Resources | As above | Watershed & Air Management |
| Threatened & Endangered Species Survey | As above | Wildlife & Fisheries Management |
| Wildlife & Fish Habitat Survey | As above | Wildlife & Fisheries Management |
| Cultural Resources | As above | Recreation Management |
| Recreation Opportunity Spectrum | As above | Recreation Management |
| Visual Management | As above | Recreation Management |
| Common Variety Minerals | As above | Minerals & Geology Management |
| Fuels Inventory | Forest/Project Plans | Fire & Aviation Management |
| Forest Pest Conditions | Forest/Project Plans | Forest Pest Management |
| Land Status & Utility Corridors | National Assessments/Forest/Project Plans | Lands Staff |

The following is an example as to how the USFS identified its information needs and developed a listing of common data elements basic to multiple resource inventories. The agency needs a follow-up analysis to determine the priority for collecting the data, surrogates for the information, and any potential overlap.

### *3.1.1 Determine the Laws Governing the Agency or Organization*

The interdisciplinary team reviewed the various laws regulating the agency to determine the minimum information needs. Table 3-2 lists the major laws calling for inventory or monitoring data for the USDA Forest Service. A review of other nations' laws may reveal similar information requirements.

**Table 3-2:** Listing of Major Laws affecting U.S.D.A. Forest Service Inventories.

*Fish and Wildlife Co-ordination Act of 1934 (ch: 55, 48 Stat. 401, as amended; 16 U.S.C. 661, 662(a), 662(h), 663(c), 663(f).* This act authorises surveys and investigations of the wildlife of the public domain lands including lands and waters of interest therein acquired or controlled by any agency of the United States.

*Wilderness Act of 1964 (P.L. 88-577, 78 Stat. 890; 16 U.S.C. 1121 (note), 1131-1136).* Section 3 permits the gathering of resource information in wilderness areas.

*National Environmental Policy Act of 1969 (P.L. 91-190, 83 Stat. 852; U.S.C. 4321 (Note), 4321, 4331-4335, 4341-4347).* Section 102 directs that all agencies of the Federal Government shall utilise a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision-making which may have an impact on man's environment.

*Endangered Species Act of 1973. (P.L. 93-205, 87 Stat. 884, as amended; 16 U.S.C. 1531-1536, 1538-1540).* Section 6 directs each Federal Agency to conduct biological assessments for the purpose of identifying any endangered or threatened species.

*Forest and Rangeland Renewable Resources Planning Act of 1974 (P.L. 93-378, 88 Stat. 476, as amended; 16 U.S.C. 1601 (Note), 1600-1614).* Sections 3-7 and 12 require the USFS and other federal agencies to conduct inventories of present and potential renewable resources, utilise information and data available from other Federal, state, and private organizations, and avoid duplication and overlap of resource assessment and program planning efforts. The law further requires a comprehensive and appropriately detailed inventory of all National Forest System lands and renewable resources.

*Federal Land Policy and Management Act of 1976 (P.L. 94-579, 90 Stat. 2743, as amended; 43 U.S.C. 1701 (Note), 1701, 1702, 1712, 1714-1717, 1719, 1732b, 1740, 1744, 1745, 1751-1753, 1761, 1763-1771, 1781, 1782; 7 U.S.C. 1212a; 16 U.S.C. 478a, 1338a).* This act requires that public lands and their resources be periodically and systematically inventoried and that an evaluation of the current natural resource use and values be made of adjacent public and non-public land.

*National Forest Management Act of 1976 (P.L. 94-588, 90 Stat. 2949, as amended; 16 U.S.C. 472a, 476, 500, 513-516, 518, 521b, 528 (Note), 576b, 594-2 (Note), 1600 (Note), 1601 (Note), 1600-1602, 1604, 1606, 1608-1614).* Sections 2, 6(f)(3), and 6(g)(2) emphasise the stipulations of the Renewable Resources Planning Act of 1974. The act also requires that the USFS establish quantitative and qualitative standards and guidelines for land and resource planning and management. Inventories shall include quantitative data making possible the evaluation of diversity in terms of its prior and present condition.

*Clean Air Act Amendments of 1977 (P.L. 95-95, 91 Stat. 685, as amended; 42 U.S.C. 7401, 7418, 7470, 7472, 7474, 7475, 7491, 7506, 7602).* Sections 162 and 165 require a classification of monitoring of Federal lands for air quality.

*Soil and Water Conservation Act of 1977 (P.L. 95-192, 91 Stat. 1407; 16 U.S.C. 2001-2009).* Section 5 authorises the Federal Government to obtain and maintain information of the current status of soil, water, and related resources. The act further requires an integrated system capable of using combinations of resource data to determine the quality and capabilities for alternative uses of the resource base and to identify areas of local, State, and National concerns.

*Forest and Rangeland Renewable Resources Research Act of 1978 (P.L. 95-307, 92 Stat. 353, as amended; 16 U.S.C. 1600 (Note), 1641-1647).* Section 3b authorises the USFS to conduct renewable resource surveys on state and private lands.

*Co-operative Forestry Assistance Act of 1978 (P.L. 95-313, 92 Stat. 365; 16 U.S.C. 2101 (Note)).* Section 8 authorises the USFS to assist State agencies in the assembly, analysis, display and reporting of state resource data.

*Public Rangelands Improvement Act of 1978 (P.L. 95-514, 92 Stat. 1806; 43 U.S.C. 1752-1753, 1901-1908; 16 U.S.C. 1333(b)).* Section 4 directs the USFS to inventory and identify current public rangeland conditions and trends as part of the inventory process required by Section 201 (a) of the Federal Land and Management Act of 1976 (43 U.S.C. 1711) and to keep such inventories current.

*Energy Security Act of 1980 (P.L. 96-294, 94 Stat. 611; 42 U.S.C. 8801 (Note), 8854, 8855 Sec. 261).* This act emphasises the need for biomass information for energy projects.

*Forest Ecosystems and Atmospheric Pollution Research Act of 1988 (P.L. 100-521, 102 Stat 2601; 16 U.S.C. 1680 (Note).* Section 3 directs the USFS to increase the frequency of forest inventories in matters that relate to atmospheric pollution and conduct such surveys as are necessary to monitor long-term trends in the health and productivity of domestic forest ecosystems.

### *3.1.2 List Reports Required by Law*

The following is a list of reports that the USDA Forest Service should produce at the national level to meet the mandates of the laws shown in Table 3-2. Organizations that have mandates and lands similar to the USDA Forest Service may have similar needs.

*General Requirements*

Forest inventory units should be able to display the following information.

Forest/Rangeland. Land areas by ecosystem, ecological type and covertype.

Land Cover. Describe land areas by ecosystem, land cover type, land cover category, stand age, and other elements that describe the existing vegetation community and optionally successional stages and the potential natural community that the area is capable of supporting.

Trend in Ecological Status. Displayed by ecological type.

(1) Express trend as toward, away from, or not apparent in relation to the potential natural community (PNC). Distinguish between an apparent trend inferred from indicators based on observations at a single point in a time and long-term trend from observations and measurements on permanently established reference or monitoring sites.

(2) A trend may also be expressed as: toward, away from, or not apparent in relation to the desired plant community (DPC) based on management objectives

(3) Do not mix hectares displayed relative to PNC and DPC.

Land Use. Land areas by land cover category, land use class, ecosystem, ownership, Regions, and States. Land classification includes the analysis of public and private land within, adjacent to, and outside of existing national forest units to determine their suitability for meeting the resource output demands for which the forests were created. Many national forest areas contain a random pattern of mixed ownership. Analysis is necessary to evaluate the land uses of and to determine the need for adjustment in the extent and pattern of land base to meet forest management goals.

Soil Protection. Include soil erosion types, erosion severity, soil compaction, and soil cover. Measure in acres (or hectares) by soil cover, erosion type, erosion severity, and percent compaction. Display soil stability in number of acres or hectares that are classed as satisfactory or unsatisfactory.

*Range Management Requirements*

Ecological Status and Resource Value Rating for Livestock Forage Condition. Display floristic similarity of the current vegetation to the potential natural community and for rating livestock forage condition in acres or hectares. Base ratings on the floristic similarity of the current vegetation to the Potential Natural Community and the current soil condition in relation to stated soil quality standards

Noxious Weed Infestation. Display areas affected by vegetation type.

Forage Utilisation. Display area by utilisation classes as needed in monitoring compliance.

Livestock Suitability. Includes forage production and accessibility.

Livestock Use. Display in numbers of livestock and animal unit months (AUMs) of grazing by Forest and State.

Range Treatment Class. Display of area by category.

Forage Production. Show existing and potential production in acres or hectares by production classes of 500 pound (225 kg) increments.

*Recreation Management Requirements*

Recreation Use. Include use numbers and patterns.

Recreation Settings and Characteristics. Include the physical and biological characteristics that make land suitable for recreation opportunities and their availability.

Recreation Opportunities and Alternative Recreation Sites. List the various types and characteristics of NFS Recreation sites (existing and potential) including setting, opportunities, and supply of facilities.

*Forest Management Requirements*

Land Areas by Major Forest Land Classes. Include conditions, forest types, suitability classes, productivity classes, by ownership, regions, and States.

Timber Volume by Forest Type and Condition. Include timber class, species, diameter class by ownership, region, and State.

Timber Growth and Mortality Estimates. Display by forest conditions, ownership, region, and State.

Timber Removals and Other Wood Products. Display by ownership, region, and State.

Present and Future Forest. Display area, volume, and potential yield. Include area and volume (including woody biomass) by treated versus untreated (natural) stands, roaded and non-roaded areas, and stand conditions (old growth and other classes).

*Watershed and Air Management Requirements*

Soil Capability Rating (area). Rate and display the potential suitability of soils for different users and for predicting the behaviour, productivity, and performance of soil under management.

Municipal Water Supplies. Display municipal supply watersheds that serve a public water system as defined in Public Law 93-523 (Safe Drinking Water Act); or as defined in State safe drinking water regulations.

Water Uses (consumptive and non-consumptive). Show the uses and amounts of water used at the present or in the future to meet USFS goals and objectives.

Flood Hazards. Provide flood risks, both natural and man-induced, that pose a threat to facilities, lands, and investments, both on and off national forest land.

Watershed Condition (area). Provide estimates of the condition of watersheds, relative descriptions of the health of a watershed by factors which affect favourable conditions of flow and soil productivity. Management objectives are the standards for determining condition classes.

Water Yield. Provide estimates of the volume of water measured, modelled, or estimated from specified watersheds, management areas, or administrative units that result in stream flow or ground water recharge from national forest land.

Watershed Improvement Opportunities. List soil or water improvement projects implemented within a defined watershed to improve watershed conditions. These projects are implemented for rehabilitation of degraded lands or protection to maintain or improve natural watershed conditions.

Water Quality. Show the suitability of the water resource in streams, lakes, ground water, and other water bodies to support beneficial uses of that water.

Riparian Area. Maintain estimates of areas in a riparian ecosystem, aquatic ecosystems, and wetlands.
Ground Water (Quantity). Inventory ground water resources, including recharge and discharge areas.

Instream Flow Needs. Determine instream water flow needs for maintaining favourable conditions of flow and meeting forest land management objectives

Perceived Visibility over National Forest System Lands. Obtain quantitative and qualitative data from an array of manual and automated visibility monitoring sites.

Floral, Fauna, Geological, and Cultural Resources Condition. Rate as a direct and indirect result of air pollution.

*Fish and Wildlife Management Requirements*

Threatened and Endangered (T&E) Wildlife Species (including populations and quantities of habitats). Document the actual and potential occurrence of threatened and endangered species in the area, based on existing and potential habitat conditions and the known range and habitat relationships of the species.

Wildlife Species Occurrence. Document the actual and potential existence of wildlife species within the area, based on existing and potential habitat conditions and the known range and habitat relationships of the species.

Wildlife Species Abundance. Describe the existing and potential abundance of wildlife species based on habitat capability within the area. Abundance usually is expressed as population density values or by descriptors of relative abundance.

Wildlife Vegetation Habitat. Interpret designations of wildlife habitats derived from features of terrain, existing and potential vegetation, and known habitat relationships of the species. Examples: deer winter ranges, goshawk nesting habitats, bear denning areas.

Wildlife Water Habitat. Interpret designations of habitat for wildlife of aquatic and riparian environments, derived from features of terrain, hydrologic features, water type, physical and chemical conditions of the water environment, existing and potential vegetation, and known habitat relationships of the species. Examples: waterfowl nesting habitats, beaver ponds, otter habitats.

Wildlife Soils Habitat. Interpret designations of habitats for sensitive plants and fossorial wildlife based on soil type and characteristics, features of terrain, existing and potential vegetation, and known habitat relationships of the species.

Wildlife Use and Harvest. Determine non-consumptive and consumptive uses of wildlife that have traditionally occurred or have potential to be supported within the area. Examples: wildlife photography, wildlife viewing, nature study, hunting, trapping. Display data as wildlife user days (WFUD's).

Types of Ponds, Lakes and Reservoirs. Classify water bodies in relation to fishery quality, recreational opportunities, and habitat capability.

Threatened and Endangered Fish and Aquatic Invertebrates. Include organisms identified by State and Federal agencies as threatened and endangered. Identify measures of habitat quantity and quality, both current and potential.

Fish Species Occurrence in River and Lake Habitats. Relate occurrence to presence or absence of fish species in aquatic habitats on the Forest. Display as a range Forest-wide.

Resident Fish Species Abundance. Measure as standing crop. Display outputs as pounds/acre or kilograms/ha or other accepted measures.

Anadromous Fish Species Abundance. Measure in number of smolts produced. Display outputs as smolts/mile or km or a function of numbers per linear distance.

Resident and Anadromous Fish Species Use and Harvest. Show recreational and commercial uses of fish. Display data as fish user days (WFUD's) for recreational use and pounds or kilograms of fish for commercial use.

Aquatic Macro invertebrate Indicator Species. Define as both diversity and abundance of macro invertebrates in a given body of water. An indicator of water quality.

Fish Habitat Index Variables. Define the relative fish habitat condition of riverine habitats. Summarise data by a quality index for each stream habitat unit.

*Minerals and Geology Management*

Mineral Occurrence. Show areas by mineral resource and land availability.

Special Geologic Interest.

*Land Management Requirements*

Land ownership Adjustment. Display land ownership adjustment due to (1) Reservation, (2) Purchase, (3) Exchange, (4) Donations, (5) Transfers, and (6) Interchange. Include fee ownership as well as partial interests such as rights-of-ways and scenic easements.

Special Uses and Rights-of-Way Grants.

Property Line Location and Status. Display property lines between national forests and other land. Prepare and maintain status records on forest land, records of ownership. Search and review the ownership, encumbrances, and use restrictions.

Occupancy Trespass and Claims. Display occupancy trespass and claims. Occupancy trespass and claims consist of any unpermitted or unlawful entrance upon forest land that involves the construction, placement, or fixing of structures, signs, or other private personal property on such land or the enclosing or usurpation of forest land, other than for mining purposes by the claimant on a valid mining claim.

### *3.1.3 Develop List of Data Elements Necessary to Generate The Reports*

Table 3-3 lists some of the vegetation data elements that the interdisciplinary team identified as necessary to produce the information required for two of the above reports. These include the timber output on timber volume by forest type and condition and range management output on ecological status and resource value rating for livestock forage condition.

**Table 3-3:** A listing of some vegetation data elements required for timber and range management.

| Data Element | Timber Use | Range Use |
|---|---|---|
| Basal Area | Yes | Yes |
| Bole Length | Yes | |
| Canopy Cover | | Yes |
| Crown Class | Yes | Yes |
| Crown Closure (Cover) | Yes | Yes |
| Diameter at Breast Height (d.b.h.) | Yes | Yes |
| Forage Utilisation | | Yes |
| Forest Land Class | Yes | Yes |
| Height Growth | Yes | Yes |
| Plant Species | Yes | Yes |
| Production, Forage | | Yes |
| Radial Increment | Yes | Yes |
| Sawlog Length | Yes | |
| Site Index | Yes | Yes |
| Stand Age | Yes | Yes |
| Stand Size Class | Yes | |
| Stocking Percent | Yes | Yes |
| Tree History | Yes | |
| Vegetation Height | Yes | Yes |

The team continued the same process for all the required outputs. The following lists of data elements or indicators the team identified as required to produce the information specified in Step 2 (USDA Forest Service 1990).

1. Air and Climate Indicators
Air Class I Boundaries
Chemistry, Atmospheric
Chemistry, pH Dry Deposition
Chemistry, pH Wet Deposition
Chemistry, Snowpack
Climate Type
Fuel Moisture
Mixing Height
Odour Type and Concentration
Pollutant Loading
Precipitation, Average Annual
Precipitation, Hourly
Relative Humidity
Temperature, Ambient
Visibility Sensitivity
Visual Quality
Visual Range
Wind Speed

2. Ecological Indicators
Aquatic Habitat Types
Ecological Status
Ecological Type (Habitat Type)
Ecological Unit
Ecoregion Code
Ecosystem/Cover Type
Land - Aquatic Type Association
Land Surface Form Code
Potential Natural Community
Protected Area Class
Trend

3. Wildlife Related Indicators
Fish Harvest
Fisheries Classification
Macro invertebrate Biotic Condition
Species Management Status
T & E Species Habitat
Wildlife & Fish Habitat Capability
Wildlife/Fish/T&E Abundance

4. Landform and Geological Indicators
Geologic Features (Special)
Geologic Formation
Geologic Hazards
Geologic Time Unit
Ground Water Aquifers
Landform
Lithologic Unit
Mineral Commodities
Mineral Resource
Paleontological Resources

5. Land Location Indicators
Administrative Unit
Authorised Use
Congressional District
County, Parish, Borough, Townships
Land Location
Land Location (Metes and Bounds)
Ownership
Private Forest Land Owner
Proclaimed Unit
Region/Station/Area
State/Territory
Subregion
Subunit
Withdrawals

6. Resource and Land Use Indicators
Fuel Model
Land Use Class
Public Access
Range Treatment Class
Recreation Opportunity Class
Recreation Use
Road Functional Class
Road Surface
Road System
Timber Treatment Opportunity Class
Time Since Disturbance
Traffic Lanes
Visual Resource Management Class
Water Uses
Wildlife & Fish User Days

7. Soil Indicators
Cation Exchange Capacity
Depth to Bedrock or Restriction
Depth to Mottling or Water
Detrimental Soil Disturbance
Effective Rooting Depth
Erosion Severity
Forest Floor (Litter) and Humus
Mass Stability
Parent Material
Particle Size
Soil Bulk Density
Soil Cover
Soil Drainage Class
Soil Erosion Type
Soil Map Unit
Soil Structure
Soil Taxonomic Unit
Soil Texture

8. Vegetation Indicators
Bark Thickness
Basal Area
Bole Length
Bole Top Diameter
Canopy Cover
Cause of Death/Injury
Crown Class
Crown Closure (Cover)
Crown Foliage Density
Crown Form (Shape)
Crown Length (Depth)
Crown Ratio
Crown Volume Percent
Crown Width (Diameter)
Diameter at Breast Height (d.b.h.)
Diameter, Basal
Diameter, Stump
Down Material Condition
Forage Utilisation
Forest Land Class
Height Growth
Height to Crown, Compacted
Height to Crown, Uncompacted
Land Cover Category
Mistletoe Infection Rating
Most Hazardous Pest
Plant Species
Principal Defect
Production, Forage
Radial Growth (Increment)
Sawlog Length
Sawlog Top Diameter
Seedling/Shrub Count
Site Index
Site Productivity Class
Site Tree Quality
Size Down Woody Material
Snag Condition
Stand Age
Stand Condition
Stand History
Stand Origin
Stand Size Class
Stand Structure
Stand Year of Origin
Stocking Percent
Stump Height
Tree Age

Tree Class
Tree Grade
Tree History
Tree Length (Height)
Tree Top Condition
Tree Volume
Vegetation Density
Vegetation Height

9. Water Indicators
Dissolved Oxygen
Fecal Coliforms
Hydrologic Unit Code
Instream Cover
Instream Woody Debris
Mean Water Depth
Nitrates
Phosphates
Pool Quality
Pool-Riffle Ratio
Reach Number
Shore Depth
Sinuosity
Stream Channel-Bank Angle
Stream Order
Stream Shade Cover
Stream Type
Stream Width
Streambank Undercut
Streamflow
Suspended Sediment
Temperature, Water
Turbidity
Water Flow Velocity

At first glance, the above list may appear daunting and overwhelming. The fact is the USDA Forest Service was already collecting most of the data on the National Forests through the independent inventories shown in Table 3-1. One may find the same situation in other organizations where much of the required data is already being gathered by some group, but the inventories are not co-ordinated or integrated.

Once the team determined the data elements, the next step was to develop a common definition for each term, codes, measurement procedures, and accuracy standards. The interdisciplinary team also carried out this task.

Definitions for the above terms may be found in USDA Forest Service (1989). Direction for the USFS to implement integrated inventories may be found in USDA Forest Service (1990). The USFS is now working to design the actual system or systems to collect the data.

## 3.2 DESIGNING MULTIPLE RESOURCE INVENTORIES: A CANADIAN EXPERIENCE

**Case Study Synopsis**

**Area of Concern:** Province of British Columbia, Canada

**Problem:** Multiple agencies collecting similar data within province with little cross sharing of data among the agencies.

**Infrastructure Created:** The Resource Inventory Committee – An interagency, multidisciplinary committee established by the Government of British Columbia.

**Vision/Objectives:** Standardisation of data needs to minimise data collection costs and duplication and to promote data sharing.

**Methods:** Review all current resources inventories; identify vital information needs, develop and test (where appropriate) common inventory standards and procedures for the province; provide training and extension in application of the new procedures; and determine costs for a comprehensive, co-ordinated multi-resource inventory of the provincial land base phased over ten years.

**Results:** Over 130 standards have been developed and published to date. A new vegetation inventory design has been developed.

A major criterion for sustainable development and balanced forest management is the availability of credible inventory information on a full range of natural and cultural heritage resources. There are several challenges to collecting inventory information: large number of agencies involved in inventories, duplication of effort, incompatibility among inventories, and gaps in the inventory databases. These challenges are being addressed in British Columbia (BC), Canada, where a major effort has been under way since 1991 to revise standards and methodologies for conducting multiple resources inventories in the province. This section is based largely on the paper by Omule *et al.* (1996). This describes the MRI process in British Columbia (BC) between 1991 and 1994 with embellishments including developments since 1994.

There are several challenges to obtaining inventory information in BC. Typically, the breadth of issues and the number of agencies involved in inventory, planning and resource management are large. This raises the danger of duplication and incompatibility among inventories used by different interest groups. The cost of collecting data not needed or not useful is potentially very high. There is also the issue of gaps in the inventory databases, especially where vital information is not collected. This case study describes how these challenges are being addressed in the province of British Columbia (BC), Canada.

### *3.2.1 Background*

British Columbia is one of 10 provinces of Canada with a population of about 3.5 million and a land area of about 95 million hectares (Figure 3-1). About one-half of the land base is forest land. In 1991 the Forest Resources Commission, established by the BC government to examine forest management issues in the province, deplored the state of the province's resource inventories and called for "... a commitment to complete inventories of all renewable forest resource values using standardised compatible systems..." The Commission recommended a complete re-design of how inventories of resources in BC are conducted.

In response, the government formed an inter-agency, multi-disciplinary Resources Inventory Committee (RIC). The mandate of RIC was to:

- review all current resources inventories; identify vital information needs
- develop and test (where appropriate) common inventory standards and procedures for the province;
- provide training and extension in application of the new procedures; and
- determine costs for a comprehensive, co-ordinated multi-resource inventory of the provincial land base phased over ten years.

Over 100 inventory specialists from a full range of resource disciplines were recruited on a voluntary basis from provincial and federal agencies, companies, academia and other resource interests to work under RIC. To co-ordinate aboriginal input and to encourage adoption of the standards, a First Nation's Inventory Committee (FNIC) was also set up.

It was argued that standardisation would be an incentive for more data exchange among users. This in turn would make data collection more cost-effective and analysis more responsive to client needs.

### *3.2.2 Inventory Design Process*

To achieve its mandate, RIC established seven task forces:

- Aquatic (fisheries and water ecosystems);
- Atmospheric (climate);
- Cultural (culture, tourism and recreation);
- Land use;
- Earth Sciences (geology, soils, surface materials, slope stability and archaeology);
- Coastal (inter tidal and near shore); and
- Terrestrial Ecosystems (timber, vegetation, wildlife habitat, range, ecology, and biodiversity).

The task forces oversee the work of smaller working groups that deal with specific inventories or subject areas. Efforts of the working groups are complemented by consultancy reports that are commissioned as required.

For some task forces, such as bedrock geology and meteorology, national and international standards already exist and are widely used. The focus is on quality control and ensuring integration of data with other disciplines. Other groups, such as archaeology and biodiversity, are pioneering in their fields. Other groups, such as the vegetation inventory, are upgrading their existing inventories to take advantage of the latest developments in high technology and sampling techniques.

**Figure 3-1:** Map showing Location of British Columbia.

Co-ordination of the efforts of the task forces and their working groups is achieved through technical progress reports during regular meetings and special workshops organised by RIC. Chairpersons of each task force are members of RIC. Direct consultation among the individual task forces and working groups is encouraged. A contract secretariat provides secretarial, contract, and proposal management services; and plans, co-ordinates, evaluates and reports on the work of RIC and its task forces and working groups. Task Force reports and other discussion documents were distributed by the RIC Secretariat. Inventory manuals are be available on RIC's Internet home page at http://www.for.gov.bc.ca/ric/index.htm. Information on print-on-demand for the manuals can be found in Superior Reprographics Internet site at http://www.superiorprint.com.

### *3.2.3 Funding*

The work of RIC is funded mostly by the federal and the BC governments through the Canada-BC Forest Resources Development Agreement. To date RIC has spent about 4.5 million dollars on the design of the inventories. In addition, $15.4 million has been allocated during fiscal 1992-94 to improve resources inventories through data collection, systems overhaul and infrastructure development, in a separate program called the Corporate Resource Inventory Initiative (CRII). CRII projects use RIC's new standards as they become available. For the 1996/97 fiscal, $125 million has been allocated to resources inventory activities in the province.

### *3.2.4 Progress to Date*

Integrated data models have been developed by RIC and reviewed by the province's strategic clients (e.g. land use allocation processes) and operational users (resource ministries and industry). Just as a map is a representation of a geographic area, a data model is a conceptual representation of the data that is planned to be collected.

The data models consist of lists of the information required by subject entity (e.g. forest stand), unique identifiers of objects within the subject entities (e.g. trees) and the relationships between the subject entities. They serve as blue prints for designing and integrating the data collection standards and techniques. Modelling also makes it possible for gaps and possible duplication between the work of various inventory agencies to be identified.

Pilot testing of some inventory standards has been undertaken. For example, testing of the new vegetation inventory (see 3.2.7), which has been on-going since the 1993 field season has been concluded.

Further development and testing, preparation and distribution of manuals, and endorsement of the new standards by the all agencies, companies and interest groups collecting resource data in BC, are planned to be completed by 1998. After that time, the mandate of RIC will be revised. RIC's revised mandate will be to carry out periodic reviews of the standards and to manage changes to the inventory standards.

Over 130 standards have been published to date. The following provides a listing of a sample of these standards by subject area and title.

**Table 3-4:** Standards listing by task force

**Aquatic Task Force**
- Field Key to Freshwater Fishes of BC

**Atmospheric Task Force**
- Explanation of Air Quality & Meteorology Networks, Databases & Bibliographies

**Coastal Task Force**
- Aerial Videotaping Manual for Oblique Shoreline Features & Vertical Stream Features
- Assessing Shellfish Culture Capability in Coastal BC: Sampling Design Considerations for Extensive Data Acquisition Surveys
- BC Physical Shore-Zone Mapping System
- BC Biological Shore-Zone Mapping System
- Near Shore Marine Habitat Inventory
- Near Shore Marine Mapping Manual

**Cultural Task Force**
- Recreation Resource Features & Recreation Opportunity Spectrum
- River Recreation
- Visual Landscape & Viewpoint
- Routes & Trails
- Caves Wilderness Monitoring Sampling Points
- Comprehensive Guidelines for Cultural Heritage Resource Inventories (Site Inventory Form & Recording Guide)
- Inventory Standards 1:250,000 Scale

**Earth Sciences Task Force**
- Ground water Mapping & Assessment in BC (Vol. I & Vol. II)
- Preliminary Seismic Microzonation Assessment for BC
- BC Archaeological Impact Assessment Guidelines (includes Archaeological Site Inventory Form)
- Guidelines and Standards for Terrain Mapping in BC

**Land Use Task Force**
- Corporate Land Use Classification System

**Terrestrial Ecosystems Task Force – Ecology**
- Procedures for Environmental Monitoring in Range and Wildlife Habitat Monitoring
- Soil Inventory Methods for BC
- Terrestrial Ecosystems Mapping Methodology
- BEC Subzone Variant Mapping
- Describing Ecosystems in the Field (revised for data modelling)
- Standards for Wildlife Habitat Capability & Suitability Ratings

**Terrestrial Ecosystems Task Force – Ecology**
- Bats
- Marbled Murrelet
- Terrestrial Salamanders
- Fast Stream Amphibians (Tailed Frogs & Pacific Giant Salamanders)
- Forest & Grassland Songbirds
- Macro fungi
- Raptors

**Terrestrial Ecosystems Task Force – Vegetation**
- Vegetation Inventory Photo Interpretation Procedures v 2.0
- Vegetation Inventory Sampling Procedures
- BC Land Cover Classification Scheme

The publication of these standards with approximately 5,000 pages of documentation present not only a publication problem but makes the task of understanding this material over a multiple subject area almost impossible. The Resources Inventory Committee is making this documentation available through the Internet and on CD ROM along with intelligent documentation browses. This solution might offer other countries a simple way of updating and distributing similar manuals among the interested partners.

Inventory training material is being produced through the DACUM process. It is anticipated that about $2 million a year will be spent on this exercise between 1995/96 and 1997/98. As an illustration of the inventory design process, the approach taken to design the vegetation inventory (forest inventory) for the Province of BC is outlined in Section 3.2.5.

### *3.2.5 Review of Existing Inventory*

The first phase of the new inventory design commenced in November, 1991 when the Ministry of Forests' Inventory Branch formed a Timber Inventory Task Force (TITF) and instructed it: "... to make recommendations to the Ministry of Forests on matters pertaining to timber inventory ... and to review current inventory programs and recommend standards and procedures for an accurate, flexible and stand specific inventory process."

The Task Force was multi-disciplinary and consisted of 15 inventory experts drawn from the federal and provincial governments, forest companies, forest consulting firms, universities, technical schools and First Nations peoples. It met in seven sessions. Individuals from direct fields of interest were invited to give presentations and numerous background research papers were commissioned. The final report of the Task Force submitted March 31, 1992 contained 33 recommendations covering administration issues, forest cover/base mapping, classification, reporting, and volume and size prediction. Fundamental recommendations included the formation of an inventory design group; an inventory covering the entire provincial land base, without exception; a complete field and office audit trail; statistically defensible ground sample design and establishment; and orientation to inventory and description of all vegetation, not only timber.

### *3.2.6 Design of New Inventory*

The second phase of the new inventory design commenced in April 1992 when RIC established the Terrestrial Ecosystems Task Force (TETF) and instructed it: "... to develop methodologies for integrating inventories of renewable terrestrial resources, as well as inventories of other resources, as fully as practical within the constraints of economic and resource management needs and consistent with the objectivesof RIC."

The new Task Force consisted of essentially the same membership as the earlier TITF. TETF formed two working groups, one for ecology and elements and one for vegetation, which worked in parallel as the design proceeded and field pilot tests were conducted. The remainder of this section deals primarily with the work of the Vegetation Inventory Working Group (VIWG) which was charged with: "... making recommendations pertaining to the vegetation inventory which includes timber and silviculture, [and] ... designing and recommending standards and procedures for an accurate, flexible, .... inventory process."

The working group formed two teams, one to deal with sampling and the other with classification. This team approach proved to be of immense value as the design work progressed. Working separately at times and together at other times, but always in parallel, the teams were able to formulate the design, gather appropriate reference materials, commission consultant projects, conduct field pilot studies, prepare management reports, and make recommendations for the final design and operational implementation.

The second and final year of field pilot testing is now concluded. Final recommendations have been made for an operational implementation of the new inventory starting in the 1996/97 field season

Training manuals have been prepared; and train-the-trainer sessions have been concluded. These manuals are available on the RIC Internet home page. Field manuals for the inventory are available on the BC Ministry of Forests' Internet home page: http://www.for.gov.bc.ca/resinv/standard/veginv/toc.htm

### *3.2.7 New Vegetation Inventory Design*

Following is a summary of the inventory design principles. The design is flexibly structured to meet a range of client needs. It is compatible with ecological classification, whether the ecological classification is carried out before, in conjunction with, or subsequent to the vegetation inventory. The inventory structure is a classification system based on aerial photograph interpretation and description, with stand aerial photo descriptions adjusted based on data from ground sampling. The sampling frame is based on a provincial-wide grid. Minimally, the inventory area of interest is a large scale management unit such as a Timber Supply Area (usually 200,000 hectares or greater). The results will be analysed, maintained and presented through a GIS and geo-referenced database linked specifically to other resource inventories. All estimates will be accompanied by statements of precision and accuracy. All mapping will be Terrain Resource Information Management (TRIM) computer based.

The vegetation inventory is based on a two-phase sampling design. Phase I involves subjective delineation and estimation of stands (polygons) using well-defined criteria and observable differences which can be recognised on aerial photographs on a scale of 1:15,000. Phase II involves establishment of ground plots based on valid sampling processes. Ground plots will be systematically located with probability proportional to polygon area. This systematic selection can be achieved by either using a sorted list of polygons and a sampling frame for plot locations defined by a polygon-independent 100 m x 100 m provincial grid, or using the intersections of a polygon-independent coarser grid as plot locations. The two approaches should give approximately the same result since the weighting in each case is by polygon area. Phase II provides the statistical rigor and a compilation process to adjust the Phase I estimates to the mean of the Phase II samples, for the management unit of interest. As well, ground sample plots will be established on a sparse grid covering the entire province for provincial and regional reporting on criteria and indicators of sustainability.

The core of the inventory process consist of the following six steps: 1) polygon delineation, attribute estimation and stratification (Phase I); 2) sampling design; 3) establishment of ground plots to adjust the Phase I initial estimates (Figure 3-2), and initial compilation of field data (Phase II); 4) statistical adjustments and analysis; 5) summary of database on vegetation; 6) reporting and maintenance of the database; and 7) special additions and corrections as required.

### *3.2.8 Findings*

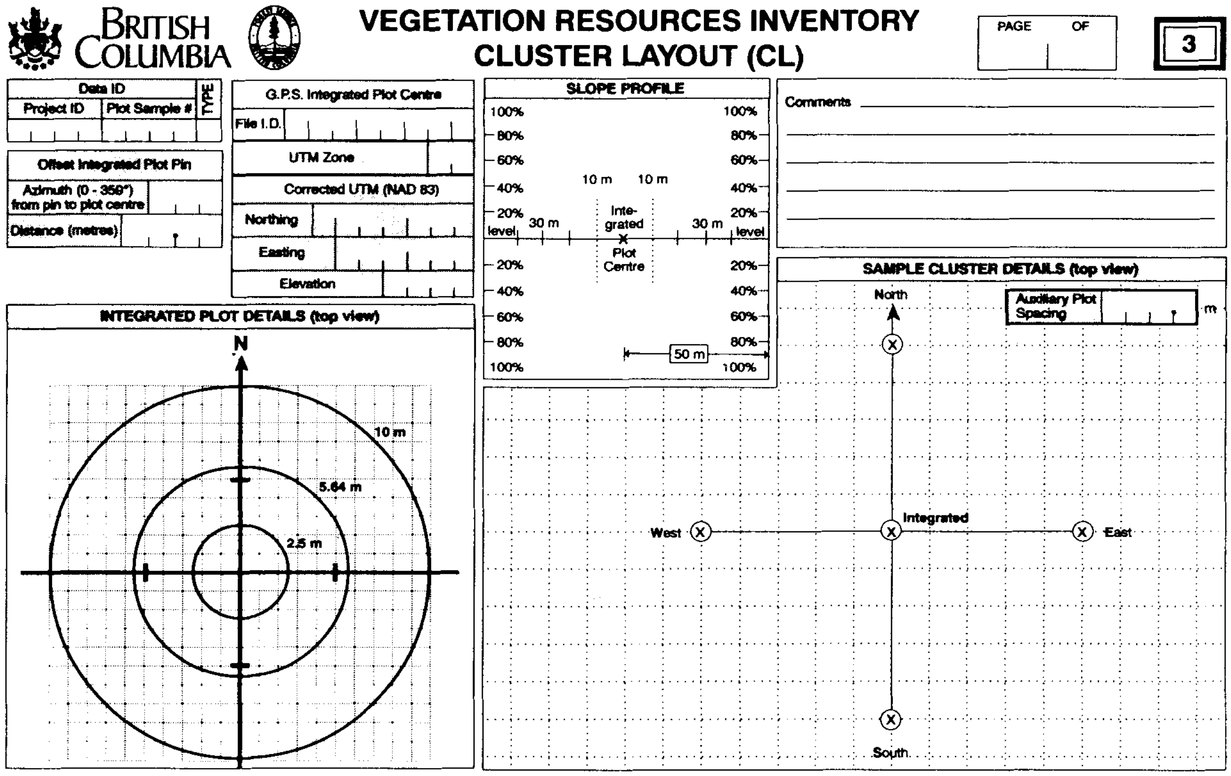
Based on the collective experience in BC, the Canadians make the following general concluding remarks:

☹ Resource-specific inventories conducted without regard for other resources are difficult to integrate meaningfully.

☺ Duplication of effort can be minimised through the adoption of common inventory standards where applicable.

☺ With adequate resources, patience, and commitment, the development of integrated multiple resource inventories is entirely possible even within large organizations such as exist in BC and elsewhere.

☺ The approach taken in BC, with modifications, can be adopted for the multiple resource inventories in other countries.



BRITISH COLUMBIA

VEGETATION RESOURCES INVENTORY
CLUSTER LAYOUT (CL)

PAGE OF

3

| Data ID | | TYPE |
|---|---|---|
| Project ID | Plot Sample # | |

Offset Integrated Plot Pin
Azimuth (0 - 359°) from pin to plot centre
Distance (metres)

G.P.S. Integrated Plot Centre
File I.D.
UTM Zone
Corrected UTM (NAD 83)
Northing
Easting
Elevation

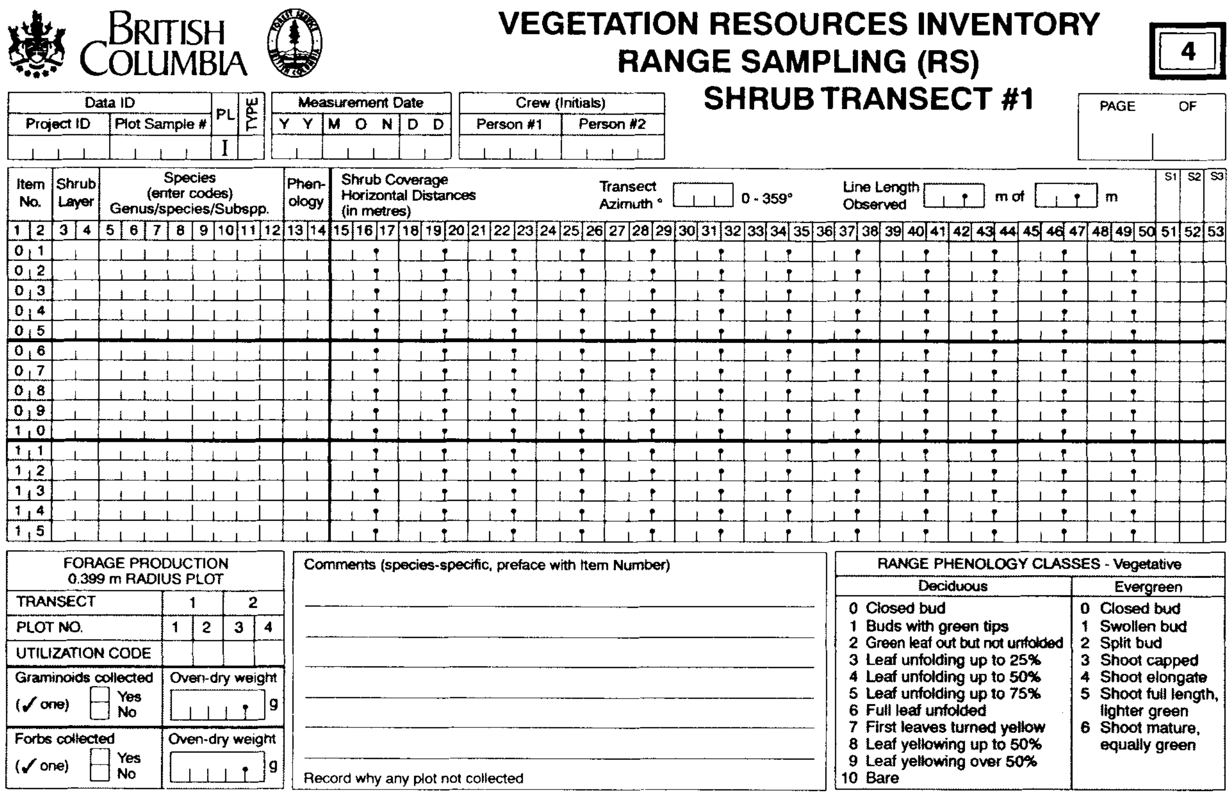
SLOPE PROFILE
100% 80% 60% 40% 20% level 20% 40% 60% 80% 100%
10 m 10 m
30 m Inte-grated 30 m
Plot Centre
50 m

Comments

INTEGRATED PLOT DETAILS (top view)
N
10 m
5.64 m
2.5 m

SAMPLE CLUSTER DETAILS (top view)
North
Auxiliary Plot Spacing m
West Integrated East
South

FS 5050 HRI 97/1



BRITISH COLUMBIA

VEGETATION RESOURCES INVENTORY
RANGE SAMPLING (RS)
SHRUB TRANSECT #1

4

PAGE OF

| Data ID | | PL | TYPE | Measurement Date | Crew (Initials) | |
|---|---|---|---|---|---|---|
| Project ID | Plot Sample # | I | | Y Y M O N D D | Person #1 | Person #2 |

Transect Azimuth ° 0 - 359°
Line Length Observed m of m

| Item No. | Shrub Layer | Species (enter codes) Genus/species/Subspp. | Phen-ology | Shrub Coverage Horizontal Distances (in metres) | S1 | S2 | S3 |
|---|---|---|---|---|---|---|---|
| 1 2 | 3 4 | 5 6 7 8 9 10 11 12 | 13 14 | 15–50 | 51 | 52 | 53 |
| 0 1 | | | | | | | |
| 0 2 | | | | | | | |
| 0 3 | | | | | | | |
| 0 4 | | | | | | | |
| 0 5 | | | | | | | |
| 0 6 | | | | | | | |
| 0 7 | | | | | | | |
| 0 8 | | | | | | | |
| 0 9 | | | | | | | |
| 1 0 | | | | | | | |
| 1 1 | | | | | | | |
| 1 2 | | | | | | | |
| 1 3 | | | | | | | |
| 1 4 | | | | | | | |
| 1 5 | | | | | | | |

| FORAGE PRODUCTION 0.399 m RADIUS PLOT | | | | |
|---|---|---|---|---|
| TRANSECT | 1 | | 2 | |
| PLOT NO. | 1 | 2 | 3 | 4 |
| UTILIZATION CODE | | | | |
| Graminoids collected (✓ one) Yes No | Oven-dry weight g | | | |
| Forbs collected (✓ one) Yes No | Oven-dry weight g | | | |

Comments (species-specific, preface with Item Number)

Record why any plot not collected

| RANGE PHENOLOGY CLASSES - Vegetative | |
|---|---|
| Deciduous | Evergreen |
| 0 Closed bud | 0 Closed bud |
| 1 Buds with green tips | 1 Swollen bud |
| 2 Green leaf out but not unfolded | 2 Split bud |
| 3 Leaf unfolding up to 25% | 3 Shoot capped |
| 4 Leaf unfolding up to 50% | 4 Shoot elongate |
| 5 Leaf unfolding up to 75% | 5 Shoot full length, lighter green |
| 6 Full leaf unfolded | 6 Shoot mature, equally green |
| 7 First leaves turned yellow | |
| 8 Leaf yellowing up to 50% | |
| 9 Leaf yellowing over 50% | |
| 10 Bare | |

FS 505G HRI 97/1

**Figure 3-2:** Sample Phase II field forms from British Columbia's vegetation resources inventory. There are a total of 13 kinds of cards or forms: vegetation resources inventory header, compass, cluster layout (upper illustration), range sampling shrub transect (lower illustration), coarse woody debris, tree detail, tree loss indicators, small tree, stump and site tree data, auxiliary plot card, ecological description, tree and shrub layer, herb and moss layer, and succession interpretations.

## 3.3 MULTIPLE RESOURCE INVENTORY GUIDES – SISKIYOU NATIONAL FOREST

☺ **Case Study Synopsis**

**Area of Concern:** Gold Beach Ranger District, Siskiyou National Forest, U.S.A.

**Problem:** Field resource specialists collecting similar data on same piece of ground or collecting incomplete data when in area.

**Infrastructure Created:** Informal, multidisciplinary group of resource specialists on the ranger district.

**Vision/Objectives:** A common field form to be used for stand examinations that would be completed by any team that went to the field.

**Methods:** Group discussions.

**Results:** The specialists developed a listing of key variables to be measured, established tolerance levels, and developed a common field form.

The Gold Beach Ranger District (Figure 3-3) of the Siskiyou National Forest (USDA Forest Service, Region 6 - Pacific Northwest) traditionally utilised separate inventories designed specifically for archaeology, silviculture, soil, timber, or wildlife. In the 1980s and 90s, emphasis on integrated forest management increased. Information needs increased while funding levels decreased. The costs were prohibitive to sustain these types of crews. Staff resource specialists began reviewing and consolidating their field crews' efforts into one heterogeneous resource inventory. Resource specialists consolidated much of their information needs into the stand examination process used for pre-sale timber inventory. The result was one crew covering the ground only once rather than three or four times.

This section is a synopsis of the data collected and the stand exam allowable errors (Gee and Forbes 1997). Each discipline collects information for a wide variety of reasons. The information is most often utilised in tabulating existing per acre (or per hectare) data. Examples are: trees per acre (or ha) by species, basal area per acre (or ha), standing or downed dead trees per acre (or ha). The latter item recently increased in importance as a measure for wildlife habitat and long-term site productivity (Maxwell and Franklin 1976, USDA/USDI 1994). Plant association data are also collected through the use of keys and guides (Atzet *et al.* 1996). Due to increased emphasis on aquatic resources (Beschta 1978, USDA/USDI 1994), stand map sketches that include location of streams are also valuable.

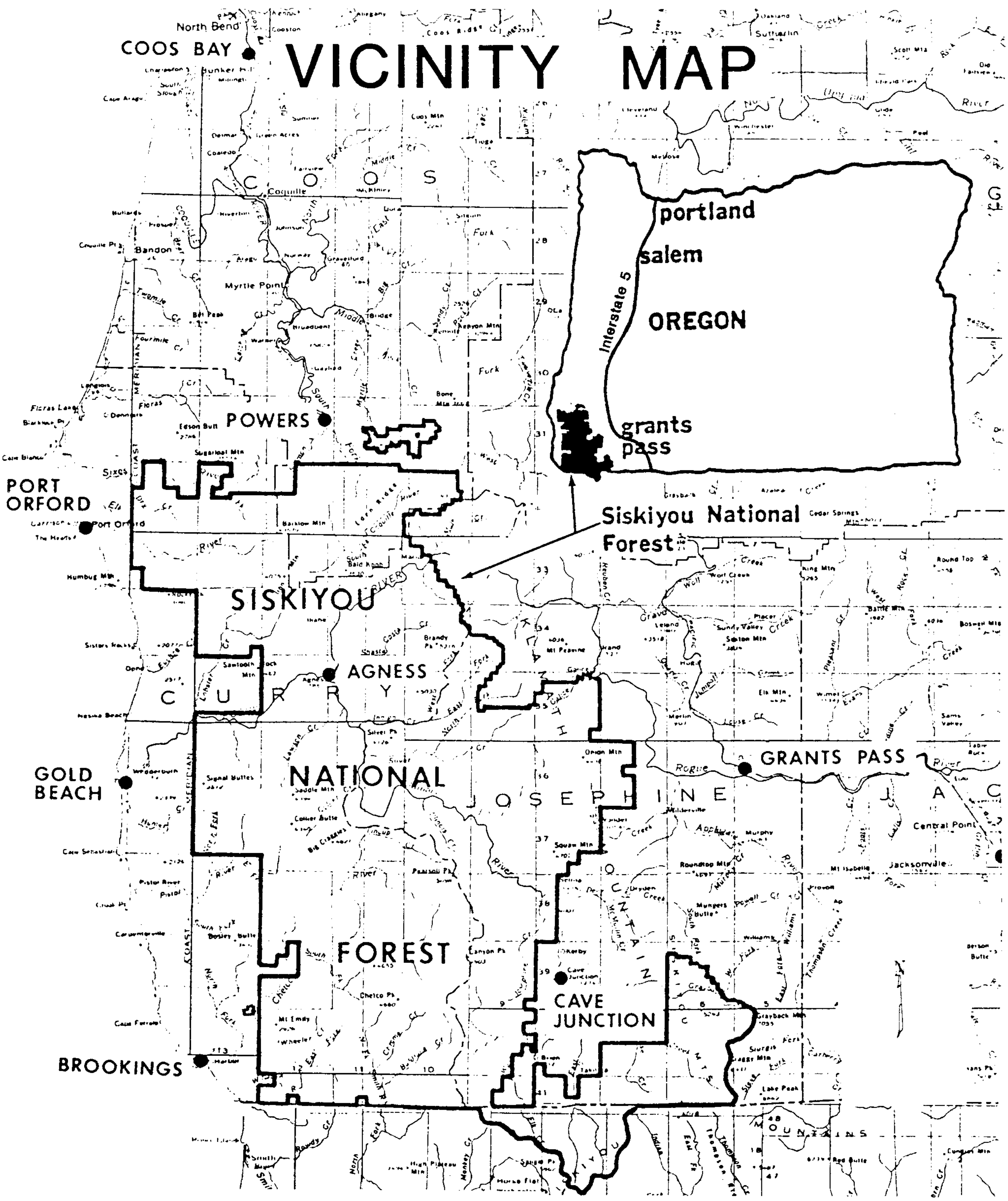
Most inventory information can be utilised for models. For example: the downed woody material items were collected to feed into a pine marten habitat model. Other items supported a pileated woodpecker model (Schroeder 1982) and the cover items supported a habitat effectiveness index (HEI) model that defines big game thermal versus hiding versus forage cover quantification. Data from the variable plot inventory can be used in growth and yield predictions for timber and competing vegetation.

All of the following data (Table 3-5) are collected on 1/5 acre (0.08 ha) plots, with the radius of the plot corrected for percent slope (except where noted) (See Figure 3-4). Record once for each plot.

Currently the plot information is collected on portable data recorders and downloaded to acquire stand summary information. Not all stands are modelled for future growth predictions.

Output products included cover closure maps, size distribution maps, habitat type maps, blow down risk maps, downed woody material distribution maps, tree species distribution and phytophthora disease distribution maps, and forage/cover ratio distributions. Verification by specialists is important.

Due to changes in resource emphasis, budgets, and personnel, the full potential of the information has not been realised. Nonetheless, early planning allowed unforeseen uses. The database is still valuable today for any specialist that wants to tap it, and it maintains a historical snapshot in time for monitoring future changes.




Siskiyou National Forest Vicinity Map

**Figure 3-3:** Map of the Siskiyou National Forest, Oregon, USA.

**Table 3-5: Resource data and allowable sampling errors for Multiple Resource Inventory, Siskiyou National Forest.**

| Attribute | Allowable Sampling Error |
|---|---|
| Stand Number | +/- 0 |
| Plot Number | +/- 0 |
| Tree Species | +/- 0 |
| Brush Species | +/- 0 |
| Grass/Forb Species | +/- 0 |
| Percent Composition Plant Species | +/- 10% |
| Average Height Plant Species | +/- 1 foot (30 cm) or 10%, whichever is greater |
| Number of Canopy Layers | +/- 0 |
| Elevation | +/- 100 feet (30 m) |
| Slope | +/- 10% |
| Aspect | +/- 1 class |
| Plant Associations | +/- 0 |
| Windthrow Potential | +/- 1 rating |
| Plantability Percent | +/- 25% |
| Soil Depth | +/- 1 foot (30 cm) |
| Soil Texture | +/- 0 |
| Coarse Fragmentation | +/- 15% |
| Serpentine Geology | +/- 0 |
| Duff | +/- ½ inch (1 cm) |
| Deer/Elk Use | +/- 0 |
| Hiding Cover | +/- 0 |
| Stream/Class | +/- 0 |
| Snag Class | +/- 1 class rating |
| Snag D.B.H. | +/- 2 inches (5 cm) |
| Snag Height | +/- 10% |
| Percent Woody Material Ground Cover | +/- 3% |
| Additional Features | +/- 100 feet (30 m) |

**GOLD BEACH RANGER DISTRICT RESOURCE CARD - SHORT FORM - APRIL 1995**

PLANNING AREA: STAND #: EXAMINER: DATE:

| PLOT # | % | HT AVG | RNGE |
|---|---|---|---|
| OS | | | |
| TOTAL OS | | | |
| UPPER US | | | |
| TOTAL UPP US | | | |
| LOWER US | | | |
| TOTAL LOW US | | | |
| BC | | | |
| TOTAL BC | | | |
| G/F | | | |
| TOTAL GF | | | |

| SLOPE POSITION | ELEVATION | SLOPE | ASPECT |
|---|---|---|---|
| PLANT ASSOCIATIONS | | WINDTHROW POTENTIAL | PLANTIBILITY PERCENT % |
| SOIL DEPTH | SOIL TEXTURE | COARSE FRAG. | PARENT MAT. |
| DUFF | DEER/ELK USE | HIDING COVER | STREAM/CLASS |

| SNAG CLASS | DBH | HEIGHT | (1/5 ACRE PLOT) |
|---|---|---|---|
| S N A G S | | | |

| DOWN WOODY MATERIALS (1/5 Acre Plot): | |
|---|---|
| % GROUND COVER >3" | |
| #STUMPS > 1'x7" DIA AND/OR # LOGS > 7" | |
| # OF LOGS >12"DIA X 20' LGTH | |
| TOTAL CANOPY CLOSURE (%) FOR ALL SPECIES OVER 16.5 FEET IN HEIGHT | |

REMARKS, FUTURE TREATMENT, INDIVIDUAL TREE INFO

**GOLD BEACH RANGER DISTRICT RESOURCE CARD - PROPOSED SHORT FORM - APRIL 1997**

SAMPLE RESOURCE CARD BELOW (SIMPLIFIED VERSION)

| PLOT # | % CROWN COVER | % BRUSH COVER | PLANT ASSOCIATION | PLANTABILITY |
|---|---|---|---|---|
| | | | | |

| SNAGS 16" DBH X 16' WITHIN 50 FEET | LOGS 16" X 16' WITHIN 50 FEET |
|---|---|
| | |

CHECKLIST
Stream location w/in 150 ft. (draw on hard copy map of stand) CLASS ______
Fire - fire scars, charcoal, knobcone pine _____ unusual fuel loads ______
Instability (evidence of slumping) ______
Cultural resources ______
Sensitive plants ______
Special forest products (>50% cover) SPECIES ______
Windthrow (unusual amount of downed trees, mounding) ______

REMARKS:

**Figure 3-4:** Field form for recording MRI stand examination data.

The inventory process is dynamic – it will continue to evolve as budgets, science, and public values dictate what level of analysis is done and what resource items rise and fall in importance. Specialists still conduct site visits as much as possible, preferably as a team. Separate resource inventories and databases that require expert field analysis are still maintained to some degree. The new integrated stand examination process combines with interdisciplinary planning to help ensure that a variety of resources values are efficiently considered.

## 3.4 THE SUDAN REFORESTATION AND ANTI-DESERTIFICATION PROJECT

**☺ Case Study Synopsis**

**Area of Concern:** Gum belt of the Sudan

**Problem:** Drought and overuse of land lead to increasing desertification. Base line data on existing vegetation and opportunities for reversing land degradation were lacking.

**Organization/Infrastructure Created:** Joint partnerships between various federal agencies of the Governments of Sudan and the United States.

**Vision/Objectives:** Develop a vegetation mapping and inventory program that would provide base information on woody vegetation for gum production, fuelwood, etc. utilising the latestmapping technologies.

**Methods:** The Government of Sudan developed their information requirements for the inventory, furnished field crews and provided logistical support. The USA provided technical support and training

**Results:** A pilot study was completed demonstrating the utility of the methods developed. As of 1992, the MRIs were continuing in Sudan.

Sudan is the 8th largest country in the world being nearly 2.5 million square kilometres in size. Its population is about 22 million, of which more than 10 percent is concentrated at the juncture of the Blue and White Nile Rivers. The country is a contrast of deserts in the north, dry tropical forests in the centre, and swamps in the south. As a consequence of a recent drought, illicit cutting, day to day use of the woody vegetation for fuel wood and construction material, over grazing and trampling, and the conversion of lands to agriculture, deforestation, devegetation, and desertification are increasing dramatically in Sudan. The end result is a loss of soil productivity and a decline in an already meagre economy.

Deforestation, devegetation, and desertification are major problems in the country. Baseline information for rehabilitation is lacking. The most recent topographic maps dated back to the 1890s for much of the area and resource inventories are non-existent. In the fall of 1989, the U.S. Agency for International Development (USAID) and the Government of Sudan initiated the Sudan Reforestation and Anti-Desertification (SRAAD) Project. The purpose was to establish base line vegetation resource information especially for woody biomass for fuelwood, construction materials, and gum production.

Working with the Sudan Forests National Corporation and the Survey Department, specialists from the USFS and the U.S. Geological Survey through the Agency for International Development developed demonstration products and procedural guidance for mapping and inventorying the Nation's land and resource base. The partners developed and completed Landsat-based image maps, vegetation maps and surveys, and socio-ethno-economic studies for a pilot area in less than three months.

In Sudan, small information systems were already operational. The Sudan Ministry of Agriculture, for example, had recently completed a survey of crop lands in parts of the country. For the woody biomass study, the Sudan Forest National Corporation (FNC) was going to exclude the agricultural lands from the inventory. However, in reviewing the available imagery, the FNC found that much of the agricultural land contained trees that were not inventoried in the crop surveys. Hence the FNC decided to include previously surveyed agricultural lands in the biomass inventory.

The Sudan Forest National Corporation (FNC) formed steering committees, with members representing participating ministries, to help overcome potential institutional and ministerial rivalries (Lund *et al.* 1990, Wigton 1991). GOS participants included Forests National Corporation (FNC), Sudan Survey Department (SSD), and the National Remote Sensing Centre. Later, the Ministry of Agriculture became a partner as the GOS expanded the inventory beyond the pilot area (Obeid and Hassan 1992). The U.S. Agency for International Development (USAID); U.S. Geological Survey (USGS); USFS; International Resources Group (IRG); and Winrock International provided technical and financial assistance for the demonstration. FNC had the overall lead for the inventory.

The original project design was to produce maps of the woody vegetation of the whole project area extending from the White Nile to the western borders of Sudan between 10 and 15 degrees north. This is an area of about 647,000 square kilometres (a quarter million square miles) requiring 38 map sheets at 1:250,000 scale for full coverage.

Because of a coup in Sudan, the U.S. Government had to complete all its project activities between 15 November 1989 (when most work got under way) and 28 February 1990. In order to comply with this regulation, the partners decided to restrict project activity to one area so that they could develop and demonstrate the techniques and have some results available for use.

Because of the short time frame, the partners had to carry out all activities at the same time rather than in a more logical order (for example development of the image base, followed by the vegetation mapping, woody vegetation inventory, and finally the socio-ethno-economic surveys). The team elected to focus on the Kazgail Rural Council area because rehabilitation surveys were already in progress there. The partners, in co-operation with the local regional council, determined the information needs for the pilot area. Local inhabitants provide logistical support for the inventory and mapping crews.

### *3.4.1 Pilot Area*

Deforestation and devegetation are quite severe in the Kazgail Rural Council area and desertification is setting in (Figure 3-5). One hundred years ago, dense forests cover large portions of the area, such as the Shekan Battlefield. Today, only a few scattered trees remain. Because the base maps and the vegetation maps were produced at the same time as the inventory was being conducted, the partners had make an estimate as to where the inventory area would actually be. When all was complete, part of the Kazgail area was missed in the inventory with some of the plots extended beyond the image mapping area. The area actually inventoried that is in coincidence with the Kazgail image base and vegetation map (which is considered as the inventory unit in the remainder of this report) was about 289,000 ha in size. Plots falling outside of this area were not considered in the production of inventory statistics.

### *3.4.2 Methods*

The objectives of all efforts were to field test inventory and mapping procedures and to develop a scientifically valid database for use by the Sudan Forests National Corporation for the management of the natural vegetation and to provide baseline information for rehabilitation. The mapping and inventory components were conducted out of a base camp near the village of Kazgail. Enlargements of four Landsat TM scenes to a scale of 1:100,000 were used in the field both for mapping control and for inventory plot location.

#### *3.4.2.1 Image Base and Vegetation Mapping*

Base maps for much of the pilot area were old and out of date. The location of some features were off by as much as one km. The objective of this phase was to produce image base and vegetation maps using Landsat TM imagery in a cost-effective way. An image base map uses digital imagery as a background to display basic planimetric information (drainage and cultural features).

Image base maps, in addition to providing location information, may be interpreted by specialists to give useful information about topography, soils, vegetation, land use, settlement patterns, and infrastructure. In order to establish control and to evaluate the accuracy of the image base maps, the partners used global positioning system (GPS) receivers. Vegetation maps are essential for summarising inventory data and management planning. If reliable maps of vegetation cover are available, they should be utilised in subsequent inventory designs.

Neither reliable vegetation maps nor image base maps were available at the start of the Kazgail inventory. The vegetation mapping team produced vegetation maps using ground reconnaissance, aerial photography, and satellite image mosaics. Personnel from the Sudan Survey Department later digitised the maps at the EROS Data Centre, superimposed over the belatedly constructed image base maps, and areas determined for each cover type occurring within the Kazgail inventory area.

### *3.4.2.2 Woody Vegetation Inventory*

The primary purpose of the inventory was to quantify the amount of woody vegetation in the Kazgail Rural Council area. The vegetation is used for firewood, timber, and gum extraction. Thus the inventory was an MRI.

1. *Sample design.* The Sudanese used a systematic sample with a random start with post-stratification of sample plots based on the vegetation map (Figure 3-6). This is particularly useful in the Kazgail area where land uses such as agriculture and livestock grazing are interspersed with the natural vegetation.

2. *Sample intensity.* For most inventories of woody vegetation, sample intensities are usually determined to achieve an allowable error based on total volume. However, often time and funding are more of a constraint than allowable errors. This was the situation in the Kazgail area where the inventory had to be completed in two months time. In the Kazgail area, the Sudanese initially determined they could establish about 74 plots on a 7-km grid in the time available using two crews. Of the 74 plots established, a total of 58 fell in the Kazgail inventory unit Only these 58 plots were used in subsequent analyses.

3. *Sample selection.* Because the image base maps were not available, a 1:100,000 image mosaic was constructed. A transparent 7 km x 7 km grid overlay was constructed for use on the 1:100,000 satellite image mosaic. The grid was overlain on the image mosaic with a random location and orientation. Plots were established at the grid intersections. These were pin pricked through the grid overlays and onto the image mosaics and later transferred to available aerial photographs.

4. *Plot configuration.* Sample plots were fixed-area, 20 m x 100 m in size similar to those used in other forest inventories of Sudan (Poulin and Ltee 1984) (Figure 3-7). Trees and shrubs 5 cm diameter or greater at root crowns were measured on the sample plots. Tree data recorded included species, diameters at breast height, diameters at root collar, bole height, total height, crown diameter, and percent cull. Plot information included land cover type, land use, land condition, tree density and rough estimates of soil texture class (Figure 3-8). A 1 m x 10 m regeneration plot was also established at each sample site.

5. *Volume estimates.* Volume equations were lacking for the pilot area. Data were collected on the sample plots using visual segmentation (Born and Chojnacky 1985). Segments included woody pieces 2 cm in diameter or greater and 0.5 m in length. Tree diameters at root collar (d.r.c.), total height, and crown diameter were used in regression equations to predict individual tree volumes.

### *3.4.2.3 Rehabilitation (Socio-Economic) Surveys*

SRAAD team members located sample villages within the Kazgail region and interviewed various components of the population regarding attitudes toward farming, conservation, and environmental and economic concerns. Part of the surveys tried to determine what the vegetation condition was like in the past decades by interviewing the older members of the community. Transects were established to record chronological and spatial variation in ground cover, changing land use, and general soil capability.

## *3.4.3 Results*

The teams completed all tasks for the pilot area. The Sudanese entered all into a computer and displayed the results in map, tabular, and computer format at a close-out meeting held in Khartoum. Review of the products were quite favourable and all the partners were satisfied with the technologyused and the results they produced.

Only through a group effort were the Sudanese and their partners able to accomplish as much as they did. Everyone worked together to produce the required maps, the MRI and GIS databases, and the socio-economic studies using advanced technology in an extremely short time frame under somewhat adverse conditions.

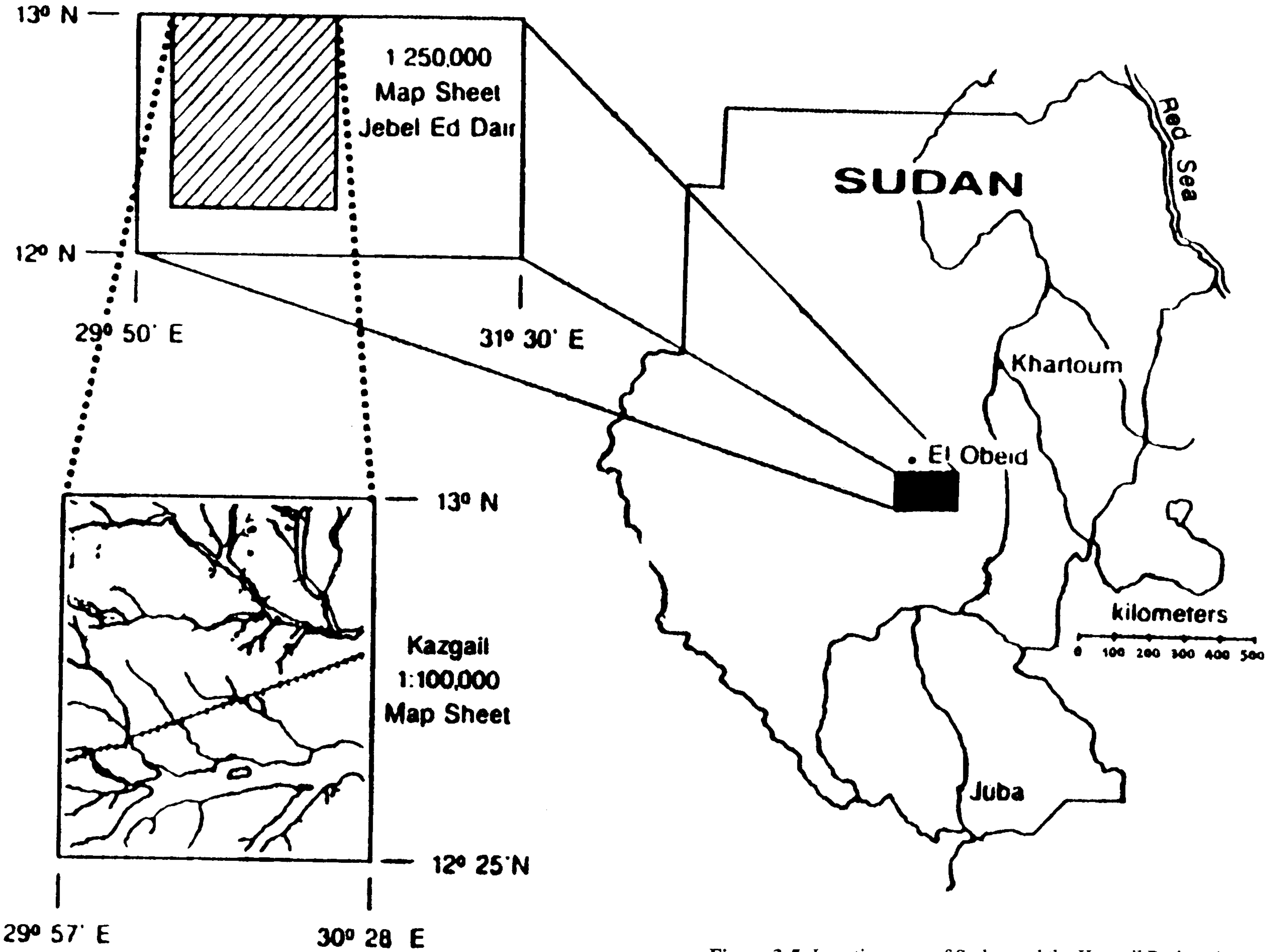



**Figure 3-5:** Location map of Sudan and the Kazgail Project Area.

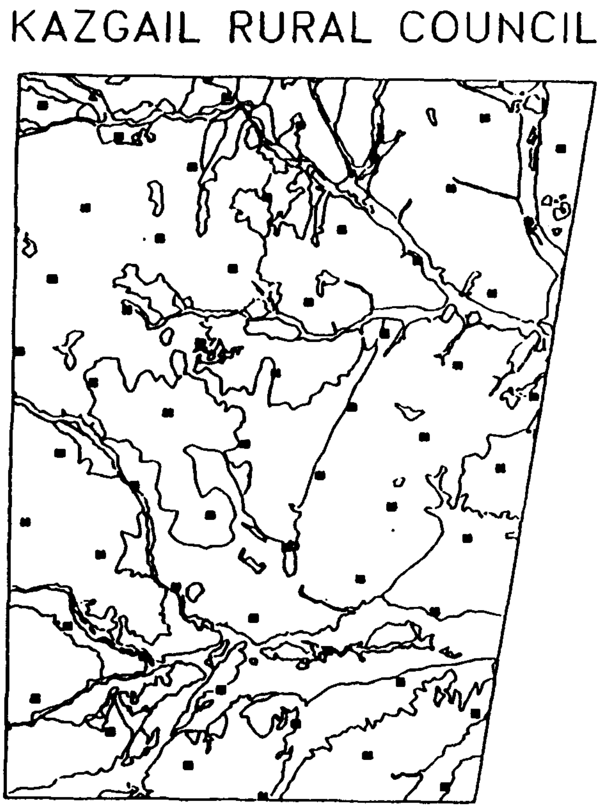



Figure 3-6: Distribution of sample plots in the Kazgail Project Area.

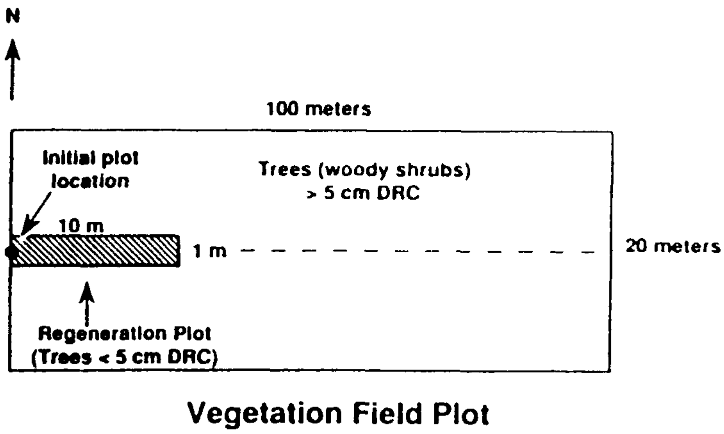



Figure 3-7: MRI field plot lay out. Herbaceous vegetation is measured along the centre line transect.

# KASGAIL RURAL COUNCIL VEGETATION INVENTORY

| | | |
|---|---|---|
| PLOT NUMBER<br>PHOTO STRATUM<br>LAND COVER<br>LAND USE | LAND CONDITION<br>FOREST TYPE<br>TREE DENSITY<br>SOIL TYPE | PLOT WEIGHT<br>CREW<br>DATE |

| TREE NO. | SPECIES NAME | SPECIES CODE | DRC (CM) | | DBH (CM) | | BOLE HT. (m) | | TOTAL HT. (m) | | CD (m) | % CULL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

REGENERATION PLOT (1m x 10m) < 5 cm

| DIST | A/P | SPECIES | DIST | A/P | SPECIES | DIST | A/P | SPECIES | DIST | A/P | SPECIES | DIST | A/P | SPECIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

REMARKS:

**Figure 3-8.** Data collection form for Sudan MRI.

The conflicts and problems confronting resource managers in Sudan and elsewhere are serious and life threatening. The lack of resource information, or the processes to evaluate resource information, present the managers with some insurmountable problems. The fragile interface between available natural resources and population practices presents the manager with very marginal management alternatives.

The state-of-the-art processes used by the SRAAD project provided the resource manager with a dramatic increase in the level of information and processes with which to improve management decisions. The geo-coded 1:100,000 scale TM image maps, inventory techniques, GPS data collection capability, and the socio-ethno-economic studies provided an effective system for resource information management.

- First, it employed the advantages of high technology in simple manners such as the use of visual interpretation of satellite imagery. Even though simple techniques were used to exploit the high technology, the Sudanese have the training, equipment, and skills to further use the tools they gained. For example, they can strengthen the vegetation mapping with supplemental automatic interpretation.

- Secondly, all lands were sampled for woody vegetation. Normally only lands that appear to be forested are inventoried for forestry needs and lands that appear to be used for agricultural purposes are inventoried for crops. In such instances there is often duplication of field visitations by different crews to the same area gathering different data. At other times, there may be gaps in responsibilities leaving voids in the resource base. The systematic sample across all lands provided the manager with a complete set of statistics for woody vegetation.

- Lastly, the project included the generally missing link of socio-ethno-economic surveys in the same area and at the same time that the resource data were gathered. Interviews of villagers included collecting information on past use of the lands and on preferences for future uses. Transects were run from the centre of sample villages to the edge of the lands the villagers used. Data were collected on current land use. This information is essential for any rehabilitation plan.

Through co-operation with other GOS agencies, such as the Ministry of Agriculture, the FNC was able to continue the inventories long after donor support evaporated.

### *3.4.4 Guidance for Future Activities*

Following are the recommendations of the National Research Council (1989) for ways to improve the pilot work:

☺ Do the tasks in proper sequence so that tasks later in the sequence take advantage of the information for the initial tasks. The recommended sequence is:

- Image Base Mapping
- Resource Inventories
- Socio-ethno-economic studies
- Analysis, plan development, and implementation
- Monitoring

☺ Establish good base maps. Satellite imagery, such as SPOT or Landsat TM, is very useful. In addition to showing major transportation routes and villages, the imagery is very useful for extracting soil, vegetation, and geologic information. Control the construction of maps with Global Positioning Systems (GPS). The systems are easy to use, particularly in open country, and are faster and more accurate than many existing sources of control for base maps. Where needed, get names of villages, administrative and political boundaries.

☺ Gather existing information, such as soil, geology, climatic, and land use maps and register to base maps. Digitise the boundaries and enter them into a Geographic Information System.

☺Conduct needed inventories, establish monitoring procedures and studies where data are lacking. Use people familiar with the local area. Tie all data in with base maps and GIS. Develop the application of GPS for establishing and locating inventory plots. Use field plots and computer-assisted techniques to improve on vegetation mapping (see Hellden and Olsson 1989).

☺Work with other Government Agencies or Ministries to include an inventory of multiple resources such as soils and non-woody vegetation for other sector uses. Note: the partners developed instructions for the SRAAD project that include the measurement of non-woody vegetation for future inventory efforts (Anonymous 1990). Since completion of the pilot study, the GOS has expanded the inventory to include crops and forage.

☺Consider using a systematic sample to cover all lands and permanent plots to establish a monitoring base.

☺ Socio-ethno-economic studies are necessary to determine local attitudes and needs and to expand and validate records of past resource conditions. Finding out what the local population needs to survive and thrive is essential for developing a successful implementation plan that people will support to combat devegetation and desertification or any other environmental concern. The local people have to be involved in the decision-making process. They have to benefit not only in the long run but also in the short term for any plan to be successful.

☺ The focus for rehabilitation should be to stabilise and protect the soil through establishing and maintaining vegetative cover. In order to have support of the local people, this vegetative cover has to yield cash income. Ideally in addition to providing income, the vegetation should also promote biological diversity. Future MRIs in the area should help address these needs.

## 3.5 PARTICIPATORY MAPPING AND INVENTORY IN TWO VILLAGES IN INDONESIA

☺**Case Study Synopsis**

**Area of Concern:** East Kalimantan Province and Jambi Province, Indonesia

**Problem:** Data on non-timber forest products are lacking. Local villagers do not have the technologies to measure and monitor their resource base. The problem is the development of a system for the inventory of non-timber forest products that is simple to use and statistically appropriate.

**Organization/Infrastructure Created:** A participatory mapping and inventory team including researchers from the UK, the Indonesia Department of Forestry, a local timber concession company, and a local non- governmental organization, with input from the villagers.

**Methods:** Series of meetings to identify information requirements, development of an inventory plan, followed by training and implementation.

**Results:** The inventories were complete and results discussed with the villagers. In general, the inventories met with the approval of the villagers.

### *3.5.1 Review of the Issues*

Participatory forestry, in which local communities that are dependent upon the forests are involved in managing them, is increasingly seen as a desirable and feasible option in many parts of the world, particularly in the tropics. One reason for this trend is the realisation of the negative impacts of ignoring local people's forest interests, especially in areas where there are high population densities and/or which are remote and poorly serviced by government. Another reason is the increased recognition of local people's rights to own and manage their traditional lands. A final reason is the current tendency of many national governments to decentralise and reduce management costs borne by the state (Carter 1996).

Participation by local people in forest management requires a number of changes to the existing management methods used by forestry or related professionals. One important change is in the way in which information about forest resources is collected compiled and analysed; participatory approaches to this are for the most part very new and/or still under development, and are reviewed in Carter (1996). Broad themes arising from this review are discussed below (Stockdale and Corbett 1996).

#### *3.5.1.1 Reasons for the Assessment*

Although local knowledge may have been sufficient in the past for controlling and managing forest land and resources, in present day circumstances the need for systematic, quantified information has arisen for a variety of reasons. Communities may map the location of, or inventory the quantities and types of forest resources important to them in order to claim tenure to forested land, or at least claim rights to harvest certain forest resources on that land. They may wish to manage specific resources in a more rigorous manner according to agreed objectives. Or they may wish to claim compensation for the loss of important resources.

#### *3.5.1.2 Methods Used*

Techniques such as remote sensing imagery, electronic data handling, and advanced statistical analyses are largely inappropriate to communities not used to such complex technology and with limited resources for gathering and handling information. Appropriate methods in conducting forest resource assessmentinclude:

- *RRA/PRA techniques:* Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) techniques include semi-structured interviews, group discussions, seasonal calendars, transect walks and sketch mapping with community members in order to obtain information about forest resources (a wide range of information not concerned with forest resources may also be obtained using these techniques) (Chambers and Guijt 1995).

- *Modified RRA/PRA sketch mapping with an emphasis on geographical accuracy*: The aim of RRA/PRA sketch mapping is to investigate the perceptions and knowledge of different forest users rather than to produce an accurate map of forest resources. However the geographical accuracy of the sketch maps produced by local people can be improved by consulting, and incorporating information from conventional maps and aerial photographs, by mapping using conventional land survey methods, or by the use of Global Positioning Systems (GPS) and Geographic Information Systems (GIS) (Poole 1995).

- *Participatory surveys and inventories*: Carter (1996) has defined both surveys and inventories as quantitative assessments of resources; however, inventories can be distinguished from surveys by their greater statistical accuracy. The challenge for participatory inventories is to develop a system that is both simple to implement and statistically appropriate.

#### *3.5.1.3 Resources Assessed*

In the tropics local people's interest in multiple resource assessment often focuses on non-timber forest products (NTFPs) such as game, fodder for livestock, fuel, charcoal, fruits, medicines, dyes, rattans and bamboo, although timber products too may play an important role at the local level. Problems in estimating NTFP include (Temu 1995):

- Poorly defined products in terms of parameters to be measured;
- Highly variable product distribution over space, time, and culture;
- Uncertainty over the present and future value of non-timberproducts; and
- Shortage of expertise and resources committed to inventory and monitoring as a whole.

#### *3.5.1.4 Social and Institutional Aspects*

Some important social and institutional aspects that impact upon participatory forest resource assessment include:

- *Attitudes of the outsider, project, or government official working within the community:* Any individual outsider must develop a relationship of trust and respect with the local people if he or she is to establish a working relationship.
- *Institutions that exist within a community through which the work can be organised:* Strong local organizations with a common commitment are key in developing a participatory approach to resource assessments.

- *Local people's perception of their ownership of the forest or resource base:* Local people's willingness to commit resources such as time and money to conducting the assessment is likely to depend on a strong sense of ownership of the forest, whether in fact it is legally recognised or not.

### *3.5.1.5 Practical Aspects*

Practical lessons learned from experiences of resource assessment in the projects described in Carter (1996) include recognition of the importance of:

- *Building upon local knowledge and experience:* Where there is a particular focus on non-timber forest products, there seems to be more likelihood of local peoples' knowledge being actively sought, as foresters' knowledge of these species tends to be less than their knowledge of timber species. Of particular interest is local peoples' knowledge of plant taxonomy, ecology, uses, and management.

- *Appropriate training:* Forestry Department members may require training in participatory forestry. Local people may require training in a number of completely new techniques. Training should be discussed at the outset, and a flexible program set up.

- *Proper species identification:* Local people, and certain individuals in particular, may have an excellent knowledge of local plant taxonomy. However, if only local names are used, this reduces the reliability and value of the assessment. Thus plant collection and the determination of scientific species names should be done in conjunction with the use of local systems of species identification.

- *Systematic, planned data collection:* Determining the information that is required, and discussing and trying out the different possible assessment techniques, should be done in as participatory a manner as possible. All parties concerned should consider carefully how the data should be recorded, stored, and processed in order to maximise local peoples' involvement and ownership of the information. A system of accuracy checking should be ensured, and attention given to data security and storage.

### *3.5.1.6 Economic Viability*

The economic viability of forest resource assessment is an important issue, especially for villagers with very limited resources, whether labour, equipment or money. At times it may be economically worthwhile for villagers to invest in an inventory, for example, for a commercial forest operation, particularly if it is aimed at a specialist, premium market. At other times it may be more appropriate for outsiders to cover some of the expenses, for example if the assessment includes long-term monitoring for forest growth modelling, where the results are of interest to a wider audience than the villagers alone.

## ***3.5.2 Two Case Studies from Indonesia***

From February until August, 1996, a trial of a new methodology for participatory forest resource assessment, called participatory mapping and inventory (*pemetaan dan inventarisasi partisipatif*, or PIP), was conducted in two villages in Indonesia. The so-called PIP team of researchers and trainers that arrived in the villages to work together with the villagers consisted of Mary Stockdale and Jonathan Corbett of the Oxford Forestry Institute and Indonesian counterparts from collaborating projects. The objectives of this work were:

- To test and evaluate the method with a view to writing a field manual on its use.

- To complete the method in both villages so that the villagers, and the larger ongoing projects that they were involved with, also received some benefit from the PIP team's work.

### *3.5.2.1 Background*

1. Indonesian legislation with respect to forest tenure and management. In Indonesia, land and resource tenure is one of the aspects of community life covered by traditional law, or *adat*, and has formed the basis of traditional forest management systems for many generations. However, although traditional law is recognised in the Basic Agrarian Law (1960) as the basis of national land law, it is often overruled in day-to-day government land-use decision-making by other more modern Indonesian laws such as the Basic Forestry Law (1966). One reason why traditional law is easy to ignore is that it is largely oral, whereas modern Indonesian laws pertaining to forest tenure and management are documented on paper, and implemented through such media as maps and inventory results.

In response, many communities in Indonesia are attempting to claim rights to control and manage what they have traditionally considered to be their own forests. An important first step is expressing their traditional law in the same language as that of government (for example, in the form of reports, maps and inventory results).

2. Long Tebulo village, East Kalimantan Province. Long Tebulo village is a community of 25 households located in the upper reaches of the Bahau River, in East Kalimantan province, Borneo, as shown in Figure 3-9. The village is partly situated in the Kayan Mentarang Nature Reserve close to the WWF-Indonesia Field Studies Centre. The mapping and inventory work conducted in this village linked in with WWF's community forest mapping project, which is being done in anticipation of a change of status of the area from nature reserve to national park. This change will permit the development of different types of forest use zones within the park, including traditional community forest use zones. Members of the PIP team included WWF staff and representatives from a local non-governmental organization.

The villagers are *Dayak* (a generic term used to describe indigenous peoples of Borneo) and predominantly from the ethnic group called the Kenya Lepo Ke'. They founded Long Tebulo village in 1970, moving from a village called Long Lio which was situated further up the Bahau River. The villagers clear the forest on a rotational basis to plant *ladang* (swidden rice fields) and *sawah* (irrigated rice fields); in addition to this they grow vegetable and fruit crops. However, the village relies heavily on resources from the surrounding primary lowland to hill dipterocarp forest to supplement their daily needs.

3. Semambu village, Jambi Province. Semambu village is a community of 130 households, located on both sides of the Sumai River in Jambi province, Sumatra, as shown in Figure 3-9. The village is situated in a KPHP concession management area which is part of a pilot project co-managed by the governments of Indonesia (Department of Forestry) and United Kingdom's Department for International Development (DFID) – formerly the Overseas Development Administration (ODA). The KPHP system is a new system of timber concession management which attempts to achieve higher ecological sustainability and to ensure that the needs of local communities are more adequately addressed. The mapping and inventory work conducted in Semambu village fitted in with the community mapping being done in the area in anticipation of boundary re-negotiation between communities, timber companies and government. Thus members of the PIP team included representatives from the Department of Forestry (BIPHUT), the local timber concession company (PT. IFA) and a local non-governmental organization.

The Semambu villagers are predominantly from the Malay ethnic group, a term used to describe Malay language speaking peoples, most of whom live in Sumatra and Peninsular Malaysia. They founded Semambu village in 1915, moving to this more central location from smaller villages in the immediate area. The predominant land use over the past 20 years has been for groups of villagers to clear small areas of forest (1-5 hectares) every two or three years to plant *ladang* (swidden rice fields); usually after two seasons of rice they convert this land to *kebun karet* (rubber plantation). The people rely on the surrounding forests to harvest resources which they use to meet subsistence and cash income needs. The forested area around Semambu consists of *belukar tua,* or previously cultivated land, linked to abandoned village sites, and *rimbo,* or natural forest, much of which has been logged over the past 20 years.

### *3.5.2.2 Purpose of Inventory*

The villagers in Long Tebulo determined some of the broad purposes of the method, or the most important potential uses for the maps and inventory data to them as to:

- Strengthen traditional claims to forest areas which are most important to the village. This is especially relevant when determining the future zonation of the National Park with outside parties such as the Department of Forest Protection and Nature Conservation and WWF-Indonesia

- Manage forest resources for the present and future needs of the village. For example, the villagers decided that smaller *sekau* saplings should be counted in the inventory as well as the larger harvestable ones. This is because this highly valuable forest resource had been so intensively harvested over the past years that the villagers were worried about the sustainability of their current practices.

The purposes or uses for the maps and inventory data, determined to be most important by the villagers of Semambu were to:

- Use them as a tool for discussion to prevent outsiders (for example, timber companies) from taking or destroying the forest resources most important to the village.

- Prevent rare (possibly over-harvested) forest resources from going extinct.

- Discuss traditional regulations about forest resource management.

### *3.5.2.3 Methods Used*

The participatory mapping and inventory method can be broken down into a series of steps:

1. First community meeting: Introduction to participatory mapping and inventory. The purpose of the first meeting was for members of the PIP team to introduce the participatory mapping and inventory method, explain what a forest resource map and inventory table are, their uses, and how they are made. Permission was also requested from the village for the PIP team to conduct this method together with the villagers.

2. Gather preliminary information. During this stage of the method preliminary information about the village, its forest area and its forest resources was gathered using a variety of PRA techniques. This helped the PIP team to gain a better understanding of the village, its forest area and its forest resources and so enable them to be more effective in facilitating subsequent meetings.

3. Second community meeting: Determining the purpose of the maps and inventory data. During the second community meeting the villagers identified and ranked the present and potential problems associated with the forest area and forest resources, and then discussed possible ways in which the maps and inventory data could be used to assist in solving these problems. They then determined the broad purpose for which they would like to conduct the method. This meeting was held in Long Tebulo only; in Semambu the subject matter of the second community meeting was discussed in the small group meetings of step 4 (below) instead.

4. Small group meetings: Making sketch maps and planning the inventory. During the small group meetings, the villagers divided into small groups (in Long Tebulo there were three, a women's group, an older men's group and a younger men's group; in Semambu there were four, a women's group and a men's group for each half of the village, on both sides of the Sumai River) in order to provide an easier atmosphere for discussion, this division into small groups was especially important for drawing out the different information and opinions of the less vocal groups. The small groups drew a sketch map showing the location of rivers, ridges, cultivated lands, forests, the traditional boundaries of the village land and any other natural or man-made features. Following this they listed the forest areas and resources they considered to be most important to them. From these lists they determined short lists of those forest areas and resources they would like to include in the inventory, and what type of information (for example age, size or condition) they would like to collect about each of these resources. All decision-making was done keeping in mind the broad purposes for the final map and inventory data that had previously been discussed in the second community meeting in Long Tebulo or at the beginning of the small group meeting in Semambu.

5. Third community meeting: Reaching consensus in planning the inventory. During the third community meeting representatives from each of the small groups presented the sketch maps and the decisions made by their group to the rest of the community. The village, as a whole, then reached a consensus concerning which forest

areas and resources would be in the inventory and what information they wanted to collect about each resource.

6. Training. Before beginning work in the forest, the villagers that had been chosen by community leaders to join the inventory team, together with other interested villagers, received two days of training from members of the PIP team. The inventory team consisted of men and women, young and old. In Long Tebulo the total number of villagers on the team was 15, in Semambu it was 18.

The first day of training was spent conveying the most important concepts needed for planning an inventory followed by the actual planning of the work in the forest. These concepts included how to use the scale of a map to calculate areas and distances, how to determine compass orientation in the field from orientation on the map and how to plan the logistics of an inventory. The second day of training was spent explaining the concepts behind and techniques involved in doing the work in the field. These techniques included how to use a compass, how to determine the boundaries of a plot, how to enumerate the forest resources within the plot and how to record the data.

7. Planning the inventory. The main steps used to plan the inventory are to:

- Produce a planning map by combining information from available scale maps brought in by the PIP team, the sketch maps of the small groups (step 4) and the villagers directly.
- Calculate the total area of the forest areas chosen to be included in the inventory using a transparent grid paper overlaid on the sketch map.
- Calculate the total area of 10 m by 10 m inventory plots that could be established given the constraints of available time and labour. This calculation was made using the assumption that one team of six people could cover 1.5 hectares per day in flat areas and 1.0 hectare per day in steep areas.
- Calculate the sampling intensity by dividing the total area of plots by the total area of forest chosen to be included in the inventory. In both inventories the sampling intensity was approximately 0.5% and this was considered to be sufficient for the purposes of the data that had been determined by the villagers (this assumption was a rough guess only due to lack of information on the variance of the forest resource populations at the time that the inventory was planned).
- Draw the inventory plots on the planning map:
  - The sampling design consisted of systematic lines of 10 m wide by 50 m long plots laid end to end.
  - The location of the first line of plots in each of the forest areas chosen by the villagers was selected randomly.
  - The total number of plots allotted to each forest area was proportional to the relative size of each forest area.
  - The compass direction of the lines was selected in each forest area such that the lines crossed the general direction of the main river at right angles. This was done to ensure that the variation in vegetation due to topography was covered most efficiently.
- Plan the logistics of the inventory (such as the location of the camps, the work schedule, the supplies needed for the camps, etc.).

8. Conducting the inventory

- Team tasks. In the forest the inventory team was divided into smaller teams, usually of six people. Each person within the small team had a specific task: One person cuts the trail to ensure a clear path for the compass and stick people to follow; one compass person and one stick person set the direction of the central line and use a 10 meter nylon rope to measure the correct horizontal length of each plot. Two enumerators count the forest resources to the left and the right of the central line, measuring whether plants are inside or out of the plot using a 5 m nylon rope measured from the plot's central line. One recorder records the information called out by the enumerators and numbers the plots.

- Checks. During the inventory work 10% (in Long Tebulo) to 15% (in Semambu) of the inventory plots were checked by a small team different from the team that had originally gathered the data. The results of these checks were then compared with the information gathered by the original team and discrepancies between the teams were discussed amongst the small teams in order to standardise the information being collected.

- Collect botanical samples. Samples of the forest resources chosen for the inventory were collected in order to identify the botanical name of the species. Members of the PIP team took the samples to the National Herbarium in Bogor to have them identified by experts, and the list of names were sent back to the villages.

9. Make the final maps and reports. On completion of the work in the forest, the inventory team compiled all data from the field in order to produce an inventory map, a forest resource map, and a mapping and inventory report.

- Final maps. The map used to plan the inventory was further modified by adding to it all information about the location of ridges and rivers which had been collected along the inventory lines. One copy of this final base map, called the inventory map, presents information about the location of the inventory lines and the boundaries of the forest areas chosen for each inventory. The other copy, called the forest resources map, shows the location of concentrations of forest resources, using data gathered from the inventory plots combined with information from the villagers' sketch maps.

- Final report. All the data from the inventory plots were compiled in order to estimate the total number and average number per hectare of each resource in each forest area. These calculations were done by villagers from the inventory team using simple hand-held calculators. The results of these calculations were presented in tables. The final report, describing the purposes specific objectives, method and results of the participatory mapping and inventory method, was written after the maps and tables had been completed.

10. Final community meeting: Presentation of final maps and report. During the final community meeting the final maps and report, and an explanation to how they were produced, were presented to the village by the villagers from the inventory team. There followed some informal discussion on how the maps and data that they now possessed could be of benefit to the village.

#### *3.5.2.3 Results*

In Long Tebulo, the inventory work was conducted in four forest areas identified as being of the greatest importance by the village, namely the Bua Alat, Tebulo, Enggeng I'ut, and Perinda watershed areas. The location of these areas, plus the location of the inventory lines in each area can be seen in Figure 3-10. Thirteen resources were counted in the inventory. Table 3-6 provides a summary of their local and scientific names, their uses, and the information abut them that the villagers had decided to collect in the inventory.

Inventory work was conducted in three forest areas in the Semambu village's traditional lands, namely the Ngayau, Tikar-tikar, and Mendalang watersheds. The location of these areas, plus the location of the inventory lines can be seen on the inventory map in Figure 3-11. Sixteen resources were counted in the inventory. Table 3-7 provides a summary of their local and scientific names, either uses, and the information about them that was requested by the villagers. Some of the major results included:

- Evidence that the densities of important forest resources were much higher in the Bua Alat and Tebulo areas than in the other two areas. This evidence helped to strengthen their existing status in Long Tebulo traditional law (these two watersheds are already designated as "protected forest" which cannot be cleared for agriculture), and emphasise to outsiders the particular importance of these areas for the villagers.

- Evidence that the densities of young *sekau* saplings is still high, despite heavy harvesting pressures. The villagers resolved to continue to adhere to their traditional law which states that *sekau* trees are not to be felled unless there is evidence of infection by the fungus that causes the aromatic wood.