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IUFRO Guidelines for Designing Multipurpose Resource Inventories

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PREFACE

In most countries resource managers and agricultural and food policy staff require periodic information for all land, soil, vegetation (timber, crops, browse, forage), water, air, fish and wildlife, aesthetics, recreation, wilderness, and energy and mineral resources. Moreover, agriculture and natural resources are so inter-related that these two cannot be disassociated. Decision-makers use this information to meet international requirements, develop national strategic plans, and for local planning. Traditionally organizations collect information on these resources in independent surveys resulting possibly in unnecessary duplication of effort, conflicting data, and information gaps. Properly designed multipurpose resource inventories (MRIs) provide much of the required information more effectively.

The International Union of Forestry Research Organization (IUFRO) Research Group 4.02 sponsored two recent workshops to address the topic of MRIs – the MONTE VERITÁ CONFERENCE ON FOREST SURVEY DESIGNS - "SIMPLICITY VERSUS EFFICIENCY" AND ASSESSMENT OF NON-TIMBER RESOURCES held in Ascona, Switzerland 2-7 May 1994 and the INTERNATIONAL CONFERENCE ON MULTIPLE RESOURCE INVENTORY & MONITORING OF TROPICAL FORESTS held in Seremban, Malaysia, 21-24 November 1994. The Monte Veritá Conference resolved that "the importance of the forest depends on social and cultural impacts. In industrialised countries, protection and recreation functions play a major role as well as ecological aspects. In the tropics and subtropics, forests are indispensable for providing the population with fuel wood and food. This situation leads to some very different rankings of forest functions." Beside all cultural and economic differences in various countries, participants accepted that the value of non-timber products exceeds the value of timber products by far (Köhl *et al.* 1995).

Participants at the Malaysia meeting developed the following conclusion and recommendations (Anonymous 1996):

> Tropical forests are continuously declining in extent, quality, and biodiversity as a result of deforestation and degradation caused by poverty and rapid population growth. This growth places increasing demands on lands for fuelwood, agricultural crops, and living space. One needs public awareness and actions by decision-makers to control the situation. The decision-makers, in particular, must have sound and comprehensive information and the necessary decision support tools. One should base this information on valid databases generated from credible research, inventory and monitoring programs covering the full range of natural and cultural heritage resources. The Conference recognised that tropical forest information is a basic pillar of sustainable development and balanced forest management.
>
> To address emerging needs and to improve the state of multiple resource inventory and monitoring of tropical forests, inventory specialists should:
>
> - Take advantage of new technologies and improved statistical sampling;
> - Involve the participation of the local communities;
> - Provide timely inventory and monitoring statistics;
> - Avoid duplication and establish compatibility among resource inventories carried out by different interest groups;
> - Avoid collecting unnecessary data;
> - Avoid gaps in the inventory and monitoring databases.

The conference participants recognised the importance of multiple resource inventory and monitoring in the tropical forests. The participants also recommended that IUFRO develop a set of guidelines that embrace the following principles for designing and implementing multiple resource inventory and monitoring programs. MRIs should:

- Meet a range of user needs.
- Utilise appropriate ecological classifications and assist in determining the value of forest resources and biological diversity.
- Provide statements of precision and accuracy.
- Stress compatibility of data from different inventories and the use of quality control to ensure data harmony, and to avoid duplication, gaps, and inconsistencies.
- Collect unbiased data.
- Account for all significant components – resources and their classifications, ownerships, community and conservation aspects.
- Utilise international and national standards and definitions.
- Allow relocation (remeasurement) of sampling units
- Evaluate the impact of management activities.
- Analyse, maintain and present inventory results using technologies such as GIS and geo-referenced databases linked to other resource inventories.

The IUFRO Guidelines for Designing Multipurpose Resource Inventories are an outgrowth of those resolutions and recommendations. They are based upon a literature review, a world wide survey of ongoing MRIs (Lund 1997a), and the personal experiences of the contributing authors. The purpose of these guidelines is to help the reader design multipurpose resource inventories to meet international needs and as input for national assessments. While monitoring is discussed, inventory is the primary focus of the guidelines. Many of the ideas we use for inventory are applicable to monitoring, and indeed, resources inventories provide the base for monitoring.

The intended audience are those people that design inventories at the state, provincial or national level, although the guidelines are also useful locally. The authors assume the reader has some prior experience in designing resource inventories.

The design of an MRI often requires working with a great diversity of people with which one may not normally deal. Therefore, we have placed as much emphasis on working with people as we have on the design aspects of multipurpose resource inventories. Following these guidelines will help ensure that one conducts inventories of land, soil, vegetation, water, air, fish and wildlife, aesthetics, recreation, wilderness, and energy and mineral resources in an effective way. However, every situation is different so the Guidelines are general in nature. Take what you can use and create the rest yourself.

Given this background and the need to inventory more than the trees, it is with great pleasure that I present these guidelines to you. I urge all IUFRO member organizations to use the IUFRO Guidelines for Designing Multipurpose Resource Inventories in their data collection activities.

I congratulate and thank IUFRO 4.02, the authors, and reviewers for their work in producing these guidelines which will help in the inventory of our natural resources.

Sincerely,

Dr. Jeff Burley
IUFRO President

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FOREWORD

Diverse and often conflicting demands upon land and natural resources around the world increasingly require that decision-makers cater for a wide range of potential human interests within any given area, such as agriculture, biomass productions, biodiversity, recreation, and urban expansion. This means that administrators have to look at the land and its resources for a variety of potential uses – agriculture, biomass production, biodiversity, recreation, urban expansion, etc. To increase the benefits of the data collected and to minimise the expenditures, inventory specialists are turning more and more to multipurpose or integrated resource inventories. This is particularly true at the broader decision-making scales – provincial, national, regional, and global.

These guidelines provide basic information on Multipurpose Resource Inventories (MRIs) for the inventory planner and decision-maker at the provincial or national level although the instructions will be useful at the local level as well. We discuss the need for MRIs, the information requirements, support structure, and the design and implementation issues in depth.

1 MULTIPURPOSE RESOURCE INVENTORIES – WHAT ARE THEY, WHEN TO USE?

Resource administrators and agricultural project officers require sound data to support management decision-making, satisfy legal mandates, maintain familiarity with available resources, understand ecosystem functions, and provide background information for use by projects and programs (Schmoldt, Peterson, and Silsbee 1994 and Peterson, Silsbee, and Schmoldt 1995). The solution to many international, national, and local problems involves agricultural, forestry, animal and fishery departments working together. Generally speaking, a manager's ability to integrate objectives or develop integrated programs is poor. The decision-maker needs basic studies and pilot activities to integrate socio-economic values across sectors and political mechanisms to stimulate action and adjudicate conflicts. The information requirements of the public land administrator have been growing. For example, in the 1950s the emphasis was on timber production on forest land in the United States. In the 1960s, interest in recreation, range, and wildlife management gained recognition. In the 1970s, there was an energy shortage. The need for biomass data developed. The 1980s brought about concerns about global warming and carbon sequestration. Interest in ecosystem management, non-wood forest products (NWFP), and biodiversity blossomed in the 1990s. In the year 2000, we will need to understand how forests relate to other lands and uses. The increased interest has brought about increased needs for data in a stair-step fashion (Figure 1-1).

Many public land administrators, as well as agricultural and natural resource project managers throughout the world are experiencing a similar need for more information on vegetation, fauna, soils, water, etc. The development of national strategies for conserving such things as biological diversity will require means for managing diversity of all sectors (Namkoong 1990).

					Other's Lands?
				Ecosystems, Biodiversity, Non-Wood Forest Products	Ecosystems, Biodiversity, Non-Wood Forest Products
			Global Warming	Global Warming	Global Warming
		Biomass	Biomass	Biomass	Biomass
	Multiple Resources	Multiple Resources	Multiple Resources	Multiple Resources	Multiple Resources
Timber	Timber	Timber	Timber	Timber	Timber
1950s	1960s	1970s	1980s	1990s	2000+

Figure 1-1: Increase in information needs about forest lands in the United States (Lund and Smith 1997).

Resource inventories and monitoring programs provide this information. An inventory is simply an accounting of goods on hand. Through periodic inventories and other means, we monitor changes in the resource base, to determine causes of those changes, and to see if our management plans are proceeding as envisioned. The challenge is how to provide the decision makers with the information they need at the lowest costs. Multipurpose resource inventories (MRIs) may be the solution. While the emphasis of these guidelines is on inventory, may of the ideas we present apply to monitoring programs as well.

1.1 WHAT ARE MRIS?

Multipurpose resource inventories (MRIs) are data collection efforts **DESIGNED** to meet all or part of the information requirements for two or more products, functions (such as timber management and watershed protection) or sectors (such as forestry and agriculture). One often collects a variety of data at the same place at the same time. Variations include:

- Data collected on the same plot but at different times to account for phenology differences or for logistical reasons (for example, availability of experts).
- Variable sampling intensity for different resources. The sampling design should accommodate these differences (for example, one may not collect all information on all plots).
- Part of the inventory needs of certain resources met by the more extensive MRIs and this then linked with a more intensive single purpose inventory.
- Resource data linked via data management systems.

A key word in the above definition is '**designed**.' This implies that before any data are collected, there are meetings between the inventory designers and the intended users of the data to learn of their information needs and to optimise an inventory system to meet their multiple needs. There are major differences between MRIs and 'single purpose' timber inventories or crop surveys. The MRI design may be more complex and the inventory planner may have to work with a number of different people. These people may have different backgrounds and needs. In these guidelines we present the combined thoughts of people actually doing MRIs. To help focus on specific points we use special boxes with various faces.

😐 is generally for information only.
☺ shows some recommended action.
☹ indicates caution or special things to watch.

1.2 WHY MRIS?

Land managers rarely make decisions in a single resource use context. Multiple resource information is integral to the decision making process (Buck 1987). Päivinen and Solberg (1996) observe "Information is gathered to improve decisions and, thus, to get a better use of the resources. The benefit of increased information is the wiser use of resources over time. The gathering of information is usually not free – it demands resources (labour, technology, energy, transport, etc.) and therefore implies costs. The main challenge related to value-added information is to collect more information as long as the marginal benefit is higher than the marginal costs of getting the information." We design and conduct MRIs to reduce costs and to improve our information databases.

We also conduct multipurpose resource inventories to:

- determine the condition, production, potential, and amounts of key ecosystem components or processes;
- identify a benchmark of the current physical and biological situation for forecasting projected changes;
- provide ecological information as a basis for protection and management decisions about land and resource uses;
- consider the current state and trends in renewable resources as they affect and are affected by resource use demands and decisions;
- tie specific units of land to information about resources; and
- avoid many field visits if different measurements can be carried out by one crew.

Moreover, land and resource managers may be required to verify that their projects do not have negative impacts on the environment (the natural resources). Agriculturists in Ecuador, for example, indicated they need to make decisions based on interrelated data from multiple sectors. The farmers needed information on soil erosion, deforestation, and other measures of environmental degradation as well as on crops and crop production (Wigton 1997b). Data must be collected so that one establishes the relationships between variables in different sectors. This is best done by designing MRIs. Periodic MRIs, collecting the same information at the same location, form the basis for monitoring changes and predicting trends.

A final advantage of an MRI is that one often must establish partnerships. Those established at the lower administrative levels are very important when implementing management programs. This co-operative attitude also contributes towards breaking down bureaucratic and institutional barriers between users of inventory information.

☺ Inventories provide static assessments of resources whereas monitoring assesses changes in states or trends of the resources.

Multipurpose resource inventories are not new. When human beings first evolved, they searched the landscape for areas that would provide food, shelter, water and fuel. They were, in fact, conducting multipurpose resource inventories. The goal was survival. As populations increased, their room to roam decreased. Humans had to settle down and start to dedicate specific pieces of lands to meet specific needs (such as agriculture, villages, timber). Sectorial inventories developed focusing on the special uses of these lands. Now, however, the Earth's human populations have increased to such a point that there are competing demands for the same terrain. We now need information for a multitude of potential uses.

Collection of data is costly and time-consuming. Collection of the same information on the same piece of ground for different sectors at different times exacerbates the situation. One way of reducing expenditures and getting complete and compatible data is to organise joint collection efforts through MRI. Thus, we return to the techniques of our ancestors. Today's goals of an MRI are to promote communications between disciplines, improve data collection efficiency, eliminate redundant data collection and procedures, and develop consistently compatible and scientifically reliable information.

1.3 WHO USES MRIS?

Today, many organizations carry out their inventory, classification, and monitoring programs on a sectorial basis -- forestry, range, and agriculture for example. However, MRIs of vegetation are becoming more common. Bruijin (1974) and Nossin (1982) reported on one of the first documented MRI carried out in Australia. This inventory used interpretation of aerial photographs by a multidisciplinary team

To answer the question of who uses MRIs, we sent out a questionnaire (see Appendix 4) to the Ministries of Forestry of some 163 countries throughout the world and publicised the survey on various nets. As of 14 November 1997, we had received a total of 73 responses. Through the survey and literature review we found a total of 55 MRIs being conducted world wide (see Table 1-1). Thirty-eight were discovered by way of the questionnaire and the remaining 16 as a result of the literature review. The questionnaire and literature review showed at least 38 countries have some form of MRI at some level (Figure 1-2). We received an additional 36 responses from individuals who expressed an interest in developing MRIs.

The map shown in Figure 1-2 may be misleading. It shows countries where MRIs are conducted, but the MRIs may be carried out only at a local site or province instead of the country as a whole. Canada is an example where the MRI is in the Province of British Columbia. On the other hand, there could be a good many more MRIs throughout the world especially at the more local levels so the findings presented in this report should be judged with that thought in mind.

All but two responses MRIs were linked to timber. That is understandable as the questionnaires were mailed to the Ministries of Forestry and the availability of the questionnaire was advertised on forestry or forestry-related nets. The purposes of the MRIs range in scope from inventorying for timber and cone production in Spain

(Garcia-Guemes 1997) to the collection of forest and agriculture data in Malawi (Wigton 1997). The MRIs reported for Spain and South Africa were timber inventories, but looking at the timber resource for multiple products. Similarly, the response from Italy was a recreation survey and again looking for multiple uses of the sites.

Most inventories in Africa and Asia focus on timber and non-timber forest products (NTFP). Note that many of the countries incorporating MRIs have large tracts of arid lands. Arid lands often provide a variety of goods and services including timber production, fuel wood production, and livestock grazing. MRIs in Europe and North America stress both the timber and environmental aspects of the forests – especially the non-wood goods and services (NWGS).

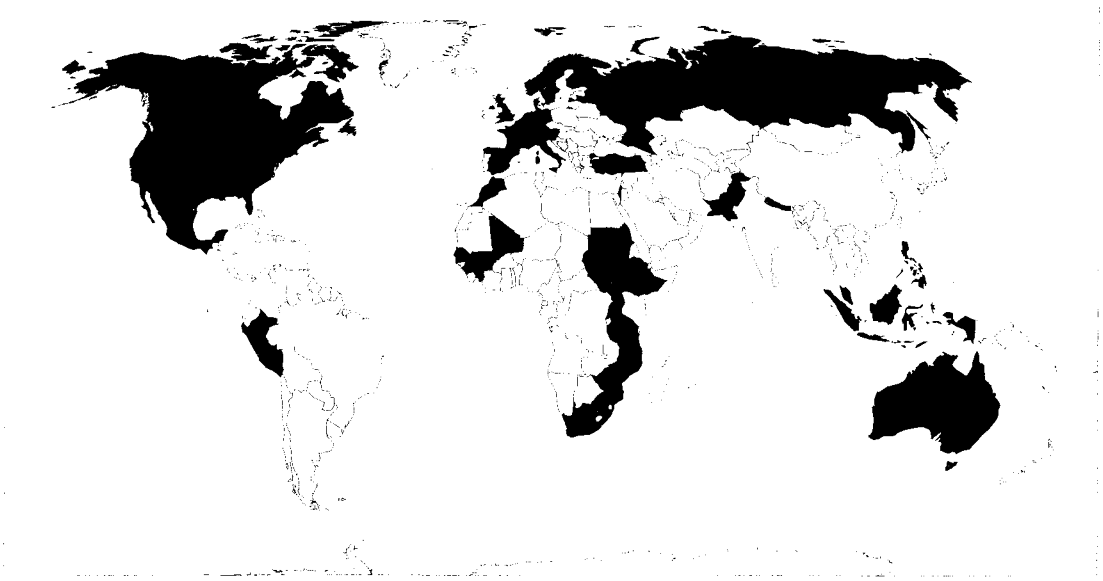

Figure 1-2: World map showing countries (darker shade) reporting MRIs.

1.4 WHEN TO USE MRIS?

Generally economics and the demand for information provide the impetus for MRIs. MRIs are useful in the following situations:

- If an agency must manage its resources for more than one application.
- If temporal and scale needs are similar.
- Several user groups require information on the same land base.
- The administrator requires information on the relationship of different resources (ecosystem components).
- Decisions about management of lands require comparable data in terms of time and space
- Available inventory expertise resides within at least one user group.
- Individual agencies are currently collecting similar information on the same area.
- Base data are lacking. For example, forest inventories often do not include surveys of interspersed crop lands while surveys of agricultural lands may not include lands devoted to agroforestry. To manage these 'in between' lands properly, the administrator needs this information.
- If agencies or ministries lack sufficient funds to separately conduct all surveys they need.

Table 1-1: Listing of countries having MRIs based upon the MRI questionnaire survey and literature review (Lund 1997b).				
Continent/Country	**Organization**	**Scope**	**Objectives**	**Source**
AFRICA				
Ethiopia		National	Timber, NTFP	WBISPP 1993
Guinea	Ministry of Agriculture and European Union	National	Ecosystem evaluation	Goussard 1997a
Malawi	Land Resources Conservation Branch	Province	Agriculture, Timber	Wigton 1997a
Mali	Mali Land Use Project	Country	Soils, vegetation, water	Treadwell and Buursink 1981
Morocco	Minister de l'Agriculture et de la Mise en Valeur Agricole	National	Timber, Ecological	Kerrouani 1997
Mozambique	National Directorate of Forestry and Wildlife	Local	Timber, Wildlife	Cruz 1997
Rwanda	World Bank	Local	Ecological	Mushinzimana 1997
Senegal	Ecological Monitoring Centre	National	Timber, NTFP	Gueye 1993
South Africa	Mondi Forests	Local	Timber, Agriculture, Water	du Plessis 1997
South Africa	Sappi Forests	Local	Timber, NTFP	Hattingh 1997
South Africa	Institute for Commercial Forestry Research	Local	Timber, NTFP	Morley 1997
Sudan	Forest National Corporation	Province	Timber, NTFP, Agriculture	Obeid and Hassan 1992
Tanzania	Forestry and Beekeeping Section	District	Timber, Agricultural crops	Haule 1997
Uganda	Ministry of Natural Resources	National	Timber, NTFP	Hedberg 1993, Drichi 1993
Zimbabwe	Forestry Commission	Local	Timber, NTFP	Mkosana 1997
ASIA/OCEANIA				
Australia	Bureau of Resource Sciences	Province	Timber, Environment	Rumba 1997
Indonesia		Local	NTFP	Stockdale and Corbett 1997
Malaysia	Forestry Department	Forest Reserves	Timber, NTFP	Yuan 1997, Salleh and Musa 1994
Nepal	Department of Environment and Geographical Sciences	Local	Environmental	Jordan, G. 1997
Nepal	Forest Resources Information System Project	State	Timber, NTFP	Pikkarainen 1997, Kleinn *et al.* 1996, Laamanen *et al.* 1994
Pakistan	North West Frontier Forest Inventory	Local	Watershed	Masrur and Kahn 1973
Philippines		Local	Timber, Ecological	Rosario 1996
Philippines		Local	Timber, NWFR	Villanueva 1996

Table 1-1: Listing of countries having MRIs based upon the MRI questionnaire survey and literature review (Lund 1997b).

Continent/Country	Organization	Scope	Objectives	Source
EUROPE				
Austria	Institute of Forest Inventory	National	Timber, Environmental, NWGS	Schieler 1997, Winkler 1997
Belgium	Unite' de Gestion et Economice forestieres	Province	Timber, Biodiversity	Rondeux 1997, Lecomte *et al.* 1997
Denmark	National Environmental Research Institute	Local	Biodiversity, Timber	Skov 1997, Plum 1997
Finland	Finnish Forest Research Institute	National	Timber, Environmental	Tomppo *et al.* 1997
France	Inventaire Forestier National	Province	Timber, NWGS, Wildlife	Valdenaire 1997, Lagarde 1997
Germany	Bundesministerium fur Ernährung, Landwirtschaft und Forsten	National	Timber, Environmental	Schmitz 1997, Kleinn *et al.* 1997
Italy	Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura	National	Timber, NWGS	Tosi and Marchetti 1997
Italy	Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura	National	Recreation	Tosi 1997
Latvia	State Institute of Forest Inventory	Subcompartment	Ecological, NTFP	Vazdikis 1997
Netherlands	Institute for Forest and Forest Products	National	Timber, Environmental	Daamen and Stolp 1997
Norway	Norwegian Institute for Land Inventory	National	Timber, NTFP	Tomter 1997a, 1997b
Norway	Norwegian Institute for Land Inventory	National	Agriculture, Ecological	Dramstad 1997
Norway	Norwegian Institute for Land Inventory	National	Geology, Ecological	Elgersma 1997
Russian Federation	All Russian Research and Information Centre for Forest Research	National	Timber, NWGS, recreation, water, wildlife, grazing	Filiptchouk 1997
Slovenia	Slovenian Forestry Institute	National	Timber, Environmental	Kovac 1997
Spain	CIFOR-INIA, ETSI de Montes	Province	Timber, NTFP	Garcia-Guemes 1997, Martinez-Millan and Condes 1997, Pita 1996
Sweden	Swedish University of Agricultural Sciences	National	Timber, Environmental	Söderberg 1997
Sweden	Skogsvårdsstryelsen Västerbotten	Province	Timber, Wildlife	Persson 1997, Merkell 1997
Sweden	National Board of Forestry, Environmental Department	National	Wetlands, Ecological	Rudqvist 1997, Merkell 1997
Sweden	National Board of Forestry, Environmental Department	Province	Ecological, Biodiversity	Merkell 1997, Noren 1997
Switzerland	Swiss Institute for Forest, Snow & Landscape Research	National	Timber, Environmental	Brassel 1997, Köhl and Brassel 1997, Brassel 1995
United Kingdom	Forestry Commission	National, Province	Timber, Ecological, Biodiversity	Dewar 1997, Jordan, P. 1997
LATIN AMERICA				
Mexico	Subsecretaria de Recursos Naturales	National	Timber, NTFP	Varela-Hernandez 1997
Peru	Instituto National d'Investigation in Ecologia Andina (INIEA)	Province	NTFP, wildlife, water, agricultural crops, ethnoecology	Goussard 1997b

Table 1-1: Listing of countries having MRIs based upon the MRI questionnaire survey and literature review (Lund 1997b).

Continent/Country	Organization	Scope	Objectives	Source
MIDDLE EAST				
Israel	Land Development Authority	Local	Recreation, Timber, Landscape Value	Sachs 1997
Turkey	Ministry of Forestry	National	Timber, NTFP, Agriculture	Çaliskan 1997
NORTH AMERICA				
Canada	SRK-Robinson	Local	Fisheries, riparian and channel geomorphology	Rennie 1997
Canada	British Columbia Provincial Government	Province	Natural Resources	Omule *et al.* 1996
United States	U.S. Dept. Agriculture, Forest Service	Local	Natural Resources	Gee and Forbes 1997
United States	Wildlife Conservation Service	Local	Ecological	Fimbel 1997, Fimbel and Fimbel 1997
United States	U.S. Dept. Agriculture, Forest Service	National/Province	Timber, NWFR, biomass	Smith 1997
United States	State of Hawaii	Province (State)	Timber, Ecological	Buck 1987

There are a variety of situations of when MRIs may be useful:

For land use planning: Forest and rangelands, in particular, offer opportunities for multipurpose resource data collection. All forest and rangelands have economic values and ecological and environmental functions (air, water, and carbon). Forest and range lands serve as gene pools and media for maintaining or increasing biodiversity. People use forest land for food, fuel, and fibre production. Some may use forest land for agroforestry, grazing and recreation. In such situations, MRIs greatly assist in the development of a rational, integrated land-use plan. Knowledge of the forest and rangeland from an MRI can benefit the management of the associated uses.

For inventorying forest and rangeland functions: Forests and rangelands provide a variety of functions including wood production, protection, water, grazing, hunting and fishing, nature conservation, recreation, and non-timber forest products (NTFP Brassel (1995). (See Figures 1-3 and 1-4.) Functions and services applicable to forest and rangelands include:

- Productive: Production of wood and non-wood products, standing volume, faunal and vegetation growth in terms of number and biomass, soil productivity and nutrient status
- Protective: Check soil erosion, protects stand density and traces of rock falls, habitat for flora and fauna
- Ameliorative: improve environmental stability, soil health, biotic interaction, sustaining of biodiversity
- Ecological stability: Maintain ecological principles, food chain, food web, energy flow, sustain climax of ecosystem succession and development
- Recreational: Offers human influence and utilisation
- Water regime sustainability: Maintains soil water, underground water regime, air humidity, etc.

- For linking forest and rangelands with other lands: Some functions extend beyond the forest. Consequently, the inventory designer may have to expand the inventory to cover larger area. These functions include, but are not limited to, avalanche defence, flooding, wind breaks, deadening of noise, purity of drinking water, protection against extremes of temperature, landscape protection, hunting, filtering, and sinks for CO_2 (Brassel 1995). A properly designed MRI can provide much of this information.

- For data checks: We can use an MRI to check on existing data and thus provide feedback loops on data and information. Organizations that only collate existing information often end up with fragmented, and sometimes highly unreliable and or outdated data, but with no clear picture of these weaknesses (Hedberg 1993).

- For monitoring changes in land use and land cover: Barton (pers. comm.) reports "Our on-going work with remote sensing in New Zealand is finding considerably more 'indigenous forest' than the official figures suggest (up to 50 % more). The dynamic interface is with scrub/high forest which follows the removal of agricultural subsidies to sheepfarming. At the peak of the subsidies period (in 1982), the sheep numbers stood at 72 million; they are now down to 47 million. Marginal grassland is either reverting to indigenous cover or is being converted to plantation-based forestry. Our land use changes will be quite dramatic if we start monitoring them more closely." An MRI and monitoring program may help to track such changes.

- For resolving conflicts: Often there are conflicting views on how an agency should administer the land or there is conflicting resource information. MRIs enable a standard database from which the decision-makers and partners can make valid comparisons. For example, development activities in agriculture, forestry, range management, industry and urban centres typically have an impact environmental on parameters. It is most efficient to design integrated systems that incorporate relevant information from different sectors. In this way, the system provides improved data for decision-makers interested in environmental impacts of project implementation. However, poorly designed MRIs may not conserve funds. For example, by not taking into account different variances associated with different resources, over sampling may occur.

- For inventory of non-timber forest products (NTFP): We also use an MRI for inventories of non-timber forest products (NTFP). Temu (1995) places NTFP into two categories – wood and non-wood. Wood includes wildings, stakes, firewood, craft materials, canes, and bamboo. Non-wood include plant products, extractives, animal products, water and intangibles (Temu 1995). Pelz (1995) categorised temperate non-timber forest products as including food (game, mushrooms and truffles, berries, hip/briers, nuts, honey, birch sap, snails, milk (sheep, goat), fish, carobs) and non-food (cork, aromatic and medicinal plants, dyes, gums/oils, resins, Christmas trees, game trophies, seeds, hides/furs). An MRI for NTFP is useful only if the land administrator uses it to improve decision-making. The inventory designer must give serious attention to the way decision-makers uses the results before undertaking major non-timber product inventories (Temu 1995).

1.5 WHAT IS THE IDEAL MRI?

Mohrmann (1973), van den Broek (1974), Nossin (1975), McClure *et al.* (1979), Lund (1986), Rudis (1993a), and Lund and Wigton (1996) document the concepts of MRI. An ideal MRI system is one that:

- Saves time and money and provides the needed information.
- Involves all concerned parties.
- Meets needs.
- Follows established standards.
- Covers all lands and vegetation types. This is especially true in areas where land use shifts back and forth.
- Makes use of appropriate technology as a base for data collection.
- Provides scientifically valid estimates of important resource parameters.
- Produces credible and defensible data.
- Has data collected and documented in a way that allows people to repeat the data process and get the same answers.
- Has an ecological/land potential classification and mapping base.
- Has a monitoring function.
- Has all data stored and viewed in a GIS using common definitions, standards, and codes which are readily available.

Some resources do not coincide with commonly surveyed variables and accompanying attributes. Resources that are rare (endangered plants and animals), ephemeral (herbs), or of low density (large carnivores), and resources valued by the number of people likely to visit them (scenic vistas, developed recreation sites), often occur at temporal and spatial scales at odds with some multipurpose resource inventories. A group may use disparate inventories to catalogue multipurpose resources with some reservations. Inventories derived from disparate data sources have additional sources of error when combined or overlaid from with collected at different sample times, scales of resolution, and levels of location accuracy. Logical planning makes disparate inventory efforts more defensible. Logical planning includes:

- Conducting user surveys at specific locations or employing user surveys geo-referenced with extensive area-based resource inventory attributes.

- Stratifying data collection to ensure that a group conducts some sampling during the seasons(s) when resources are readily identifiable, such as sub-sampling herbaceous species in each ecological community type during the summer.

- Incorporating indices for rare, ephemeral, or low-density resources, such as inventorying animal habitats, rather than conducting an animal census. Such efforts clearly are sub-optimal, as indices lack actual sightings of the resource. MRIs should measure variables (preferably continuous rather than classes) that analysts convert into indices. Feasibility of collecting more widely valued observations and alternative single resource inventories are issues inventory designers must resolve among stakeholders. To be widely accepted, use indices that have been validated with the resources they represent.

- Linking resource attribute data from one resource inventory to another, related resource, through standardisation of definitions and geo-referencing all samples. For example, until the 1970s, the U.S. Forest Service designed forest surveys in the eastern United States chiefly to catalogue spatially extensive resource attributes fixed in time and space. One can find numerous examples of the use of one or more of the three approaches above in Rudis (1991) to determine or analyse multipurpose resources. More recent efforts suggest a greater need for logical planning, particularly with advances made to standardise forest survey data (Hansen *et al.* 1992), links with other regional agencies, and distribution of data that groups integrate simply by federally standardised geo-referencing (Kress 1996).

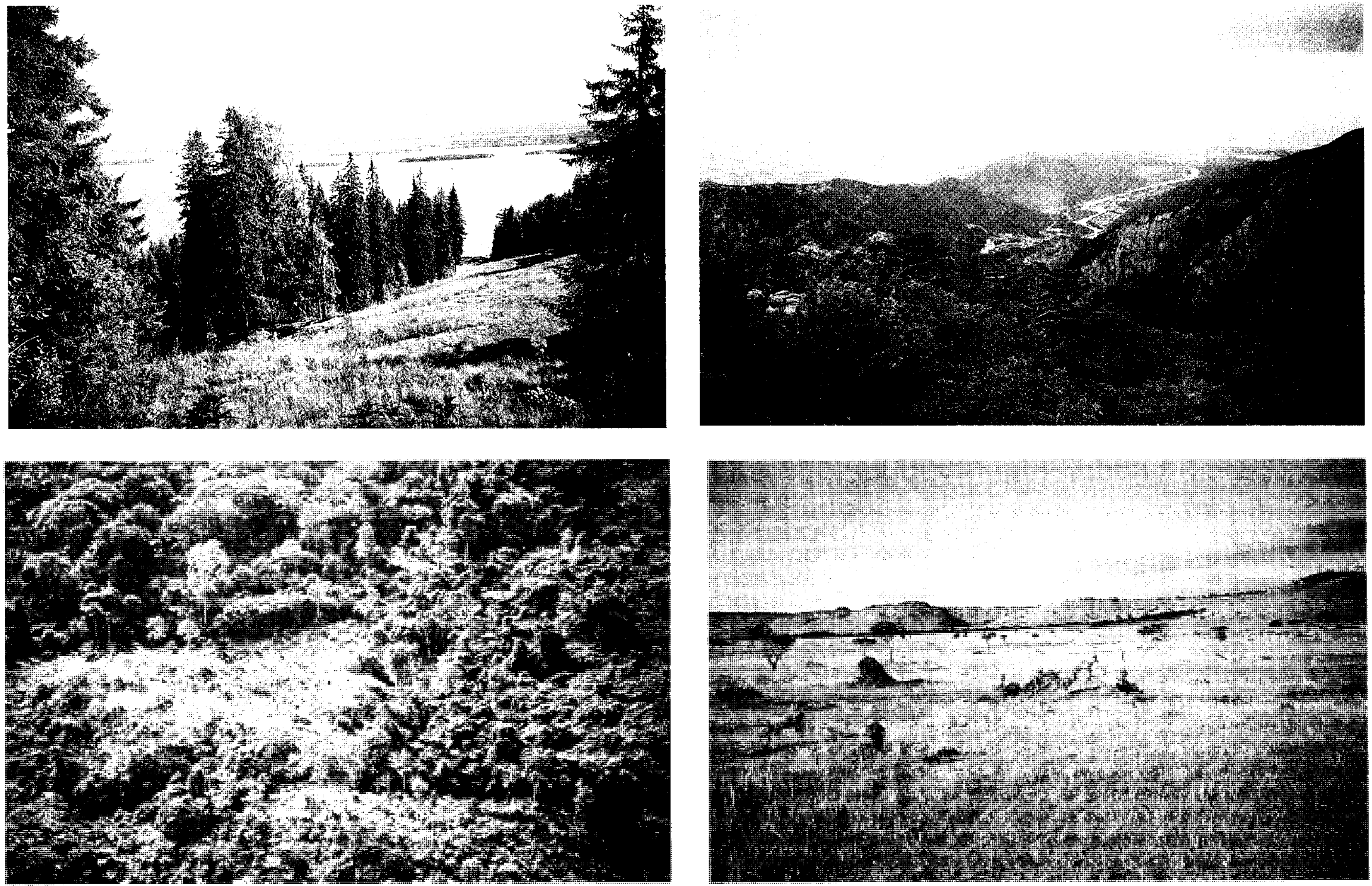

Figure 1-3: Sample situations where MRIs may be useful. Upper left – Forests used for recreation and timber production (Finland). Upper right – Forests used for watershed protection, recreation and timber production (Korea). Lower left – Lands where land uses are interspersed – agriculture and forestry (Papua New Guinea). Lower right - Grasslands used for livestock grazing and wildlife habitat (Kenya).

Figure 1-4: Non-wood forest products (blueberries) from forest (upper photo) to market (lower photo) – Finland. The collecting of non-wood forest product information in conjunction with a timber inventory is an example of an MRI.

- Establishing protocols (through research) that link disparate surveys. Recent efforts that show promise in this regard include those involved with recreation user surveys (Freimund *et al.* 1996) and animal occurrence estimates (Flather *et al.* 1990, Rudis and Tansey 1995). Inventories not specifically designed to assess particular resources, but crafted from selected resource attribute combinations, provide hypotheses about interrelationships. In such cases, analysts must always guard against spurious relationships. Correlated resource attributes are, by chance, associated rather than causative agents for the resources of interest. At the very least, conclusions drawn from these linkages should identify the spatial and temporal scales of underlying data sources. These may include details about questionnaires, sample bias, etc., for wildlife occurrence estimates, user surveys, and forest and rangeland area characteristics. Inventory designers should also make efforts to reduce likely sources of error when associating statistically or overlaying geographically disparate data layers.

1.6 WHAT ARE THE CHALLENGES?

In the United States, if one compares resource data from one National Forest to another, there are differences in the information available even where biological, physical and human situations are similar (USDA Forest Service 1993a). As a result, data between adjacent units are inconsistent and incomplete. Inefficiencies and duplication abound in both sampling design and data collection activities. Some inventories are not well focused on answering critical questions and meeting critical modern objectives. Inventory data are being used inappropriately to answer questions they were not designed to address. Some key areas are being ignored while reams of information are collected to answer questions that are no longer relevant or have lowered priorities. Much data are collected but never analysed.

In a recent survey, the USDA Forest Service (USFS) identified three resource inventory problem areas – these included the individual, the organizations, and current inventory designs (Lund 1995). Table 1-2 shows the advantages, challenges and recommendations for changes in developing MRIs based upon our questionnaire survey and literature review. These echo some of the USFS findings. Underlying themes generic to the challenges are people's attitudes, perceptions, and willingness to work together.

1.6.1 Individuals

Most of this section comes down to a willingness of people to learn or change and not being afraid to take risks. Some of the factors that may influence an individual's willingness to take part in an MRI include:

- *Recognition* – One of the challenges is to have people recognise the value of and know how to properly use information they could get from an MRI. If people do not have the desire or ability to use the information, this is little incentive for input into designing the inventory. It often is easier to continue in current ways (for example, to not have time to learn anything new) than attempt to change. People must be willing to change.

- *Personalities* – Many natural resource specialists are independent and may have trouble working as team players. An MRI requires team work.

- *Functionalism* – Many specialists are suspicious of other disciplines. For example, some environmentalists may oppose foresters collecting data on wilderness areas because they may assume foresters are looking at ways of converting the lands to timber production. Industry and private groups may be afraid that data collected on rare and endangered species may lead to restrictions on the use of the land. Functionalism also leads to a failure to consult other specialists about their areas of expertise. Failure to do so may result in reinventing the wheel by ignoring the collective experience.

- *Knowledge* – Some functional experts may declare knowledge or express demands on what and how to inventory but have no experience in doing the inventory work. This may lead to unrealistic expectations, inapplicable results, and frustration with those that bring up sampling difficulties or budget realities.

Table 1-2: **Advantages, challenges, and recommended changes for MRIs based upon the MRI questionnaire survey and literature review (Lund 1997b).**

MRI country	Scope	MRI type	MRI advantages	MRI challenges	Recommended changes	Source
Australia	Province State	Environmental	Comprehensive Regional Assessment (CRA) provides multiple assessment results at a given point in time	Cost and time - 9 months for CRAs, scale		Rumba 1997
Austria	National	Environmental	Data reliability, data acceptance			Schieler 1997
Belgium	Province State	Environmental	Easy to implement, able to give tendencies	Lack wildlife diversity information, too superficial for some studies, lack of precision on some estimates, grid does not show fragmentation	Use of remote sensing. Conduct studies to link stands with richness in plant and animal species	Rondeux 1997
France	National	Environmental	Vegetation types and forest stands are mapped complete forest mensuration data base	Costs of aerial photos and field measurements	Use of satellite imagery	Valdenaire 1997
Germany	National	Environmental	Ability to make repeated measurements			Schmitz 1997
Guinea	National	Ecological	Knowledge of spatial distribution and inter-relations, information on anthropic and natural phenomena impacts on ecosystems, prevention of land miss-management risks.	Material and human resources, need of time and funds, need for a co-ordinator and dedicated team		Goussard 1997
Israel	Local	Multi-sector	Increased speed	Inaccurate mapping, lack of yield tables, insufficient use of results	Improving and updating maps, training of managers in the survey and use of its results.	Sachs 1997
Italy	National	User	Precision of data and Low costs	Memory of citizens and rate of reply, timing of surveys	Simplify questionnaire	Tosi 1997
Malaysia	National	Multi-product	Provided the necessary information	None	Need to recognise international commitments	Yaun 1997
Mali	National	Environmental		Getting imagery of proper dates on a timely basis		Treadwell and Buursink 1981

Table 1-2: Advantages, challenges, and recommended changes for MRIs based upon the MRI questionnaire survey and literature review (Lund 1997b).

MRI country	Scope	MRI type	MRI advantages	MRI challenges	Recommended changes	Source
Mexico	National	Multi-product	Provides the necessary information	Costs and lack of infrastructure	Get private organizations involved, develop international standards	Varela-Hernandez 1997
Morocco	National	Ecological		Costs and human resources	Establish a continuous inventory project and establish a permanent infrastructure	Kerrouani 1997
Nepal	National	Multi-product	Limited amount of field work	Rough terrain		Pikkarainen 1997
Norway	National	Ecological	Give overview of landscape types	Time in map preparation		Elgersma 1997
Norway	National	Multi-product	Long tradition and established inventory	Lack of adequate indicators		Tomter 1997
Peru	Province State	Ecological	Knowledge of spatial distribution and inter-relations, information on anthropic and natural phenomena impacts on ecosystems, prevention of land miss-management risks.	Material and human resources, need of time and funds, need for a co-ordinator and dedicated team		Goussard 1997
Philippines	Local	Ecological		Shortage of skilled people	Use partnerships	Rosario 1996
Rwanda	Local	Multi-product	Spatial knowledge of resources, information on impacts, prevention of land miss-management	Time, funds, need of passionate team and a co-ordinator with wide knowledge	Do data verification as often as possible	Mushinzimana 1997
Slovenia	National	Environmental	Objective method for assessing goal variables, repeatability, estimation of sampling errors, control of set goals.	Budget, skilled staff	Provide a guaranteed budget, establish a permanent staff, provide independent control over data.	Kovac1997
South Africa	Local	Multi-sector	Provides control over data in a holistic way	Adequate sample sizes, use of remote sensing	Centralise efforts for data standards for collection and analysis. Develop technology	du Plessis 1997
South Africa	Local	Multi-product	Provides relatively accurate estimates of volumes to be harvested.	Tedious, expensive to perform on large scale, variations on individual areas can be large.	Investigate alternative technologies.	Hattingh 1997
South Africa	Local	Multi-product	Growing species in appropriate situations regarding growth and yield requirements.	Due to spirit and agreement of co-operators, most obstacles are behind us. Problems remaining are validating and converting		Morley 1997

Table 1-2: **Advantages, challenges, and recommended changes for MRIs based upon the MRI questionnaire survey and literature review (Lund 1997b).**

MRI country	Scope	MRI type	MRI advantages	MRI challenges	Recommended changes	Source
				historical data to required standards and formats.		
Spain	Province State	Multi-product	Provides sound data	Cost of field samples and lab work		Garcia-Guemes 1997
Sudan	Province State	Multi-sector		Costs		Obeid and Hassan 1992
Sweden	National	Ecological	Good basis for decisions and for education	Date of imagery, lack of indicators, funding	Start small and test methods	Rudqvist 1997
Sweden	Province State	Ecological	Provides new information			Noren 1997
Sweden	Province State	Multi-sector	Balance point between reindeer herding and forestry	Costs, multitude of GIS	Get one GIS	Persson 1997
Switzerland	National	Environmental	Simple and flexible design, open for following inventories.	Problems with cumbersome data base	Higher computer performance	Brassel 1997
Tanzania	Province State	Multi-sector		Accessibility in Rainy season		Haule 1997
Turkey	National	Multi-sector			The intensity may be reduced in areas of homogenous forests	Caliskan 1997
Uganda	National	Multi-product			Obtain GPS units for plot location and the use of stratification in sample selection	Hedberg 1993
United Kingdom	National	Environmental	Provides a digital map of woodlands > 2 ha	Access to private lands		Dewar 1997
United States	Local	Ecological		Seasonality	Get more collaborators	Fimbel 1997, Fimbel and Fimbel 1997
United States	National	Multi-product	Systematic spatial arrangement of samples allows analysis of multiple scales and variable boundaries.			Smith 1997
Zimbabwe	Local	Multi-product	Maximises information collected with minimum field effort and consistency of data base	Incorporation of non-woody products		Mkosana 1997

- *Tradition* – Tradition is the one of the biggest reasons for insufficient co-ordination. Some methods and terms in use functionally by various groups within an organization may not have changed since their inception. There is general unwillingness by leaders and resource specialists to change definitions, standards, or procedures when it will disrupt the ability to analyse trends.

- *Perception* – Perception of priority shifts from one resource to maintaining other resources on an equal priority is a concern. An example is an increased emphasis on watershed management in an area once managed primarily for timber production. Such a change may seem a threat to the manager rather than an improvement of the resources that were previously dominant.

- *Fear* – Fear of losing control over a project by letting other resource sectors or specialists gather data. Getting all resource specialists to feel ownership in the process may be difficult.

- *Communication* – The use of unfamiliar terms and definitions can be an obstacle to communication. It may prohibit the sharing of data, informing others what the information provides, and clearly communicating the types of data they gather and how one uses it in analyses.

- *Skills* – Lack of interdisciplinary or multiple resource inventory skills is another concern. Individuals are normally trained in one or two disciplines, not the several required of an MRI task. Where does an inventory planner find enough specialists and how do you get them to go to the field?

Leadership – Lack of initiative or someone or some group taking the lead is another problem. Overall direction may be present, but field specialists may wait for immediate supervisors to tell them to follow it. Also, there may be a reluctance by some people to follow new direction. Many people do not like direction. They prefer persuasion and to be part of the decision.

1.6.2 Organizations

Organization problems occur at two levels. First there is the organization of the design of the MRI that should be a separate but highly linked process. We discuss this later in this publication. Secondly, as we discuss here, there is the agency organization or the operation of the MRI once the design is in place. This section focuses on organizations rather than organization.

USDA Forest Service field units, a literature review, and some of the respondents to the MRI questionnaire identified the following problems relating to organizations:

- *Self-interest* – A not-invented-here syndrome may occur within groups in an organization. People ignore techniques or processes developed outside a particular group. Such a closed-shop approach fosters inbreeding and stymies innovation.

- *Benefits* – Lack of trust in imported or introduced methods, techniques, and technologies where previous interventions have led to little or no benefit to local people or institutions.

- *Fear* – Agencies that historically have had a single goal may have difficulty changing direction because of past successes and fears of future changes. Associated with this is the fear of implications of issuing new direction. If decision-makers issue new direction, such as consolidating inventory efforts, then they need to fund, implement and enforce the direction. If the agency does not take any of the above actions, then the courts may challenge the agency for not following its own policies. On the other hand if an agency implements the direction, courts may challenge the direction, but not the data.

- *Focus* – Poor understanding and no consensus on the priority questions requiring answers is another concern. These questions form the objectives for databases, inventory, classification, mapping, and monitoring. Without clearly articulated goals, it is nearly impossible to develop appropriate sampling designs, etc.

- *Communication* – Poor co-ordination or communication between organizations, organizational levels, and administrative units is another issue. This includes differences in perceived priorities between the headquarters and the field units, headquarters and other organizations, etc. The information that people need to share and mutually agree upon includes objectives for the inventory, roles partners will play, goods and services partners will provide, etc.

- *Support* – Lack of support from within the agency for adequate time and money to do the job. Focus on immediate outputs adds pressure to developing the best survey methodology. It takes time to make changes from a single inventory to a multipurpose resource inventory. Decision-makers may have a feeling that it takes more time to think through and develop a new process rather than just following the "old way" of doing business. Consequently they may not be willing to support the new initiative.

- *Priorities* – Functional budgeting, attitudes, and approaches are other problem areas. In some organizations, one may only have sufficient funds to inventory the timber resource. For example, 'timber dollars' may not be appropriate or appropriated to conduct vascular plant and soil inventories while collecting the overstory data. On the other hand, potential funding and interest by other disciplines, may be low when the inventory only addresses timber production. Other agency interests and priorities result in lack of true commitment in funding and completion of the project. These characteristics hamper appropriate resolution of the problems. They increase in severity in times of budget stress.
- *Structure* – The placement of inventory specialists in separate staff units (for example inventory specialists in a timber staff, wildlife staff, etc.) for inventorying natural resource basic data, presents real and perceived obstacles to integrated inventories, data collection, and information management.

- *Co-ordination* – Lack of a strategic and co-ordinated inventory plan, a process to implement the plan, and a system of checks and balances to ensure the plan is going as envisioned are additional issues. Management does not recognise planning as something that it must do.

- *Power* – Lack of an organization to enforce direction once it makes a decision is another problem. An agency or staff develops a plan, but not all parties follow. Consequently pieces of the inventory are missing or incomplete.

1.6.3 Design

We noted the following comments regarding the design of MRIs in the context of ecosystem management. The design of an MRI must account for these different needs of the individual resources. It may be possible to accommodate these differences within the design (such as same sampling scheme, but different plot shapes) or it may not.

- *Focus* – Most inventory efforts concentrate on vegetation structure and composition. The elements of system functions or processes for ecosystem management may not be present. A challenge is designing inventory systems that are dynamic so that, as the understanding of social and biological components of ecosystems develops, we will have access to the information we need. This is an extremely difficult task.

  A full assessment of forest and range ecosystems needs to take into account a number of aspects of the ecosystems. These include (Innes 1995):
  - the hierarchical nature of ecosystems within the landscape
  - the need for highly specialised staff to undertake modular assessments
  - the absence of any steady state within the ecosystems, regardless of the scale of the assessments.

  Bailey *et al.* (1994) and Meidinger *et al.* (1996) provide instructions on how to map ecosystems.

- *Needs* – Designs that emphasise one need and accommodate other needs by add-on-type inventories may not work for all add-on resources. For example, timber has driven the inventory process for most of the USDA Forest Service. Timber surveys make use of aerial photography. An inventory planner logically selects photographs that emphasise the timber resource. Foresters select a colour and tone on the photographs for tree species identification. He or she also selects a timing of the photo flights and a scale to provide optimum contrast for tree identification. Other resources may have needs for different kinds of imagery at different scales, at different times of the year, and using different parts of the spectrum.

  Available timber information may not be suited for a particular use, such as for a goshawk habitat survey. The existing information can cause the specialist to go to the wrong places, reach the wrong conclusions, and waste time. Decision-makers may find that the standard timber inventory does not provide information they need for environmental assessments. For a more comprehensive assessment, the inventory designer has to increase the scope of most forest inventories to include additional variables. In many cases, the inventory planner may have to change the design of the inventory because the assessment of non-timber functions and environmental variables may require statistical alternatives (Pelz 1995). On the other hand, the cost of abandoning information or converting the existing information is often enough to tempt agency managers to say no to the new design.

- *Scale* – The spatial and temporal scale of single-purpose inventories often are perceived as obstacles to integration of other inventories collected at other scales. Most inventories vary by the resource of interest, the home range (geographic scale) and the life-span (temporal scale) of the organism(s) in question (Pelz 1995, Rudis 1993a, b). Wood volume inventories may be sampled year-round and used address state and national data needs. Faunal inventories may be sampled over several years and focused on a local watershed. Recreation inventories are very site-specific and focus more on users than the physical resource. Inventories of fruit production and herbaceous species may require wildlife exclusion sites (deer enclosures) and specific seasons.

- *Measurements* – Inappropriate or invalid measures are also problems. Wildlife resource assessments, for example, may require a census of animals to be accepted as valid correlates – not just their habitat. Measurement of a location's suitability for timber growth, wildlife, or forest recreation activities does not always correlate with use or production. Much depends upon factors outside the inventoried sampling frame, such as economics, wildlife population dynamics, and nearby recreation opportunities (such as a Disneyland theme park).

- *Geo-referencing* – Lack of spatial or geographic linkages is a concern. If one cannot link resource characteristics to geographic locations then it is not possible to assess the degree to which any one resource affects, or is affected by, other resources. One may not be able to consider the extremely important management costs linked to location. Resource data that are not location specific will only support a coarse level management plan (such as at a provincial or state level but not at a forest stand or pasture level).

- *Standards* – Lack of standard definitions and objectives is another issue. There may be both common and dissimilar attributes collected by each sector. Where methods are different, surveys may not be compatible and analysts may not be able to group data or results together. In addition, there may not be a uniform understanding within and among all partners of the distinction between classification development, and mapping and inventory and the processes one uses to produce each. These misunderstandings prohibit effective communication and resolution development.

- *Testing* – Failure to test the system adequately before implementing is also a problem. One may design an ideal system from a scientific perspective only to have it fail because of some logistical aspect.

1.7 HOW TO MEET THE CHALLENGES?

One can easily advocate multiple objective inventories, but they can be quite difficult and expensive to implement (Temu 1991). MRIs are complex in scope and nature (Rosario 1996; Villanueva 1996). The question on which resource(s) to base the sampling design and specifications can be problematic. The related issues of costs, field crew overload, and data quality become much more serious in MRI (Revilla 1996). In addition, one has to adopt appropriate models and to estimate detection probabilities. These depend very much on training status and experience of the responsible crew member (Kleinn 1996).

In spite of the challenges, properly designed and executed, multipurpose resource or integrated inventories are technically, quantitatively, and qualitatively sound and environmentally oriented. MRIs make optimum use of available expertise and ensure multipurpose resource appreciation (Rosario 1996; Villanueva 1996). An agency or organization may most easily implement an MRI where there is no entrenched bureaucracy defending an established way of data collection and inventory.

Developing a multipurpose resource inventory protocol or set of procedures involves many steps. The effort requires careful planning and execution. Inefficient planning results in increased costs and inefficient use of time and personnel. If one does not have time to do the job right the first time, will there be time to do it over?

☺ Remember the five P's – Proper Planning Prevents Poor Performance!

2 HOW TO DEVELOP AND IMPLEMENT AN EFFECTIVE MRI

Figure 2-1 outlines the steps for developing and implementing an MRI. Note actions one and two may be carried out simultaneously. Similarly, steps five and six may be done a the same time. Documentation (and testing) should occur through all steps.

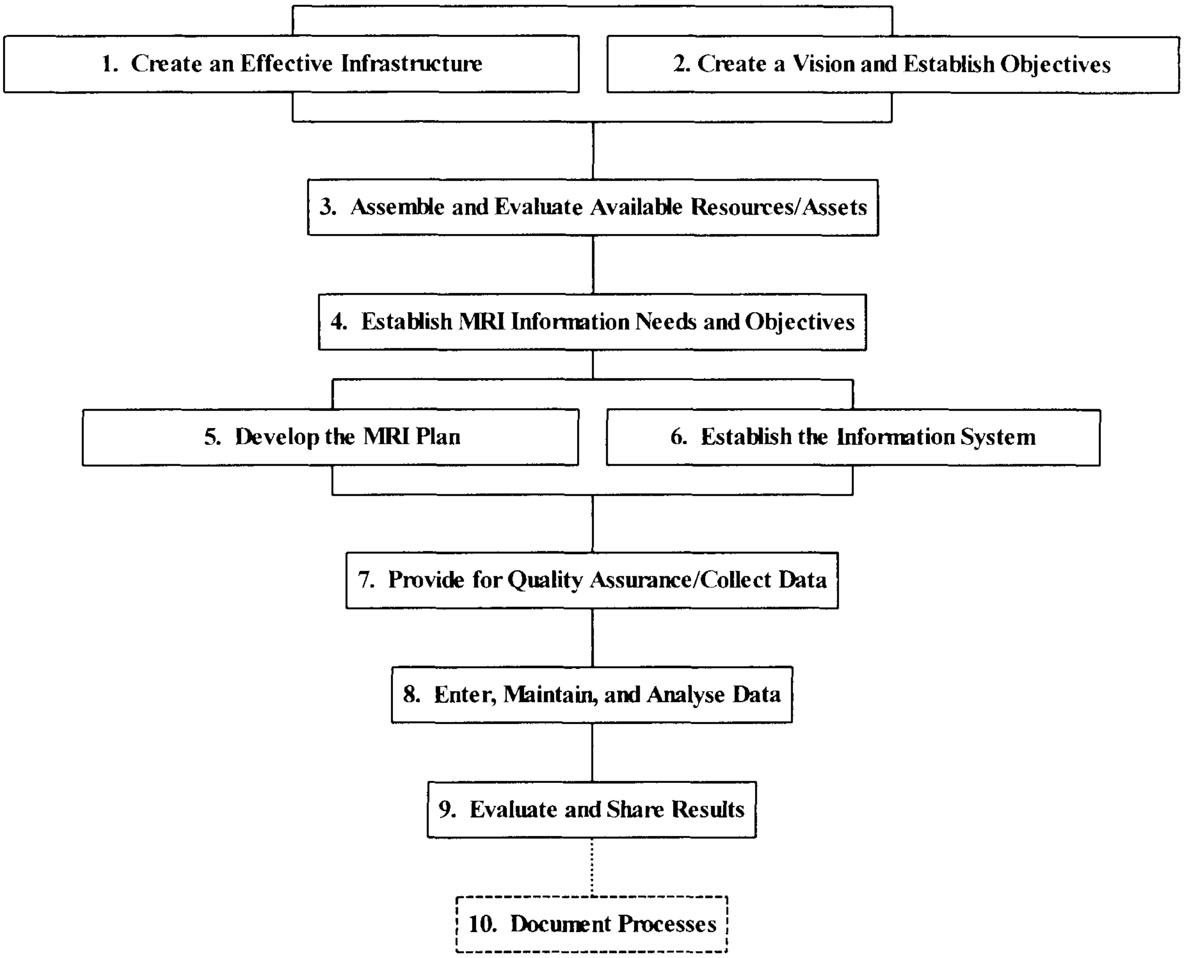

Figure 2-1: Steps in implementing an MRI.

Steps two and four are similar in that they both develop objectives. The objectives for step two is the establishment of a corporate database. The objective of step four is the objective of the inventory per se. The following provide detailed discussions of each step.

2.1 CREATE AN EFFECTIVE INFRASTRUCTURE

The greatest single challenge for effective implementation of a multiple purpose database and developing MRIs is addressing past physical and political separation of data gathering activities and fostering co-operation between institutions, groups and individuals to get comprehensive and accessible information (Baum and Tolbert

1985). Co-ordinating inventories that fall under the jurisdiction of one ministry or agency are easier to co-ordinate than those that fall under several ministries. Of all the countries responding to our MRI questionnaire, only Norway has consolidated most of its inventory responsibilities under one ministry (NIJOS n.d.). The Province of British Columbia is working towards consolidation through a Resource Inventory Committee (Omule *et al.* 1996).

There are many cases, world-wide, of territorial boundaries created and maintained at the expense of information system development. For example, organizations such as a country's Ministry of Agriculture (MOA) and National Statistics Office (NSO), frequently generate competing data, and spend considerable time debating which institute has the superior data and methodology. The NSO typically has prominent capabilities in survey design and data collection, whereas the MOA frequently is the country's main data user.

2.1.1 Consolidate Efforts

In a large organization, the most efficient way to co-ordinate and integrate data and data collection is to centralise the efforts. Restructuring an organization to include sector inventory specialists (for example, timber, fish, wildlife, soil, water, and ecology) under one staff group reduces functionalism. It also allows cross-walking data analysis needs, promotes consistency of timing and designs, optimises "integrated" budget development opportunities, promotes overall consistency, and reduces duplication of efforts via closer day to day contact related to inventory and mapping programs.

There should also be a central control centre and procedure for development and maintenance of definitions and standards within the agency. This centre should have responsibility for co-ordination outside the organization. Direction must come from a neutral, but knowledgeable source. Leadership by traditionally functional organizations and individuals defeats the purpose of integrated standards. A separate data management authority, one that is not beneath any one particular group or sector, may be necessary. This group will be more objective and will not be subject to the whims or desires of any one department or user group. The data administrator should be on the same footing as the line managers, providing the organization with the necessary support and authority.

Clearly assign responsibility for data administration, including how to address and implement proposed changes in data structures, definitions, and codes. Encourage the use of a corporate information system and sharable data collection and storage.

Establish a well-defined review process for new terms and to change definitions of old terms. Develop a well-defined process for submitting comments and changes regarding standardised terms and definitions. The process must clearly be one of facilitation, rather than dictation. It must follow a prescribed process to solicit input from all potential users of the data. During changes or the development of new databases, keep both models operational.

> ☹ Keep in mind, however, that in centralisation, some specialists and staffs may view their jobs as threatened. Management needs to address these concerns. In addition, centralisation may decrease innovation in data collection technology.

The Administering Unit should:

- Co-ordinate interagency or intersector standardisation of land and resource inventories.
- Strengthen information, systematic observation, and assessment systems for environmental, economic, and social data related to the various resources at the global, regional, national and local levels.
- Harmonise the methodologies for programs involving data and information activities to ensure accuracy and consistency. Use compatible standards and systems.
- Gather multi-sectorial information (forest, range, agriculture, wildlife, soils, water, etc.) and integrate the data

from these sectors with adjacent areas. Develop integrated information systems for environmental monitoring, accounting and impact assessment

- Develop and maintain a catalogue of inventories done within the region and evaluate the effectiveness of each inventory. Develop a bibliography on the content and description of existing inventories within the region.

- Develop a data dictionary and a list of variable descriptions that will document the content and descriptions of all inventories of lands and renewable resources within the inventory unit

- Establish goals and accuracy standards for the inventories conducted by the organization.

- Ensure that the standards and rules for resource inventory are uniformly and correctly applied.

- Co-ordinate MRI planning and data collection activities. Avoid duplication of data collection and ensure the use of the most efficient inventory designs to meet management objectives. Develop linkages between inventories used for international and national assessments, state and provincial needs, and for local planning.

- Define boundaries of inventory units.

- Develop an inventory schedule for each inventory unit

- Involve the local population in the information needs assessment, data collection process, and in the analyses as appropriate. This may be in the form of planning the MRI, serving on field crews, providing logistical support, and analysing the results. Participatory inventories are a growing area of interest, particularly at the small-scale community level (Carter 1996).

- Co-ordinate and review quality control of ongoing inventories.

- Maintain current inventories and periodically evaluate existing results for validity.

- Establish and maintain required assessment databases.

- Improve public access to information. Promote sharing of information and technology between co-operators. Provide reliable data and information with relevant international and national organizations to improve data and information exchange.

☺ Each contributor to the MRI effort must be a partner in the data collection effort, benefit from the activity, and share in the credit for its completion. See Lund (1987 and 1995).

☺ One typically implements MRIs with greatestease in organizations and countries that have yet to develop a comprehensive information system. The goal, in such a case, is to change the fragmented system to co-ordinate multi-variable databases that are mutually supportive of all information userswithout duplication.

2.1.2 Build a Team

Table 2-1 shows the various groups involved in developing MRIs based upon our questionnaire survey and literature review. Note that most MRIs involve a variety of organizations and disciplines and use a team approach for making decisions.

This section discusses the procedure for getting a multidisciplinary team together. An organization can use such a team to identify information needs, develop data standards, create MRI plans, build information management systems and to analyse and report the results. In fact an organization may use a different team to carry out each of these tasks.
An interdisciplinary team translates the vision and objectives into an MRI program. Multipurpose resource inventories require multiple approaches, input from other disciplines, and an atmosphere of trust and

partnerships. Inventories linking socio-economic and ethno-botanical surveys with other resource needs are very complex and require the services of social scientists (Figure 2-2). The need and motivation of various specialists are key to developing a team. Have professionals from all appropriate disciplines represented on the team. Case examples 3.1, 3.2, 3.4, and 3-5 in Chapter 3 provide examples of interdisciplinary teams.

Data users are becoming more sophisticated. Most data users want data analysis of the data to provide possible outcomes of alternative choices. The majority of data is not as helpful as the analysis that provides information for alternative decisions and possible impacts on resource management. Wigton (1997b) reports that in an agricultural information needs assessment of some 19 institutions, there were 113 information needs identified. Of there 113 requirements, there were only four that did not require an analysis of the raw data. The remaining 109 data requirements needed some type of analysis in order for the decision makers to interpret data for applications in decision-making. Therefore, the data analysts must be members of the team. They must take part in the decision- making process. The analyst will be crucial in the process of linking the inventory information to cost effective land management programs.

Benedict *et al.* (1992) list the following skills a team needs for successful participation in partnerships:

- Communication skills
- Capacity to identify common affinities
- Ability to analyse common problems
- Capacity to accept different points of view
- Mediation and negotiation skills
- Capacity to develop and gain trust
- Honesty, openness, and fairness
- Basic administration skills
- Lobbying skills
- Basic understanding of organization structures
- Good training and education

Figure 2-2: Co-ordination meeting between foresters and socio-economists in the development of an MRI in Sudan. See Chapter 3.4.

Table 2-1: Groups involved, leaders, and decision process for various MRIs based upon MRI questionnaire survey and literature review (Lund 1997b).

MRI country	Groups involved	Leader	Decision process	Source
Australia	Technical Committees - State and Commonwealth	Jointly develop Assessment methodology	By consensus of technical committee and if necessary refer to steering committee (state and commonwealth) for decisions. Some regions/state have stakeholder input representation. Most of the following applied depending on the agreement.	Rumba 1997
Austria	Federal Forest Research Centre/Institute of Forest Inventory and Federal Ministry of Agriculture and Forestry			Schieler 1997
Belgium	University of Gembloux, Ministere de la Region Wallonne	Division Nature et Forets		Rondeux 1997
Canada	SRK-Robinson, MacMillan Bloedel Company			Rennie 1997
Denmark	National Environmental Research Institute, University of Aarhus, Centre for Forest and Landscape Research	Co-ordination Board	Annual meeting	Skov 1997
France	French Ministry of Agriculture which provides funds to the French National Inventory (IFN)	French Ministry of Agriculture	An administrative committee manages the IFN aided by a manager and technical manager	Valdemire 1997
Germany		Forest Department	After discussions with agreement	Schmitz 1997
Guinea	Ecologists, foresters, pedologists, hydrologists, geologists, botanists and economists from national and international groups.	Ministry of Agriculture and EU	Results examination and discussions	Goussard 1997a
Israel	Forest Resource Dept. with 2 subdepartments - Forest Information Management and Forest Engineering	Forest Information Management Section	Specially appointed design team	Sachs 1997
Italy			Brainstorming	Tosi 1997
Malawi	Ministry of Agriculture, Land Resources and Conservation Branch, Ministry of Research & Environmental Affairs, Ministry of Lands and Resources, Department of Natural Resources			Wigton 1997a
Malaysia	Forestry Dept. Peninsular Malaysia with assistance from FAO		Discussions and cross reference with officers from Forest Research Inst. of Malaysia	Yuan 1997
Mexico	Secretaria de Agriculturea, Ganaderia y Desarrollo rural, Unidad del Invtario Nacional de recursos Naturales, Comision Nacional del Agua, Comision Nacional para el Concimiento y Uso de la Biodiversidad, Insitutto Nacional de Ecologica., Inventario Naciona	Subsecertario de Recursos Naturales		Varela-Hernandez 1997

Table 2-1: Groups involved, leaders, and decision process for various MRIs based upon MRI questionnaire survey and literature review (Lund 1997b).

MRI country	Groups involved	Leader	Decision process	Source
Morocco	Service de l'Inventaire Forestier National, Serves des Amenagements de Forets et de Bassins Versants (Par region)		Comite Consultatif des Amenagements	Kerrouani 1997
Nepal	Local population with technical assistance from development agencies			Jordan 1997
Nepal	Forest Survey Division, FORESC, HTIGN			Pikkarainen 1997
Norway	Norwegian Institute for Land Inventory	Ministry of Agriculture		Dramstad 1997
Norway	Botanist, Landscape architect, geologist, GIS people	Geologist	In plenum	Elgersma 1997
Norway	Foresters, Biologists	Head of Department	Group discussions	Tomter 1997b
Peru	Instituto National d'Investigation in Ecologia Andina, ecologists, pedologists, hydrologists, geologist, botanists and economists from national and international institutes.	Ministry of Fishing and Agriculture, and E.U.	Results examination and discussions	Goussard 1997b
Philippines	Silviculturalist, soil technologist, wildlife biologist and sociologist.			Rosario 1996
Russian Federation	Forest inventory and planning enterprises	Head of Forest Inventory and Planning Dept.,	Following official instructions and orders of the Federal Forest Service	Filiptchouk 1997
Rwanda	Resource specialists, Univeriste Nationale du Rwanda, Ministry of Agriculture, and others	Ministry of Agriculture and World Bank	Results examination, consultation, experience, field team validation	Mushinzimana 1997
Slovenia	Slovenian Forest Service	Slovenial Forest Service	Reached through forest management planning	Kovac 1997
South Africa	Institute for Natural Resources, Institute for Commercial Forestry Research, Agricultural Research Council, National Water Forum. Mensuration and Modelling Research Consortium (MMRRC).	Technical Services Dept. and Environmental Dept.	Through research and consensus	du Plessis 1997
South Africa	Mensuration and Modelling Research Consortium (MMRC).	Industry through Consortium	Through consensus	Hattingh 1997
South Africa	Technical Working Groups of the Mensuration and Modelling Consortuim (MMRC).	MMRC	By consensus through consideration of growth and yield modelling requirements and their associated practical and financial requirements.	Morley 1997
Spain	Dept. of Silviculture and Forestry Genetics of CIFOR-INIA	Head of Department	Group discussions	Garcia-Guemes 1997
Sudan	Forest National Corporation, Survey	Forest National Corporation	Consensus with verification a local level	Obeid and

Table 2-1: Groups involved, leaders, and decision process for various MRIs based upon MRI questionnaire survey and literature review (Lund 1997b).

MRI country	Groups involved	Leader	Decision process	Source
	Department, Min. of Agriculture, Donors			Hassan 1992
Sweden	County Boards of Forestry	National Board of Forestry		Rudqvist 1997
Sweden	Swedish Forestry Administration, Biologists, Researchers, NGOs, Threatened Species Unit, Environmental Protection Agency	National Board of Forestry		Noren 1997
Sweden	Employees from the Forestry Companies, Sami villagers			Persson 1997re
Switzerland	WSL	Federal Agency for Environment, Forest & Landscape	Discussion and decision in Task Force	Brassel 1997
Tanzania	Forest Division	Forest Division		Haule 1997
Turkey	Forest Management Teams, Forest Engineers	Senior Forest Engineer	Group contribution	Caliskan 1997
Uganda	Forest Department, Surveying and Mapping Dept., Statistics Dept., Min. of Energy?	Forestry Dept.		Hedberg 1993
United Kingdom	Forestry Commission Staff, Dept. of Agriculture - Northern Ireland	Forestry Commission		Dewar 1997
United States	Federal and State agencies at State level	Regional Program Managers		Smith 1997
Zimbabwe	Foresters, Taxonomists, Design Consultants, Donors, Clients.		Consultative efforts	Mkosana 1997

Williams and Ellefson (1997) conducted a survey of some 40 partnerships involved in landscape management to find out what motivates and deters people working together. Benedict *et al.* (1992) list instruments for success. As Table 2-2 shows, these results also apply to teams developing MRIs.

Table 2-2: Motivations, barriers, and instruments for successful partnerships (Williams and Ellefson 1997, Benedict *et al.* 1992).

Motivations for Joining Partnerships	Barriers Inhibiting Membership	Instruments for Success
Improving stewardship of resources	Limited amount of time to actively participate	Defined alliances
Sharing or receiving others information	Indifference to the issues	Defined common objectives
Inhibiting expansion of government activities	Inadequate assets (personal and organization) to support involvement	Surveys of existing data
Influencing partnership actions	Apprehensions and misgivings from past deals	Defined problems to be resolved
Improving overall relationships	Fear of losing control over land use and management decisions	Defined means of publicity and developed public awareness
Enhancing economic development	Antigovernment sentiments	Information on available expertise and assets
Obtaining assistance and incentives	Dislike or antagonisms toward some participants	Written co-operatives or agreements
Monitoring activities in general	Potential financial losses for participating	
Preventing financial losses		
Interacting with important leaders		

To be politically successful, "co-ordinated" is the key word. It is possible that co-ordination is simply getting the appropriate parties together. However, the team must also co-ordinate the planning, design, and development of the resource databases. All interested user groups must have the opportunity to provide input into the process and have their needs heard and addressed. The end-users (field foresters, range managers, agriculturists, wildlife biologists, resource specialists, etc.) must have ownership(involvement) in the MRI design process.

It is important to get all the necessary people involved early and working as a team. The task of the team is to establish common linkages such as standard definitions, methods for measuring the common elements, and units of measure. The team should also establish a common process for geographically registering and storing the MRI data and a common process for managing the data.

Seek team members that are knowledgeable, have authority to make changes, and are willing to make the necessary changes to carry out their charges. Each function must be willing to give up "ownership" of its data and share the data management and collection duties with others. In addition, seek team members that will with the job until the task is completed. Educating new members slows the progress. However, for sustaining the long drawn management function, new members could be enrolled. Therefore, timely provision for such members of the team, their training, education for better understanding, and inculcating interest and sense of participation should be made simultaneously right from the step of planning. It is seen important for the uninterrupted continuation of the task. Where skills are lacking, provide additional training or consider contracting.

2.1.3 Define Responsibilities and Obligations

One of the first tasks is to identify the team leader. Benedict *et al.* (1992) recommend to:

- Watch people under stress, check them out for leadership abilities
- Check for an individual's experience in other programs
- Allow active, adaptive, flexible leaders to emerge
- Make use of community leaders
- Use existing traditional leaders

Three key items that the team needs to resolve are:

- Who is responsible for what?
- Who has the final say in any decisions or changes that need to be made?
- Who will have access to the final results of the MRI?

A crucial element in setting up a cross-departmental or sectorial team is a decision about who has the final responsibility for ensuring that a good product is produced, and who is responsible for covering which costs (e.g. actual staff time, field equipment and transport, database maintenance, map and report production, etc.). It may be that all parties involved contribute in advance to a fixed budget to which the MRI team has to work, or that they agree to some mechanism to cover the eventuality that some or all parts of the MRI may cost more than foreseen.

Clearly describe the responsibility for all phases of the MRI. All partners should not only share in the design and resulting data, but should also shoulder part of the burden and costs of actually collecting the data. Partnerships should provide mutually beneficial collaboration on a practical level. Start informally at first and work up to more formal links as necessary. Starting with formal agreements first may lead to turf wars, bureaucratic delays, and numerous meetings of representatives producing reports which appear to be the only net result (Hedberg 1993).

Equally important is a clear understanding of who will have access to what information, at what costs, and in what form once the MRI is complete. One may expect that most MRI data would end up in the public domain, but this may not be the case. In addition some people may not wish to share the data for fear of exploitation of the resources. Others may fear the imposition of regulations on how they may use the lands and resources. Discussing and resolving these issues early in the planning phases will help to avoid problems later.

2.1.4 Work Together

Effective team work involves the ability to understand what may otherwise hamper co-operation and then taking steps to make work flow smoothly.

2.1.4.1 Form Successful Partnerships

Williams and Ellefson (1997) report on threats to continued collaboration and the attributes for successful partnerships (Table 2-3).

Table 2-3: Threats to and conditions for continuing partnerships (Williams and Ellefson 1997)

Threats	**Conditions Contributing to Success**
Lack of financial and related assets to implement or complete agreed upon plans	Recognition of common goals
Lack of assets to support continuing involvement of individual members	Mutual respect for interests and goals of partners
Interest and goals of partnerships and individual members in conflict	Willingness to openly share information
Lack of funds to organise and carry out necessary meetings	Informal and open structure for partnership operations
Difficulty co-ordinating the activities of participating organizations	Partnership viewed as a leader in the field or community
Lack of member agreement on mission, plans, and schedules	Participants' willingness to negotiate and compromise
Lack of benefits clearly attributed to partnership	Ability of partnership to adapt to new challenges
Personal antagonism between members and organizations	Facilitation by outside neutral party
Lack of authority to implement agreed-to plans and programs	Decisions based on partnership consensus
Interference and bureaucratic approach	Nature of participants' personalities
Lack of interest of the sponsors	Personal friendships of participants outside the partnership

2.1.4.2 Find Common Ground

First and foremost, learn the names, backgrounds, interests, and needs of the people with whom you will be working (Shopland 1992). Benedict *et al.* (1992) recommend the following:

- Identify objectives clearly
    - Study the situation carefully
    - Define all objectives
    - Rank objectives (draft a clear statement of principles)
    - Develop a mission statement that
    - everyone agrees to
    - Prepare a pert chart between objectives and time-frame, time-frame and staffing needs, time-frame and financial power
    - Make sure the objectives are reasonable and feasible
    - Fix the priorities
- Seek common interests
    - Negotiate
    - Delegate responsibilities
    - Determine common goals
    - Set aside issues not pertinent to task at hand
    - Set priorities in interests to be discussed
    - Encourage all parties (maintain a positive attitude)
    - Be willing to compromise
    - Be helpful
    - Educate all parties about the common goal
- Resolve personality problems
    - Develop tolerance and create social interaction
    - Develop a feedback system
    - Create conditions for negotiation
    - Develop team leadership
    - Identify common issues
    - Stick to science
    - Maximise and recognise strengths in diversity
    - Plan numerous social as well as business meetings and retreats
    - Use professional facilitators
- Build up the team's scientific knowledge
    - Educate members

- Focus on training and teaching
- Share knowledge through communication
- Seek scientific advice and peer review
- Ensure long term support for continuity
- Invite experts to participate and contribute
- Synthesise knowledge on the issues
- Determine and set research priorities

- Create an atmosphere of trust
  - Maintain an open-door (transparency) policy
  - Make all information available to all parties
  - Agree that nothing is to be released to media until approved by the whole group
  - Involve everyone - everyone has a role
  - Take advantage of individual's skills, especially those with strong leadership abilities
  - Plan a group experience outside subject of interest

- Consider the politics of the MRI
  - Involve somebody from the government
  - Maintain ability to compromise and to come to a consensus
  - Include respected, objective non-political representatives
  - Have a strong legal and policy infrastructure
  - Maintain scientific objectivity
  - Make decisions which are based on proper professional ethics
  - Establish effective communications with politicians
  - Seek a champion – someone in a position of influence and authority
  - Demand a strong commitment from all participants

- Address funding early
  - Begin process with proper planning and a realistic budget
  - Ensure accountability of spending
  - Identify wealthy partners and sources of money early in the process
  - Share responsibilities for the development of activities
  - Engage in skilful smoothing
  - Develop legal arrangements which are obligatory
  - Produce an effective marketing plan and market the product effectively
  - Maintain good communication and overall good package
  - Make use of volunteers

- Keep communication effective
  - Develop an information highway through Internet, telephone, teleconferencing, fax, and mail
  - Plan numerous face to face meetings
  - Allocate travel funds to abridge gaps
  - Allocate funds for meetings and exchange of ideals and technology

2.1.4.3 Develop Team Operations

Being focused is important. By addressing a large number of needs, a group may have a large number of people involved in the process. All the team members may not be working on the same design items, but it is important that each team member be aware of the others are doing.

It is also important to have a good documentation process and to agree upon the documentation procedure in advance of designing the process. Good documentation of the process and an ongoing document of what is the MRI design will insure that the process stays on track.

☹ "All of the troubles of man are caused by one thing, which is their inability to stay quietly in a room" – Blaise Pascal.

Strive for consensus, but accept general agreements. Consensus may not be expected, nor should an inordinate amount of time be devoted to reaching it. Not everyone will agree in most cases, but yet a majority opinion must eventually be adopted to move the group forward. Dissenting opinions should not be forgotten, but should be documented, so they can be re-evaluated if the majority course of action seems to be failing and alternatives need to be explored. Some suggestions to move teams to general agreement include:

- During team meetings, have a fixed agenda which is distributed in advance. Strive for a limited number of specific decisions from each meeting and follow-up actions. Document every decision and keep files on the resolutions. Circulate minutes and frequently invite comments from the field. This strengthens the program, keeps others informed and prevents surprises, builds support for the program, and alerts those who may be on parallel tracks of opportunities to co-ordinate. Document to whom the team sends the minutes or notes, when, the comments received, and any follow-up actions taken.

- Keep the objectives of the database and MRI in mind throughout deliberations. Keep the goals in focus. Then develop the design. Do not start with the design and attempt to re-engineer the objectives. Construct the data collection system to meet the goals, even though it initially may not be the most efficient system that one may develop. Methodologies will have to evolve over time.

- Keep an open mind. What one sector thinks may be an improper method of gathering data, may be fully acceptable to other disciplines, and *vice-versa.* Design data collection methods using scientifically valid methods that are consistent with previously defined decision reliability. Recognise that the same sampling design may not work for all resources. For some, sampling may not work at all. Many disciplines may not have a feel for statistical sampling and may not be able to use it effectively. For example, soil surveys are a combination of science and art. This is acceptable to those in the soils profession. Team members need to be sensitive to the practices of others and incorporate those methods into the design.

- No single resource group, or a cabal of several, should steamroll the rest and impose their favoured techniques at the expense of others. Everyone must participate and be heard. Speak to seek - not to preach. Listen. Try to understand what others have to say. Always provide constructive feedback when requested. Say what needs to be changed and provide the new wording so there is no misinterpretation. Strive for a win-win consensus.

☺ Start simple and take small steps and implement in the same way. Work from the known to the unknown and move from what can be agreed upon to the more complex.

2.1.5 Provide Follow-up

To determine if partnerships are working (Benedict *et al.* 1992):

- Periodically check to see if the team is meeting their objectives
- Set milestones in an evaluation plan and check to see if milestones are achieved
- Build in feedback system
- Conduct periodic evaluations by peers and the public
- Synthesise information and provide it to the public
- Develop a communication plan
- Check to see if information collected is useful
- Be aware of possible drawbacks – expect the unexpected as it will occur.

2.2 CREATE A VISION AND ESTABLISH OBJECTIVES

Resource managers are finding that their information needs are dynamic. They are having to address more economic, environmental, ecological and social issues at all levels of management. They are having to take a broader and more integrated perspective of the lands and resources they manage. This is becoming more readily apparent at all levels of management. As resource managers move toward integrated issues (such as ecological classification) and a more adaptive management approach, information needs will continue to change on a regular basis.

Setting the objectives for a multipurpose database and inventory is elementary, yet essential. Each potential land use has a sphere of information the manager requires to adequately manage that land. Information overlaps among sectors, uses, or functions provide the starting point for building databases that will meet multiple purpose needs. By focusing on these points of overlap, the team creates a vision of where it wishes to head in developing multipurpose databases and inventories.

One of the key factors for setting objectives is to have some prior understanding as to how the land and resources in question may be used and developed (Nossin 1982). This will help focus the database and inventory design. Information decision-makers need to manage lands that are to serve primarily a protection function is different from that required for managing land for economic development. Both situations may require information on vegetation, but production data is more important in the latter than in the former situation.

Therefore, there must be a vision, mission, and objective regarding where the agency wants to go with resource management and the information system that will support that vision. An interdisciplinary team with representatives from concerned staffs, agencies or organizations should establish this vision. They may establish an initial vision from the top-down in the organization or from the bottom-up. In the case of the latter, the field units establish a vision based on local situations or perceptions. It is important that such a vision become an 'official' vision in place at all levels if implementation of the database and the MRI is to succeed.

Top level management should communicate its priority to those who will eventually design, use, maintain, and benefit by the integrated system. These are the ones who must understand the concept and make significant contributions to its development. Involve decision-makers and line to the point where they know what is going on. In a large organization, line officers must recognise the need for and support the allocation of resources before any attempt to co-ordinate is possible. They must get the message that the task is important, that it has priority over everyday chores, and that everyone must contribute.

In reality, the vision needs to be both top-down and bottom-up. A top-down perspective provides global and national views, while a bottom-up perspective provides the reality within which much of the MRI and resource management work gets done. Ignoring top-down issues will result in an MRI that lacks a "big picture", and ignoring bottom-up may result in an MRI that is untenable and useless – or worse, detrimental to the land managers.

There is a temptation to inventory and monitor anything and everything. Starting from stated management goals allows you to concentrate on the measurable variables that have the most significant implications for carrying out the organization's mission. If possible, include all stated goals in the MRI and monitoring program. You may also want to consider goals not stated by the management agency but also on the agenda of supporting organisations or agencies. In many cases, the information-needs assessment team gleans management goals from existing documents such as the charter, mandates, or laws that govern an organization's mission (Shopland 1992).

The decision-makers and resource managers determine the objectives for the MRI and database. The goals may be to provide basic data for agriculture, forestry, livestock, wildlife, and watershed management and to establish a system for monitoring changes in response to various land management approaches.
Broad MRI and monitoring objectives must follow from the management objectives for the inventory unit. Start by clearly identifying the major land management questions needing answers (establishing objectives), arranged

by each level of the planning process and along an ecological hierarchy. The line officer should identify and prioritise the critical questions and determine the desired information at a conceptual level.

> ☺ Start by examining the laws or charters that apply to your organization and the reports that upper management requires. This will indicate the minimum information the organization requires and generally fund.
>
> ☹ Keep in mind, however, that the laws and charters may not adequately reflect what the organization currently needs or may need for the future.

Information needs vary by scale and level of interests. The following sections lists the kinds of information today's resource manager needs – internationally, nationally and locally. MRIs help provide much of the data in an effective manner.

2.2.1 Review Global Obligations

Since 1964, the United Nations has recognised the need for integrated studies of natural resources for development and for the natural environment (Nossin 1982). The 1992 United Nations Conference on Environment and Development (UNCED) reinforced this need. Most nations are signatories of the following international agreements and conventions resulting from UNCED or are participants in global resource assessments.

UNCED Agreements – Agreements include:

- Rio Declaration on Environment and Development (Rio Declaration or RD)
- A Programme of Action for Sustainable Development for Now Into the 21st Century (Agenda 21 or A21);
- Non-Locally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests (Forestry Principles or FP).

Conventions – Conventions resulting from UNCED include:

- United Nations Convention on Biological Diversity (Convention on Biodiversity or CBD);
- United Nations Framework Convention on Climate Change – (Convention on Climate Change or FCCC);
- United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (Convention on Desertification or COD)

Assessments – In addition, many nations provide input to the Food and Agriculture Organization (FAO) of the United Nations for the following periodic global appraisals:

- Forest Resources Assessment (FRA)
- World Agriculture (WAG)

Requirements – As per the UNCED documents and resulting conventions, nations will:

- Provide reliable data and information and collaborate where necessary, with relevant international organizations, including undertaking activities to improve data and information continuously and to ensure its exchange.
- Strengthen information, systematic observation, and assessment systems for environmental, economic, and social data related to the various resources at the global, regional, national and local levels.
- Harmonise the methodologies for programs involving data and information activities to ensure accuracy and consistency. Use compatible standards and systems.
- Gather multi-sector information (forest, wildlife, soils, water, etc.) and integrate the data from these sectors with adjacent areas. Develop integrated information systems for environmental monitoring, accounting and impact assessment.

- Involve the local population in the data collection process.
- Improve public access to information.

Table 2-4 lists the lands and land types a country needs to inventory and monitor to meet the international requirements from UNCED and for Global Assessments. Grasslands and homestead lands are additional categories to consider. Table 2-5 lists the indicators a country needs to inventory and monitor to meet the international needs (Lund and Boley 1995). A 'Yes' indicates the particular international agreement or assessment requires that information. Human population is another indicator that should be added.

Table 2-4: Land and land types nations should inventory and monitor to meet international requirements[1] (Lund and Boley 1995).

Land and Land Type	A21	FP	CBD	FCCC	COD	FRA	WAG
Low Laying Coast		Yes	Yes	Yes		Yes	
Arid/Semi Arid		Yes	Yes	Yes	Yes	Yes	Yes
Wetlands		Yes	Yes			Yes	Yes
Suitable for Reforestation		Yes		Yes			
Suitable for Afforestation	Yes	Yes		Yes			
Prone to Natural Disasters	Yes			Yes			
Liable to Drought			Yes		Yes		
High Urban Pollution				Yes			
Fragile Ecosystems			Yes	Yes			
Forested	Yes	Yes	Yes	Yes		Yes	
Suitable for Timber Production						Yes	Yes
Diminished Biological Components			Yes			Yes	Yes
Significant Soil Erosion					Yes		Yes
Diminished Soil Properties					Yes		Yes
Managed for Recreation						Yes	
Plantations						Yes	
By Forest Type						Yes	
By Age Class						Yes	
By Protection Class			Yes			Yes	

1 Where: A21 = Agenda 21; FP = Forestry Principles; CBD = Convention on Biological Diversity; FCCC = Framework Convention on Climate Change; COD = Convention onDesertification; FRA = Forest Resources Assessment; and WAG =World Agriculture Assessment.

Table 2-5: Indicators nations should inventory and monitor to meet international requirements[2]

Indicators	A21	FP	CBD	FCCC	COD	FRA	WAG
Biomass	Yes			Yes		Yes	Yes
Climate	Yes			Yes	Yes		
Ecosystems and Habitats		Yes	Yes			Yes	
Emission Sources and Removals		Yes		Yes			Yes
Employment		Yes					Yes
Energy	Yes						
Forest Fragmentation			Yes			Yes	Yes
Fodder		Yes					Yes
Food	Yes	Yes					Yes
Fuel		Yes				Yes	
Land Cover	Yes		Yes	Yes	Yes	Yes	Yes
Land Degradation	Yes			Yes			Yes
Land Productivity	Yes			Yes		Yes	Yes
Land Use	Yes		Yes			Yes	Yes
Landscape Diversity			Yes				
Medicine		Yes					
Minerals	Yes						
Non-Timber Products and Removals						Yes	
Plants and Animals	Yes	Yes	Yes			Yes	Yes
Recreation		Yes					
Shelter		Yes					
Soils	Yes						Yes
Water and Water Use	Yes	Yes					
Wood Stocks		Yes				Yes	

2.2.2 Identify Regional Needs

Since UNCED, many countries have grouped together to develop criteria and indicators for sustainable forest management. These include the International Tropical Timber Organization (ITTO) Initiative, the Helsinki Process, the Montreal Process, the Tarapoto Proposal, and the United Nations Environment Programme (UNEP)/Food and Agriculture Organization (FAO) Dry Zone Africa Initiative. All have the common goal of defining sustainable forest management and the monitoring process towards it. Each initiative has developed national level criteria and indicators. These vary widely. However, the need to inventory and monitor the extent of the forestry resources, biological diversity, health and vitality, production functions, protective and development functions, and development and social needs is common to all (Granholm *et al.* 1996). These requirements extend the normal timberinventory to include new variables. Thus MRIs may be appropriate.

2.2.3 Determine National (Provincial or State) Requirements

Based on our MRI questionnaire survey and literature review, the majority of the MRIs in use are designed to provide data at the Province or National levels. By default, most international (global and regional) requirements and obligations become national requirements. One may find additional needs in the various laws regulating an agency or government. The National (Provincial or State) requirements found in various mandates and laws may affect multiple or individual agencies within a government. The economic, environmental, and social needs of the jurisdiction may drive these mandates. For example, the national requirements for the USDA Forest Service are initially given in the Renewable Resources Planning Act (RPA) of 1974 (See case study 3.1 in Chapter 3): "The data which were requested in the RPA shall include but not be limited to:

2 Where: A21 = Agenda 21; FP = Forestry Principles; CBD = Convention on Biological Diversity; FCCC = Framework Convention on Climate Change; COD = Convention onDesertification; FRA = Forest Resources Assessment; and WAG = World Agriculture Assessment.

1. An analysis of present and anticipated uses, demand for, and supply of the renewable resources of forest, range, and other associated lands with consideration of the international resource situation, and an emphasis on pertinent supply and demand and price relationship trends;

2. An inventory, based on information developed by the USFS and other Federal agencies, of present and potential renewable resources, and an evaluation of opportunities for improving their yield of tangible and intangible goods and services."

In addition to the requirement of periodic assessments, the Act directs the Secretary of Agriculture to develop a long-range plan for renewable resources that will assure an adequate supply of forest and range resources in the future while maintaining the integrity and quality of the environment.

2.2.4 Identify Local-Level Information Needs

At the local level, the locations of particular resources are crucial. Resource trends are important as well. Managers need to develop resource management plans and prescribe specific strategies for treatment of project areas. At this level, managers need to know where the resources are, what their condition is, and what their potential is under various management practices. Thus, thematic maps are important at the local level.

Decision-makers must identify the questions that need to be addressed for resource or ecosystem management, the kinds of modelling techniques, and the tools that help answer those questions. This section focuses on those questions that computerised analysis can support. The analysis questions in this report were derived from input from resource specialists, planners, and managers in the USDA Forest Service National Forest's Districts and Supervisor's Offices (Thompson 1997). The questions are not mutually exclusive, rather the analyst and decision-maker need to examine these questions as a whole, together, and interactively. Where known, we have provided examples of modelling tools that may help a person to answer the questions. These tools are further described in Appendix 2. Questions today's resource manager must answer include those concerned with history, current resource situation, management alternatives, effects of management, resource allocation, and implementation.

2.2.4.1 Historical Information

Questions often requiring answers include:

- What is the historic range of the structure, composition, and processes of the resources in question or the ecosystems?
    - What boundaries are used to examine the historic variation?
    - What time period is used examine the historic variation?
    - What variables are examined? Landscape patterns? At what scale?
- What are the natural processes (including disturbance) that occur and at what scale?
    - What are the effects of these processes on the structure and composition of the resources or ecosystem?
    - What are the successional trends?
    - What are the type, frequency, intensity and scale of disturbances?
- What conditions indicate a healthy resource or ecosystem?
    - What conditions are necessary to maintain the viability of native wildlifeand plant species?

The range of historic variation (RHV) of a resource or an ecosystem is key to identifying future management needs. In theory, if an ecosystem is maintained within these historic ranges, species that occur within these ecosystem types will be retained. Determining the RHV is primarily through data collection and research of historical records, fire scar analysis, pollen analysis, etc. However, models can be used to project the range through time and space. The RHV is determined for a sample of areas and projected to similar areas and through time. GIS and relational databases are well suited for projecting ecological conditions through space. Analysts can use a variety of simulation models to project the conditions through time including successional models such as VDDT (Vegetation Dynamics Development Tool) and SIMPPLLE (Simulation of Patterns and Processes at Landscape Scales), and vegetation growth models such as FVS (Forest Vegetation Simulator). See Appendix 2 for description of software acronyms and program summaries.

2.2.4.2 Resource Situation

Questions include:

- What is the current condition of the resources or ecosystem?
- What are the current composition, structure, and processes of the resource base or an ecosystem, including biodiversity and indigenous species?
- What are the current departures from historical ranges of variability? (including invasive exotic species and their impacts)
    - What are the implications and new limits imposed by those changes?
    - If conditions are outside the historic range, is the trend toward or away from the range?
    - What lands are in imminent danger from insects and diseases and weeds?
- What land is suited for the various resource uses? (Resource uses include agriculture, timber, domestic and non-domestic grazing, recreation, religious and social uses, mushrooms and other non-timber forest products (NTFPs), water, etc.)
    - What are the supplies of the various resources?
    - What are the economic and productive potentials?
    - What are the ranges of opportunities?

Resource suitability is determined by physical and economic considerations. Particularly, resources will be harvested only where:

- soil, slope, or other watershed conditions will not be irreversibly damaged;
- lands can be restocked within a specified period of time; and
- water resources can be protected from detrimental changes in water temperature, deposits of sediment, or blockages of water courses.

The majority of natural resource inventories are just a sampling of the environment. Statistical analysis is required to determine the sample size and location. Analytical tools include databases, GIS, FVS, Nearest Neighbour Analysis and other interpolations.

2.2.4.3 Management Alternatives

Questions often needing answers are:

- What are potential alternative desired conditions of a given land base?
- What are the demands of the various resource users?
- How does the potential desired condition change over time?
- What are the benefits and costs of each desired condition?
- What management practices can help us achieve the desired conditions?
- What is the range of variability around the desired condition?
- What allowable management practices are within the desired conditions for the land base?

The analyst derives potential desired conditions from stakeholders' input, the current condition of the ecosystem, and range of historic variability. It is expected that different interest groups will have different desired conditions. The resource manager needs to describe the desired conditions for the physical, biological, social and economic environments. Use these to develop alternatives that may be assessed in an environmental impact statement (EIS) for the area under consideration. The selected desired condition becomes the Resource Management Plan. Desired conditions must take into account the dynamics of the resources or the ecosystems. Analytical tools include AR/GIS, GIS, Spectrum, FRAGSTATS, and FVS. (See Appendix 2 for description of acronyms and modelling software).

2.2.4.4 Effects of Management

Questions to consider are:

- What are the effects of alternative desired conditions?
- What are the biological, physical, and social effects of each alternative?
    - How will each alternative react to natural disasters?
    - What are the social effects? What social groups will the management affect and how?
    - What are the economic effects?
    - What are the effects on biodiversity, including the viability of plant and wildlife?
    - What are the effects on resource or ecosystem health?
- What are the spatial constraints and cumulative effects of each alternative?

- What is the long-term sustainable resource or ecosystem condition?
  - What is the long-term sustained yield of the various renewable resources?
  - What is the long-term sustained yield of the resources capacities? Is the use of a resource limited to a quantity equal to or less than a quantity which an agency or land owner can remove annually in perpetuity on a sustained yield basis.
  - What is the long-term sustained yield special products capacity (for example, mushrooms and other non-timber forest products)?
  - What is the long-term sustained yield biodiversity capacity? Can the agency or land owner sustain the historic biodiversity through time?
- What is the risk of possible future outcomes?
  - What uncertainties are there?
  - How accurate is the allowable resource use prediction?
  - Given the uncertainty, risk, and problems with data and predictive models, what is the range for the resource use?
- What are the short- and long-term costs and benefits of reforestation, site improvements, and sale of timber or other resources?

The analyst determines risk when one knows all possible future outcomes and their respective probabilities of occurrence. Uncertainty exists when all possible outcomes are known, but their probabilities of occurrence are unknown. Incomplete knowledge exists when not all outcomes are known (Westman 1985). Analytical tools include spreadsheets, databases, Spectrum, resource simulation models for wildlife, hydrology, etc., IMPLAN, and FVS.

2.2.4.5 Resource Allocation

Questions include:

- What land allocation and mix of resources will best meet the needs of the people or, rather, which is the preferred desired condition?
- Does the current land management plan meet these needs?
- Where is the land and its resources relative to the desired condition?
- What activities will move the land towards the desired condition?
- What are the trade-offs among alternative management scenarios (or, rather, among alternative desired conditions)?
  - What is the balance between economic factors and environmental quality factors?
  - Can the agency or land owner produce the desired goods and services while managing within the range of historic variation?
  - What are the trade-offs of managing with the range of historic variation and the production of goods and services?

Analytical tools include simulation models, GIS, Spectrum, and decision analysis tools such as Analytic Hierarchy Process [AHP] and Simple Multi-attribute Rating Technique [SMART]. See Appendix 2 for explanation of acronyms and description of software.

2.2.4.6 Implementation

Questions to be answered include:

- Can the strategic plan be implemented at the landscape and project level?
- What are the proposed and probable actions, including the planned resource sale program and proportion of probable methods of harvest?
  - What harvesting systems will one use?
  - What are the harvesting levels?
- What are the spatial constraints and cumulative effects of each alternative?
- What are the critical environmental aspects to monitor?

Analytical Tools include RELMDSS, SNAP, MAGIS, Spectrum, GIS, and site-specific expert systems. See Appendix 2 for explanation of acronyms and description of software.

2.3 ASSEMBLE AND EVALUATE AVAILABLE RESOURCE INFORMATION AND ASSESTS

The primary purpose of an MRI is to provide the decision-makers with the information they need at the lowest costs. Reviewing what information is already available and what are the assets for collection any additional data is a fundamental step.

2.3.1 Assemble and Evaluate Existing Resource Information

Since the outcome of the team work and any MRI is essentially a corporate database, the next step is to review previous and current inventory data to see how they meet all parties' needs and how it affects follow-up data collection (see Figure 2-3). This provides the opportunity to identify previous successes and failures locally, to determine local variability for sample size determination, and to identify alternative measures from the literature. This step is a further check to ensure that all user groups affected by any change in data collection are part of the design process.

Often it takes awhile to assemble disparate discipline-specific inventories into a coherent interdisciplinary framework. The important point is to build on existing systems that are sound and established. The purpose is not only to avoid 'reinventing' the data and reducing costs, but also to build support and ownership by existing disciplinary infrastructures.

Use existing data where feasible or design co-ordinated inventories to meet the essential data and information requirements. Assembly of background information on existing inventories and methods requires good investigative skills, such as intergenerational contacts, sensitivity to the language of other disciplines, detective work, and detailed documentation.

2.3.1.1 Check the Internet

Some free existing natural resource databases can be searched and downloaded from the Internet. Current MRI Internet information can be found at: World Source of Multipurpose Resource Inventories (MRI), World Species List, US <http://www.panix.com/~mavs/mri/> Public AccessNetworks Corporation (panix.com).
Some other inventory data sites include:

- FIA (Forest Inventory and Analysis) Database Retrieval System, US <http://www.srsfia.usfs.msstate.edu/scripts/ewdbrs.htm>
- IOPI Database of Plant Databases <http://chaos.mur.csu.edu.au/iopi/dpd/iopi-dpdbycountry.html>
- Internet Directory for Botany: Checklists and Floras, Taxonomical Databases, Vegetation <http://w3y.pharm.hiroshima-u.ac.jp/botany/botflor.html>

There are several ways one can find databases.

- Direct search of entire the World Wide Web (WWW) by one of several robotics search engines.
- Search using one of the many specialised WWW menu pages that index (link to) databases.

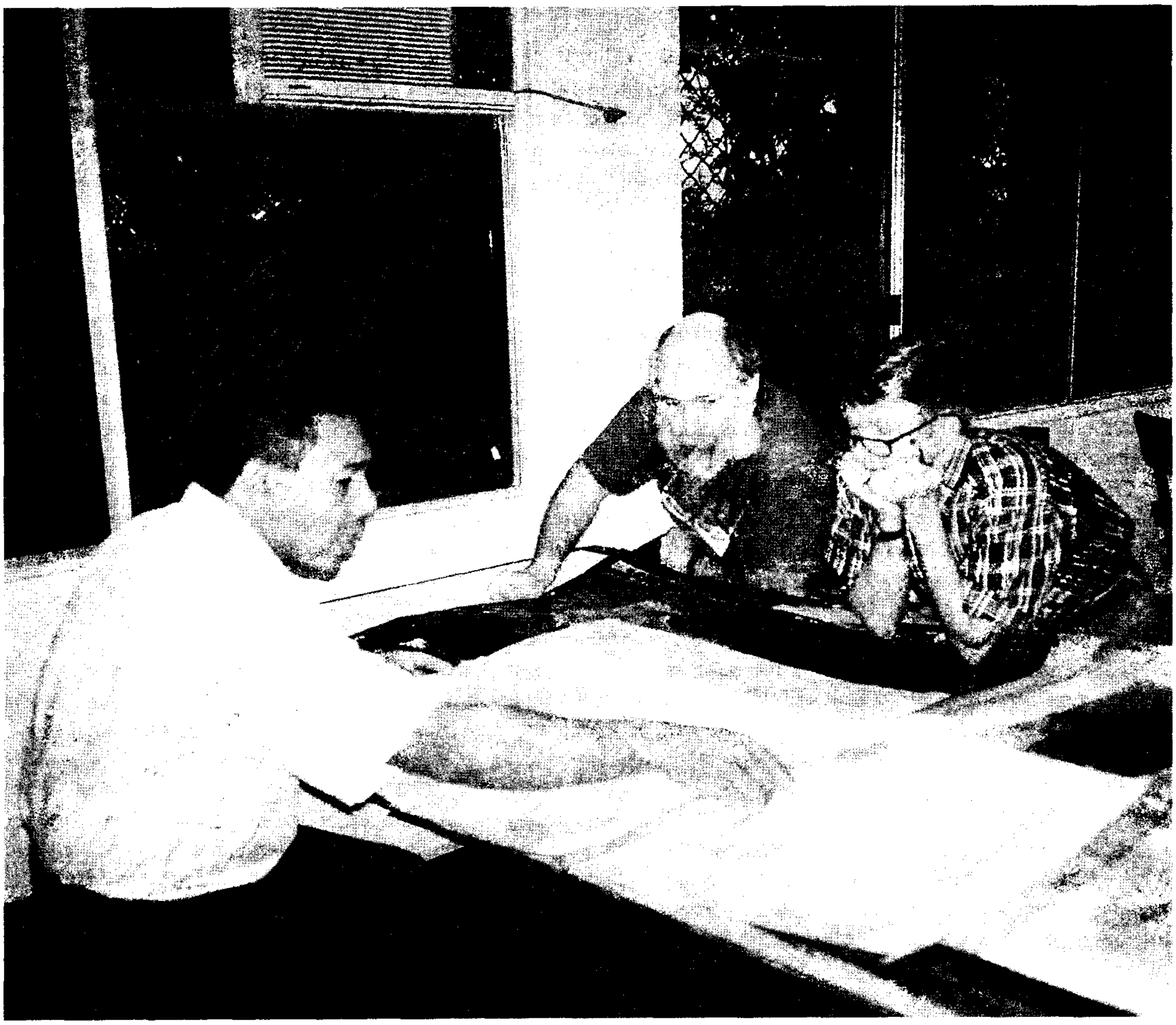

Figure 2-3: Reviewing existing maps and imagery in preparation for a forest inventory in Papua New Guinea. Such a review saves unnecessary expenditure of funds on information that may already exist.

Robotics Searches – WWW robotics searches are excellent, however, they take time and require skill. They require a knowledge of keywords in several languages. They are free, although commercials sometimes are attached to pay the costs. Usually they are on home pages as links called "Search The Web".

A direct robotic MRI search that will produce a good output. On September 29, 1997 this "Advanced MRI Searches" produced 476 items (including unrelated items):

title:(multipurpose near (resource* or inventory)
or title:(multiple near resource* near inventory)
or title:(resource* near inventory)
or title:(forest near inventory)
or title:(heritage* near inventory)

If MRI, itself, was used as a key word it would conflict with several MRI acronyms that are unrelated to forest inventories. Therefore, if MRI is included in a title the title should also include forest related words such as forest, tropical, timber, vegetation, flora, fauna, or biodiversity. Until more MRI inventories come online the unabbreviated title key words should be used.

Title is preferred in online searches because a title is short and is NOT likely to contain extraneous keywords inserted by the file owner and because the title is the listing used in the browser bookmark tool.

Menu Pages – The second method, finding a good referral page (online menu page), will save time and WWW connect costs. Simple lists of files without the organizational menus are helpful. They are basically extended personnel browser bookmark pages with the menus items removed. An example is the World Species List <http://envirolink.org/species/>. This referral page also has links to well though out web searches using keywords as shown above (Advanced MRI·Searches).

2.3.1.2 Evaluate Information Utility

Compare what partners are gathering data that may answer questions and needs of other resource areas. It is important to share how partners use these data and the type of answers they provide. Look at areas where redundancies occur and determine if they are necessary. Determine if a field crew can collect information to meet the needs of multiple users and at the same time so that it does not slow the MRI process. This not only cuts redundancy of field surveys but provides a database that is common for several resources.

Assembling background information on existing inventories and methods is important and again requires good documentation. Inventing the wheel takes time. The important point is to build on existing systems that are sound and established.

Look for what is valid and established and strive to make existing systems more cost-effective and utilitarian. Decision-makers make qualitative inferences in the absence of more quantitative information. For example, a large, extensive forest often contains wildlife species dependent on a single stage of stand development. Wood inventory information organised by stage of development provides the decision-maker with qualitative information with which to infer wildlife population changes if that stage were harvested.

Having limited funds to conduct their own inventories, decision-makers concerned with conservation values, for example, often infer relationships from quantitative inventories aggregated or disaggregated to the spatial scale of interest. Informally, they take advantage of the fact that samples of single-resource attributes across large areas commonly are spatially correlated at some scale of aggregation. More formal inferences among sampled attributes at various spatial scales are possible with knowledge of geo-statistics, such as Isaaks and Srivastava (1989).

A simple, yet effective integrative approach is to geo-reference available data measured at different scales to one accepted scale (Rudis 1993b). Geo-referencing wildlife occurrence data with disparate and sometimes more detailed forest measurements by political subunit permits valid linkages at a coarse scale, such as black bear habitat inferred from timber inventories (Rudis and Tansey 1995). When inventories become too coarse for local management decisions, specially-design inventories must be made to obtain additional detail.

Scrutinise the proposed inventory efforts to ensure the information is not already available. Then determine if the desired information is adequate for the intended use. Explore opportunities to interpret, stratify, classify, and extrapolate existing information before instituting additional inventories. Consider implications for trend estimation when making changes. Where necessary, convert existing data into the standard formats to make them more useful. Avoid using prior data that does not meet the objectives. Lund and Thomas (1995) provide guidance on how to evaluate existing information for corporate databases.

2.3.2 Review Existing Assets

Existing data and associated infrastructure may include (Shopland 1992):

- Human assets such as staff, student associates, visiting scientists, local communities, boards of directors for non-government organizations, volunteers.
- Material assets: field stations, offices, field equipment, vehicles, pack animals, radios, computers, software, etc.
- Financial assets: annual budget, special grants, overhead from external projects. Can the MRI program count on long-term support?

- Process assets: procedures already in place for collecting or tabulating data useful for the MRI.
- Information assets: maps, imagery, plot records, lists of flora and fauna, databases, socio-economic studies, published reports.

Use these assets to the fullest to reduce overall data collection costs.

2.3.3 Identify Additional Studies

In addition to MRIs, the decision-makers may need other studies especially if they are managing the lands for sustainable economic development. For any given resource, managers need to know:

- What is the potential or anticipated market and demand?
- What is the access? Can people reach the resources and move the goods to markets effectively?
- Can we meet the demand?
- How can we extract the resources?
- Can we manage the resources sustainably?

To answer to many of the questions given, the decision-maker may need biodiversity inventories, cultural studies, and user, product, market surveys in addition to MRIs (Lund 1996).

- *Biodiversity Inventories.* Biodiversity inventories provide lists of species found in a given area. Inventories of biodiversity are essential when surveying new areas and wanting to seek out to develop new products or to preserve what already exists. They require the employment of specialists in identifying plants and animals. While biodiversity inventories tell us what species may be available in a given area, they may not tell us what are used and what the abundance and distribution of the species are. MRIs can assist with that need.
- *Cultural Studies.* Cultural studies provide an understanding of local customs and needs. Without understanding who the local people are, their histories and customs, and including them in the design and application of management strategies, you may find it impossible to carry out sustainable or ecosystem management programs. You may wish to involve the local people or harvesters in all the other inventorying and monitoring aspects since they are on the ground nearly every day anyway. Local people may take to training well and generally know the terrain better than anyone. Employment of ethnographers would be a good place to start methodologically with harvester interaction. In seeking harvester knowledge, you may want to consider some forms of compensation as a way of resolving potential intellectual property rights issues.
- *Survey of Users, Products, and Markets.* User, market, or product surveys identify what resources are being used and how. If we are going to have a product efficient inventory and monitoring program we need to know what and how people will use the plant or animal. User, product or market surveys tell us what people are using. Techniques for gathering information include:
    - Direct observation – what are people gathering, how are they using it, how it gets to the market.
    - Surveys by personal interview/telephone/email/regular mail.
    - Surveys of local markets – what is being bought and sold, quantities, sources.
    - Monitoring the sale or issuance of permits, licences, vouchers, etc.
    - Spot road-side checks such as for hunting or fishing.
    - Literature review.
    - Consulting of historic and archaeological sites. These sources may reveal past and forgot uses.
    - Research and development

When we have a clear picture of the products we intend to produce and the biotic source of those products, then the inventory of the resources becomes more straight forward. We only mention these special studies here. Additional information may be found in Appendix 1.

2.4 ESTABLISH MRI INFORMATION NEEDS AND OBJECTIVES

The broad objectives were set out in Section 2.2 and refined based on the time constraints and available information and assets. The next step is to develop specific goals.

☺ State the goals for conducting the MRI including the area to be covered, the source of the data (whether field-collected or derived, and from what source), and the needs to be met by the inventory. Include goals for meeting international needs, national assessments, and for local planning needs as appropriate.

It is easy to develop a wish list of information needs. The challenge is to separate actual needs from those that are simply desirable. Nossin (1982) recommends identifying that information decision-makers need for developing and managing the resource first and then designing resource inventories or surveys to yield the necessary information. This is a change over traditional inventories where one collects data independent of likely land management needs. The clear and exact formulation of the survey objectives in relation to management objectives is of paramount importance.

Set out MRI objectives in an interchange between the levels of data collection and data utilisation. The data user should be able to specify the data or information needs, at what level of detail, and for what purpose, in communication with the people that will provide the data (Nossin 1982).

Agree on the MRI objectives including the degree of reliability. Agree on the inputs needed to generate outputs. Concentrate efforts on developing an efficient, workable, single repository for data useful in ecosystem analyses and focus on data elements that are not geographically limiting. Do not become bogged down in discussions of techniques before you know what are the inventory objectives (Shopland 1992).

2.4.1 Review Users and User Needs

One strategic element in the design of any information system is a clear understanding of the end users' needs (Falloux 1989). Needs vary by discipline. Each resource sector has a 'sphere' of information that it needs (Figure 2-4). Areas where these spheres overlap provide the basis for common information and the MRI. For example:

- Foresters need to classify the lands as to their suitability for timber production. Information that helps foresters to do this includes soil types, condition of the vegetation present, potential yields from the lands, etc.
- Recreation specialists must be able to determine the value of the visual resources, user preference and opportunities. Each of these information needs is met by measuring at least some attributes in the field.
- Range conservationists need to evaluate the land suitability for forage production and will use some of the same information foresters would gather from a "cow-eye" view.

It is essential to clearly specify the objectives and proposed products so that the users identify that their needs are being met. With too broad objectives a user may not see that his or her needs are being addressed .

To reach any resource management decision, administrators need generic information on infrastructure, existing resources, land capability, and desired future conditions. The infrastructure includes organization, roads, access, population, markets, and socio-economic data. For most natural resource and agriculture sectors, decision-makers need information about vegetation. Administrators need adequate displays about the current resource situation including information about the kind, extent, amount, volume/biomass, production, and condition of existing. Interpretation of ecological data on soils, landform, geology, climate, and topography determines land capability. Economic, environmental, social, and political needs dictate the desired future.

Hoekstra (1982) and Lund (1987) describe methodologies to assess data users' needs. The assessment tool focuses on questions crucial to survey design and implementation. These include the most appropriate timing for information, which indicators to inventory, and level of accuracy demanded. Hoekstra (1982) lists four steps for defining user information needs:

- Establish information flows. That is what information needs to flow from the local level to upper levels and *vice-versa*. It also includes how the partners share information, in what form, and at what schedule or frequency.

- Define how the team will process and use the information.

- Establish system costs through analysis of both costs and benefits.

- Make provisions that give the system flexibility for changes in information needs, uses and users. Consider adjusting data needs if a user organization undergoes significant, operational changes, including changes in personnel or responsibilities.

To accomplish the above mentioned four tasks, the information requirements team must first identify data users at all levels of the organization(s). Once potential data users have been charted and contacted, the team should meet with the individuals to discuss data requirements and uses. In the meeting, the design team should review information required by laws, mandates, policies, and management objectives.

Use information gathered from data users to make concise statements describing data requirements for each representative at every functional level in participating organizations. Hoekstra (1982) recommends that the summary of information needs starts at the organization's top and moves down through the previously defined ranks.

Review summary statements in total. The assessment and its analysis are most applicable when the team and the users review the statements as soon after the interview process as possible.

2.4.2 Define Specifications

The next task is to prepare a comprehensive, preliminary document that specifies user requirements. Clearly define specifications as to accuracy and timeliness. With some MRI projects, assessment activities may be more complex because they may involve multiple agencies, each with specific interests and responsibilities

Using information summarised in the preliminary document, as well as a second review of data user comments, produce a more formal document. In this document, list specification of identified data needs for key decision-makers in a matrix. List key decision-making institutions (all from the public sector in the examples in Table 2-6) across the top, with possible items or resource parameters listed in the left column. The body of the chart characterises the data needs.

The next step in the process for determining information priorities is to circle the appropriate users. If all the needs cannot be met by the information system because of limited resources (such as funds, personnel, and time Peterson *et al.* 1995), prioritise the important users in the matrix and circle them. The following factors may play a role in refining the specific MRI objectives and priorities (The Nature Conservancy 1995):

- Agency objectives that may not be of a biological nature
- Objectives of other interested parties
- Known trends in ecosystem components
- Recovery potential
- Threats, such as exotic species
- Representativeness of the ecosystem
- Conflicts with other resource uses

It may also prove useful to use ranking tools, such as those presented by Smith and Theberge (1987), Peterson *et al.* (1994), and by The Nature Conservancy (1995). After identifying the most important users, start to develop the MRI system.

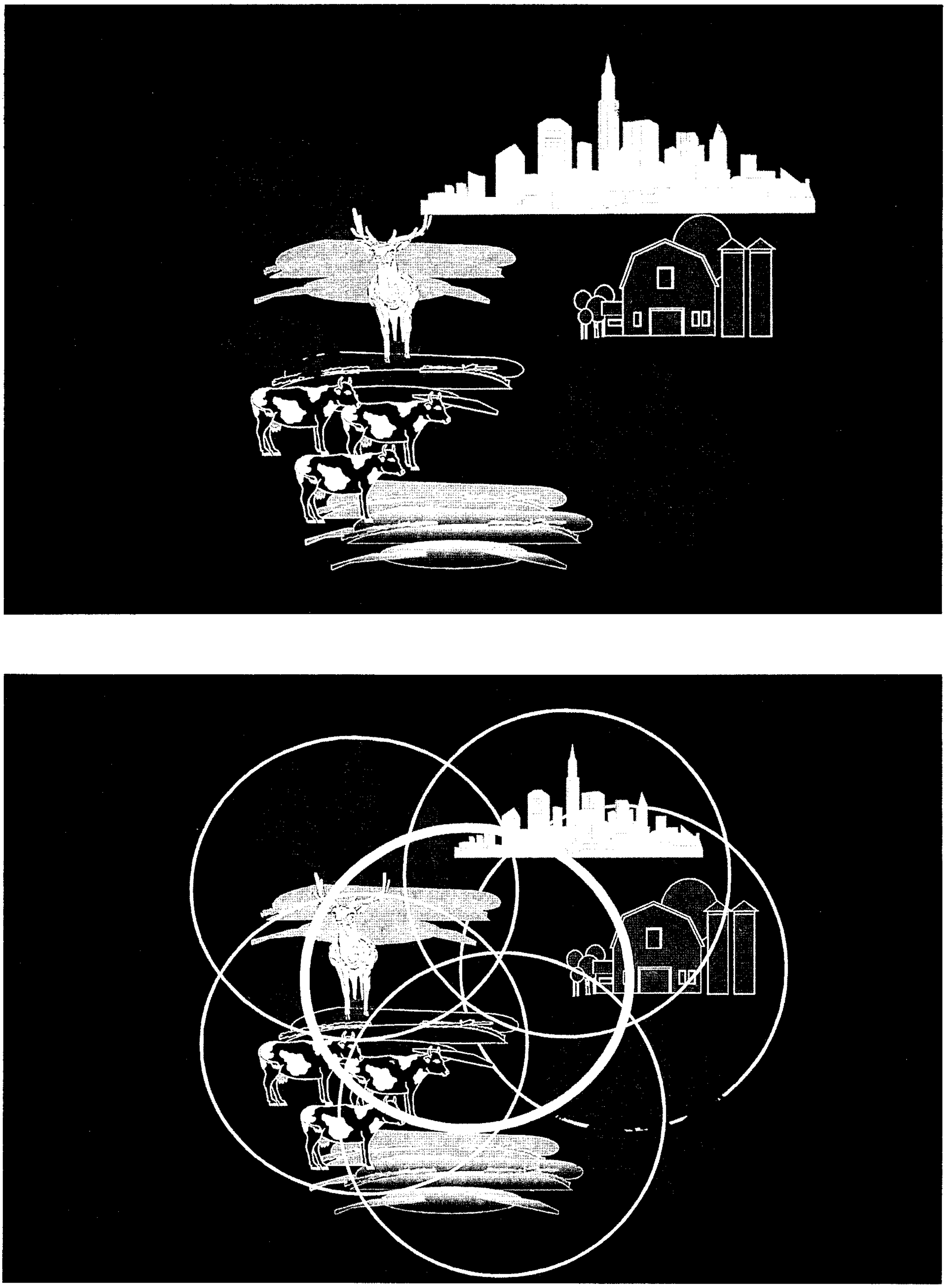

Figure 2-4: Each resource has a sphere of information requirements (upper drawing). Where they overlap are opportunities for integration of data collection (lower drawing).

Table 2-6: Priority of selected criteria by resource sector.				
Attribute or Data Element	Agriculture	Forestry	Range	Wildlife
Vegetation Type	High	High	High	High
Canopy Cover	High	High	High	High
Concealment	None	None	None	High
Tree Diameter	Low	High	Low	Low
Stand Age	Medium	Medium	Low	Medium
Plant Growth	High	High	High	Low
Crown Ratio	Low	Low	None	Low
Water Regime	High	Low	Medium	Low
Soil Type	High	Low	High	Medium

☺ **Determine the informational needs and uses for the data. Identify who these usersare at all levels and what their end uses are. Ensure the end users confirm that the data will address their needs.**

2.4.3 Select Attributes to be Measured

The next step for the MRI team is to select the attributes the field crews will assemble or observe. Päivinen *et al.* (1994) provide a list of useful attributes for forest monitoring.

Data useful for decision-making have certain characteristics. The data must be accurate, timely, comprehensive, objective, credible, and defensible. In addition to these classical characteristics, more modern characteristics have emerged because of social, economic, agricultural, natural resources, and environmental issues that require manages and policy-makers to consider simultaneously different parameters and the relationships among these issues (Wigton 1997b).

Data collection and dissemination of results, however, are expensive investments, both in time and money. The return on the investment is the value received by the user. Therefore, it is useful to assign a value to data that are requested so that the design of the information will be efficient. (Wigton 1997b). Ask what hypothesis is being tested. If this cannot be answered, do not add the data (Dewar, pers. comm.). Additional questions to ask (Schreuder and Singh 1987) are:

- Is there considerable loss in sampling efficiency due to collecting the additional information? For example, does it require coming back to the ground plot a second day, or can it be obtained comfortably within the time allocated for plot sampling?
- Is there a potential loss in quality of the other information gathered on the plot because too much is expected of the crew?

☺ **Filter requests to ensure that all data elements are useful, cost effective and integrated within the total inventory system (Buck 1987).**

Some attributes are qualitative, such as condition, and some are quantitative, or measured. Some attributes are map-based and others are ground-based. Considerable information about the history, landscape, and study area is generally available. Some of it may be useful.

It is important to distinguish between variables that crews measure or classify in the field and those that are compiled. That is, measured data are used to classify the plot, to develop an index, or are used in a predictive model. In designing the MRI, identify both types of information and establish linkages. Prior to changing or deleting physically measured variables, ensure that any linkages to the desired end uses remain. Focus on elemental data. Avoid classifying if possible for more flexibility.

Often the key attributes are clear, such as numbers of oak seedlings in a given area. However, there are almost always other factors (covariates) that affect the results in ways similar to the primary factor or driver of interest. Thus, crews must also collect information on these covariates (independent variables), such as edaphic characteristics of the site. Reducing other sources of variation aids in isolating the effects of the primary factors.

At other times, it may be impossible to measure the item of direct concern – for example the number of elk a given area may contain. Usually, a field crew measures or observes indicators of elk populations instead. These may be evidence of browsing, pellet groups, antler rubbing marks on trees, etc. Identify indicators that address the problems. Considerations are:

- An indicator must be a good measure of, or surrogate, for the characteristic of concern. Look for efficient surrogates.
- Indicators should detect a problem before it is too late to solve it.

Often the list of desired attributes grows longer than the time and cost constraints allow. Return to the priorities developed in Chapter 2.4.1 *Review Users and User Needs* to pare down the list of attributes to a manageable level.

A field crew may not be able to observe all indicators directly, but may collect information on one or more observed attributes to form an indicator variable, such as an index. Comparisons between sites may require collecting the same attributes with a compatible sampling system. Rely heavily on models for information of interest that is not readily measured. Be aware of the strengths and limitations of the models, test them, and develop them further (Schreuder and Singh 1987). Table 2-7 presents some attributes recommended for modelling many forest resource components.

Table2-7: Minimum data for modelling the extent of Forest Resources (Sources: Schreuder and Singh 1987, Päivinen *et al.* 1994, Tomppo 1995, and MRI Questionnaire survey).

Resource Attribute	Source of Information
Type of vegetation (overstory and understory)	Remote sensing, field surveys
Vegetation height (overstory and understory)	Field surveys
Percent vegetation cover	Field surveys
Soil type	Field surveys, existing maps
Climatic data	Weather Service
Topography (aspect, slope, elevation)	Digital elevation models, field surveys
Geographic co-ordinates	Field surveys (global positioning systems)
Past treatment, uses	Historical records, interviews, field surveys
Planned treatment, use	Interviews

2.4.4 Agree On Definitions, Standards, And Formats

Agree on definitions of terms. This provides opportunities for all resource groups to use the same terminology rather than each resource's lexicon. Different resources may use the same term differently. For example, range specialists in one U.S. Federal Agency interpreted the term 'aspect' to mean the general land cover. Foresters in the same agency used the same term to describe the direction a slope faces (Lund 1979). In order to design multipurpose resource inventories, we need agreement on terms, definitions, codes, uses, standards for measurements and on tolerances allowed (Figure 2-5).

☺Use functional terminology, something that all partners can understand (Buck 1987).

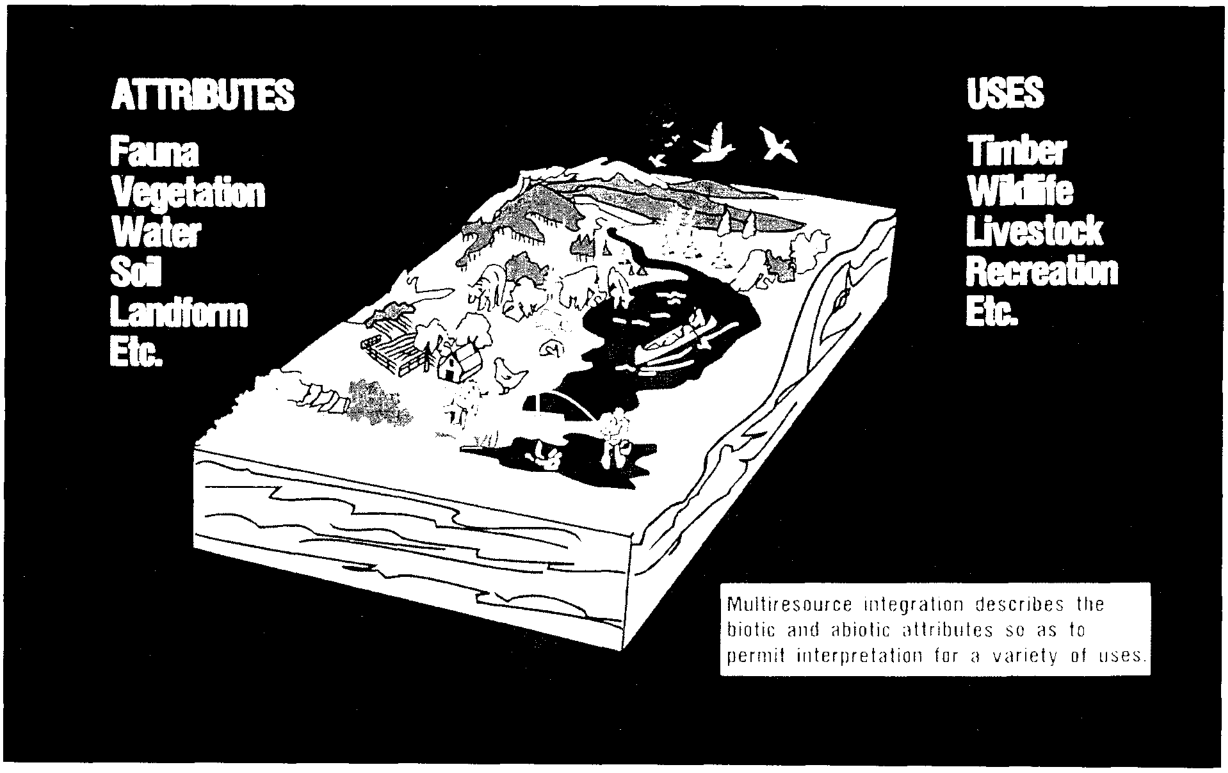

Figure 2-5: Describing the resource database so that it can be used by a number of people is fundamental to MRIs.

The development of standardised definitions is the basis of standardised methods and is essential to ensure comparability of data across different regions. An example of a standardised definition is diameter measurement that has been refined to a diameter at breast height (d.b.h.). This term has been further refined to be measured at 4.5 feet or 1.37 m above the ground in the United States. The issue of comparability is further complicated because in European and Canadian inventory systems d.b.h. is not 1.37 m but 1.3 m above the ground. The MRI planning team needs to resolve this type of situation or the data may not meet the required level of comparability.

One way to develop common definitions, especially among those used in different resource areas and sectors, is to gather up any known definitions. Cut and paste those that are similar. Then, as a team, agree on the term and definition to use. Use international and national definitions and standards in designing, implementing, and maintaining the inventories to ensure that multi-functional data have a common frame of reference and to ensure consistency of information between planning levels. The International Union of Forestry Research Organizations has develop a set of standards for forest mensuration (IUFRO 1959) and for forest monitoring (Päivinen *et al.* 1994). The Food and Agriculture Organization of the United Nations has developed standards for Land Cover Classification (FAO 1997a).

When considering multiple products from the inventory, define each product in terms of size and minimum quality requirements. There may be a need to develop and adopt common standard product definitions and the method of presenting them in inventory reports so a common ground for evaluation and monitoring can be achieved. The definitions must emanate and be responsive to the needs of the consumer. At the same time, they must remain stable for a long period of time for effective resource monitoring (Temu 1991).

Where there is a large diversity within the range of the administered lands, the standards must be flexible enough to encompass this diversity. Choose the level of acceptable error carefully. It has major implications for the appropriate sampling design, sampling methods, and costs of each. Arbitrary decisions on error levels could lead to bank-breaking costs or to the collection of useless data. Specific agency-wide standards for error may be appropriate for broad, agency-wide objectives but generally limit direction to broad statements of intent and policy. The amount of error we should allow will vary depending upon the nature of the question being answered. The answer depends upon risk of a variety of types and benefits or costs.

Define a common geo-spatial reference system and format. The format should provide an assessment of what the variable is, its importance, its end use and user, methods of collection, possible covariate or substitute, and source of existing data for determining items such as variation.

Different data-producing organizations or entities are likely to have differences in data definitions as well as resolution, accuracy, and other data quality components. Up front efforts to agree on standards minimises these differences over time. An immediate need to integrate, however, may be daunting to the point of overwhelming. Given that many analyses will deal with overlay and edge-matching of different layers and coverages, the bare minimum for such efforts to be successful is a common way to reference all data layers to the face of the Earth. This is served by developing or acquiring common foundation data to which all other data are spatially referenced. Digital terrain elevation models and digital orthophotoquads are examples of foundation data. These foundation data are so fundamental that every effort should be made to make it as broadly applicable as possible (Correll *et al.* 1997).

The team must also look at how to get the information to the user. This may require providing a format already in use or developing a new procedure that is more effective. It may also go as far as identifying or creating tools for the user to access the information. In any case, the usersmust be able to continue to do their business.

2.5 DEVELOP THE MRI PLAN

Do not be in a hurry to get to the field. Take time to lay the ground work. Set aside enough time to develop the MRI plan (Figure 2-6). Do not underestimate the length of this process (Shopland 1992).

☹Do not let the planning process develop a life of its own so it becomes the primary focus and the inventory is secondary.

Include the following in the plan:

- Users of the MRI information.
- Inventory unit (size, location, legal description, variability, use, condition, access).
- Dominant issues, concerns, and opportunities within the inventory unit
- Information required to address the concerns and issues.
- Applicability of current information, existing remote sensing imagery, and geometronics technology to provide needed information.
- Required precision and statistical reliability for the needed information.
- Sample design and intensity.
- Scheduling of the MRI to meet budgets and time frames.
- Integration of other existing and proposed resource inventories through the use of co-ordinated data collection and geographical information systems (GIS).
- Detailed field procedures, codes, editing procedures. This should include quality control - field checks of inventory crews, random checks, and validation of compiled data against original data sheets, etc.
- Analysis procedures, interpretations to be made, and report format (tables, databases, reports).
- Dissemination of the resulting information (who gets what, where, when, why, and how).
- Maintenance and monitoring requirements.
- Schedules for re-inventories or updates.
- Useful life span of collected data.

Figure 2-6: Example MRI field manuals and handbooks from around the world. See Appendix 1.2.8.

Once the team decides upon the attributes, sampling units, and sample size, determine sampling unit locations using maps, photos, or co-ordinates. Describe details of inventory and monitoring and develop instructions for data collection and quality control. Provide for sample handling and storage, as well as for data handling and storage. Co-ordinate the resources needed to complete the survey.

Build flexibility into the plan. Weather, security, change of administrations, funds, etc. often makes it impossible to efficiently allocate manpower and other resources on the basis of detailed plans. Use outlined future events or tasks and specify which of these is dependent on others. Several tasks may be worked upon simultaneously and priorities may be shifted (Hedberg 1993).

2.5.1 Identify and Address Constraints

Before any MRI begins, some time and cost constraints must be set. Time, expertise, and money are limited. Thus, the team must develop a realistic MRI and monitoring system. If the inventory objectives cannot be met within these constraints, then modify the objectives.

2.5.1.1 Funding

Not surprisingly, the costs of inventories and the lack of funds were the most frequently noted obstacles to implementing an MRI based on our questionnaire survey and literature review. Look at objectives and needs with respect to available time, funds, and personnel. Look at potential costs of various options, then agree on design.

Major funding for MRI has traditionally been through a specific resource, such as timber, with small amounts for other resources, such as soil resource surveys. Establishing a generic inventory budget line with direction to create an ecological resource information base shifts MRI into an integrated light. The development of a resource-combined budget for inventory, survey and monitoring will help reduce functionalism brought on by some budgeting processes.

Depending upon the scale of the question being addressed, the agency may need the co-operative participation of adjacent and sister units, outside interests, universities, other agencies, other governments (States), and other interested parties and co-operators.

"Those who pay the freight get what is delivered" and those who benefit from the information should pay. It is usually industry and the timber interests who support resource inventory programs with money, in-kind assistance, or lobbying efforts. Often secondary data are gathered but the driving force behind the inventory is the source of funds. When funds are limited, the MRI design team has to be selective about which data are measured and evaluated. To gain support:

- Develop a message justifying the database and MRI system. Focus on benefits to interested parties (win-win). Be persuasive and persistent.

- Enlist co-operation. Identify key external interest groups and agencies as well as non-traditional groups and key internal leaders, individuals, and champions.

- Emphasise that all resources and land uses are consequential, that all resource programs are significant, and that the PEOPLE involved with the various resources are all important.

- Keep everyone informed and involved (management, specialists, core teams, extended teams, users, maintainers) and versed in the language and methodologies before starting anything.

Many inventory programs are designed to address immediate economic needs. MRIs often focus on social and environmental needs as well. These usually require long term monitoring efforts. Long term efforts are often overshadowed by local "brush fires" or problems requiring immediate solutions.

☺ If the partners and decision-makers consider natural resources 'natural capital,' (Baum and Tolbert 1985) the importance of long-term maintenance becomes obvious. Surveying and mapping natural resources and environmental parameters helps country planners to effectively manage their "natural capital." Describing and analysing information about the status and trends of natural resource use, and its later impact on the environment, is basic to national development.

☺ MRI planners need to stress this point when dealing with policy-makers and those who control budgets.

The stability of the government and inventory program is also a factor. MRIs and monitoring programs require a long term investment.

☺ Have inventory responsibilities built into laws. In situations where changes in government or administration are frequent, continuation of inventory and monitoring programs can be a prerequisite for support from possible donor groups.

Channel funds directly to the project to avoid paying overhead. Use staffing from collaborators as much as possible (Hedberg 1993).

As noted in the beginning of this paper, some of the poorest and least developed countries are actively using MRI. Such countries have no excess funds and have to look at inventory problems in a co-ordinated manner. If a country conducts a multitude of functional inventories then it should have sufficient funds to conduct an MRI.

2.5.1.2 Timing

Another challenge resulting from an MRI's multiple variables relates to survey timing – that is, the periods when the field crew collects the data. This problem was also noted in our MRI questionnaire survey and literature review. Crews may be able to collect some data items any time, whereas they must collect other items at specific times, especially those that are seasonally related. For example, crews can gather data on tree diameters nearly any time of the year, but if they are seeking information on agricultural crops, the timing is different. Agricultural data are very time-sensitive. Crop cycles often range between three and 18 months. If the decision-makers need information on agricultural production, crews must collect data after planting to estimate hectares planted and again at harvest time to estimate yields and production. These times, however, may not be appropriate for collecting other data, such as pest damage in forests or on rangelands.

☺ Schedule inventories to support the preparation of international and national assessments and/or the development of resource management plans. Co-ordinate scheduling and budgeting of data collection for all resources and uses.

☹ Keep time frames as short as possible so commitments do not lag with personnel turnover, shifts in priorities, or fiscal direction.

A multipurpose resource inventory does not have to have all the measurements occurring at once. The MRI design team may advocate separate surveys at different times but using the same sampling scheme and plot location. Even in this case moneys will be saved due to reduced logistical costs (such as bench-marking plots, access notes, etc.). Generally, it is more cost efficient to have a single crew measure everything they can at once, but sometimes it is not.

While we may not be able to collect all the data we may need at a given point in time, we may be able to collect enough data to model the distribution of developing resources. An ecological inventory, a form of multipurpose resource inventories, is one method of developing a database for modelling. The presence or absence of a species in a given location is a function of the site's bio-geo-chemical and physical characteristics and past history or treatment. In ecological inventories, one collects and combines information about soils, climate, hydrology, topography, existing vegetation and past history (Tomppo 1995) into a mapped database. This may be done through the use of a geographic information system (GIS) or through field surveys. From this information, one may be able to predict the location and likelihood of a certain species being found, assuming one knows the ecological requirements of the species. The GIS can also help answer some of the questions about access to resources especially if information on roads and trails are incorporated into the database.

A general rule may be to schedule data collection at the peak of vegetation production. Conduct additional surveys as required to meet other seasonal information needs. When conducting special purpose inventories, however, use standard terms, definitions and codes so resulting information is shareable. When using remote sensing, co-ordinate the imagery acquisition with field data collection. This will assist in the linkage between field data and the imagery for modelling and extrapolation.

2.5.2 Incorporate Available Technology

To reduce field costs, be inventive (Figure 2-7). Incorporate available technology (global positioning systems (GPS), Landsat/Thematic Mapper, aerial photography or videography/image processing, etc.) into the data collection process as appropriate. Based upon our MRI questionnaire survey and literature review, nearly 60 percent of the countries having MRIs use remote sensing in one form or another. Aerial photography is the most commonly used followed by satellite imagery.

The use of remote sensing and GIS technologies provides techniques that would aid in classification, mapping, and inventories of ecosystems and resources. These techniques allow standardised approaches across large areas, increasing compatibility of procedures. One can add other levels of information in a GIS format. Remote sensing itself is a great integrator. Imagery covers a variety of lands and resources irrespective of administrative boundaries. By pooling funds partners can join together to purchase imagery and necessary interpretation equipment one may not normally afford. In addition, imagery:

- serves as a map showing the distribution of the resources,
- is a source of information for vegetation, land cover and to some extent land use,
- serves a 'road map' for field crews,
- provides a means for stratification of field samples,
- serves to verify field data,
- provides a means for extrapolation of field information, and
- is a base for monitoring.

The use of remote sensing is especially useful for inventorying and monitoring some of the functions and services of the forest, such as watershed protection, soil stabilisation, and carbon sequestration. Many of these are reflected by the amount and extent of vegetation cover which interpreters can generally extract from imagery. Some ecological functions may also be derived from remote sensing such as biodiversity. This depends on the type, resolution, and scale of the imagery being used. See Appendix 1.2.2 for publications on remote sensing and mapping.

2.5.3 Select Sampling and Plot Designs

The inventory design specifies how one selects the sampling units. The multipurpose nature of an MRI is significant since aspects of development activities, natural resources, other environmental parameters and social welfare are interrelated spatially and biologically.

Sampling is the process by which one makes inference about a whole population by examining only a part. Sampling methodology involves the application of rigorous (replicable) procedures for selecting sampling units that provide desired estimates with associated margins of uncertainty (Houseman 1975). Sample surveys have many potential advantages over complete enumeration including greater economy, shorter time-lags, greater scope, higher quality of work, and appraisal of reliability and even greater accuracy (Cochran 1977).

There are two types of sampling – subjective or purposive and statistical. Both may be used in MRIs. Subjective (non-statistical) sampling is often a cost-effective precursor to statistical sampling. Correll *et al.* (1997) list the following situations where inventory planners may prefer this form of sampling:

- Variations between elements of the population are large and sampling is expensive.

- The needs for information about a population are immediate and a decision must be made before a well-executed statistical sample can be carried out.

- Funding is short or unavailable and the only alternative is to use existing information and extrapolate to the population of interest.

- Approximate knowledge of some of the population parameters are needed to design an effective statistical sample.

- A suitable model exists such that model-based sampling methods are appropriate.

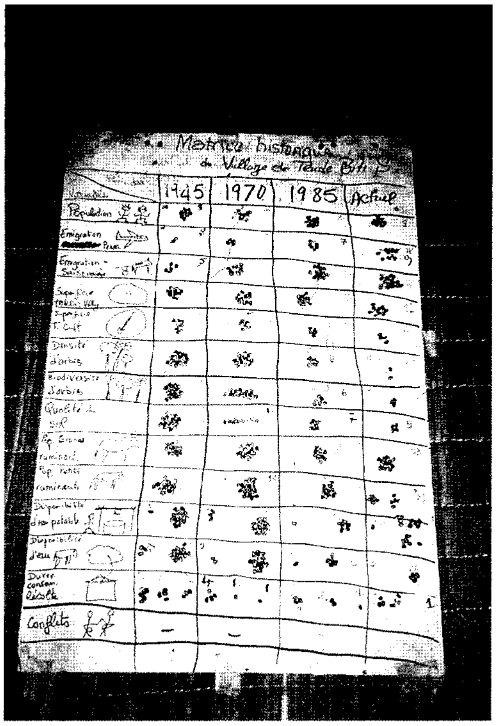

Figure 2-7: Innovative ways of recording data in the field. Upper photo shows a data recording 'form' etched in the soil that local farmers are using to record perceived changes in their village in Senegal. This photograph is the 'hard copy' of the form. Lower photograph, a similar innovative form. Here, a flip chart and beans serve as the form and markers. Again, the photograph is the hard copy. Source: U.S. Geological Survey, EROS Data Center.

Sampling may be direct or indirect (see Table 2-8). One uses the first four direct methods for gathering socio-economic data. One may use voucher collections to track the flow of goods and services. Crews use plots, points, and transects for surveying vegetation and in some cases wildlife.

Table 2-8: Direct and indirect sampling techniques (Correll *et al.* 1997).

Direct sampling includes:	**Indirect sampling includes:**
• Telephone/email survey	• Literature review of similar conditions
• Mail, questionnaire	• Visual observation (counts of wildlife)
• Personal interviews	• Aerial photography and videography
• Voucher collections	• Satellite imagery
• Mark-recapture (banding/tagging)	• Laser profiling
• Dimensional plots (circular, rectangular, etc.)	• Radio telemetry
• Point sampling (horizontal and vertical)	• Radar/sonar
• Transect/traverse sampling	• Other remote sensing systems
• Profile/content sampling (soils)	
• Volume/content/flow sampling (air and water)	

An MRI frequently includes both direct and indirect sampling especially when inventorying vegetation. Remote sensing may be used in the first phase of a sampling scheme to stratify the landscape for subsequent field plot sampling.

When one bases the method of sample selection on the principles of probability, the sample is a probability sample, in contrast to a purposive sample or an informal sample. Only a probability sample provides measures of statistical reliability by showing the extent of error due to sampling. When one combines probability sampling with statistical procedures to reduce non-sampling errors or biases associated with the sampling frame, data collection and data summary, there are strong arguments for the credibility of the results.

Choosing a statistical design is a critical step in inventory development. Different designs may yield significantly different results. Variations in results can be due to differences in the type of sample frame, method of sample selection, sampling intensity, timing of data collection, and design of survey forms, including differences in question order. Lund and Thomas (1989) provide a variety of sampling options for collecting data.

2.5.3.1 Decide on Scope

The sampling design reflects the scope of the MRI. Broad planning, such as at the state or national level, often concerns 'what' resources are present. Local project planners are interested in not only the 'what' but the 'where' and the 'how much.' The difference affects how the MRI team derives the area information (for example, mapped or sampled) and the sampling design.

Either mapping or sampling can provide area information. Information on other attributes, such as forage production or tree volume, is usually derived from sampling. Statistically valid designs provide a basis for an unbiased estimate of past, present, and potential resource conditions. Well-designed inventories provide information to support a full range of land use alternatives based upon resource capability.

The basic design for surveying extensive areas usually includes a systematic sample of imagery points across the survey units. At these points, one extracts information from imagery and or field plots. If an interpreter can determine land cover and other characteristics from the imagery (or from secondary sources such as existing maps), he or she can classify the points. These points can then be stratified and a sub-sample selected for field measurements.

Nearly all inventories at the local level use mapped polygons in the inventory designs. Ideally, each resource function agrees on a common mapping scheme. The mapper identifies and classifies each polygon. These polygons are stratified and sub-sampled for additional data in an integrated data collection effort or individually by resources (Lund 1978, Mehl 1984).

2.5.3.2 Inventory Unit, Sampling Design, Sample Intensity, and Plot Configuration

Much depends on the MRI goals, the nature of the resources inventoried, the size and skill of the inventory crews, access, the amount of time and funding available to do the inventory, and allowable sampling error. Start with a simple design and with a system that the inventory design team can explain and the partners carry out. Always try to build on existing systems but do not be afraid to discard them. Look for what is valid and established and strive to make the existing systems more cost effective and utilitarian. Add to, or remove parts of, the system as needs and capabilities change.

2.5.3.2.1 Inventory Unit

A first step in any sampling design is to define the population of interest. The population of interest is typically the study area or inventory unit. Designation of the inventory unit usually depends on the goals and objectives of the MRI. For national assessments and forest and rangeland planning, political or administrative boundaries often define the inventory unit. National assessments often use a state or province or a subdivision thereof as an inventory unit. The inventory unit may be further divided into sampling strata. Physical and biological conditions often define sampling strata.

If inference is to be made for similar areas in the region, then the population of interest is the aggregation of these areas, for example, oak savannahs in the Midwest. Knowing the population of interest helps to define the *sampling frame* – the sample area or set of all possible sample locations.

One typically states the *sampling objectives* in terms of estimating some population value within a specified level of precision. An example is estimating the number of black walnut seedlings per hectare, plus or minus 10% at the 95% confidence probability level. This forms a 95% *confidence interval* - the range within which the estimated parameter is located with a given probability. The bounds are termed *confidence limits* and the probability is *the confidence probability.* This means that if one repeats the sample one would expect that 95% of the confidence intervals constructed in this way would include the true mean. For a given sampling design, narrow confidence intervals reduce risk in making management decisions, but require large sample sizes. Before one determines the sampling design and sample sizes, the inventory specialist must specify the sampling methods and sampling unit (plot) design.

Very often people, unused to dealing with inventory data, find it easier to understand confidence intervals than standard errors. Therefore, confidence intervals should be included in publications of inventory data (Köhl 1993).

2.5.3.2.2 Sampling Design

The sampling design specifies how one selects the sampling units. Sampling designs have changed over time with technology and information needs (Figure 2-8).

Many possible sampling designs exist, but simplicity is important, particularly for long-term monitoring (Figure 2-9). Agricultural surveys of large areas often depend on an area sampling frame. This is a special case of cluster or two-stage sampling. The sampling units are areas of land, commonly called segments. The inventory specialist divides the entire land area of the population to be surveyed into sampling units and then selects a sample of these units or segments. For agriculture, the population may be the number of farm fields in a given province and the sampling unit may be an individual field (Houseman 1975). In this case, the designer needs a map showing the farm fields. Fields and crops are easily distinguished using aerial photography and other forms of remote sensing.

Large area forest inventories, where stands are mapped, (or in the case of rangelands where pastures are mapped), the designer may use a sample design similar to agriculture. However, mapping of stands is a bit more complex. Boundaries of stands may not be easily discerned from remote sensing or on the ground. In addition, stand boundaries may change due to natural causes or human intervention. Where maps do not exist, foresters usually employ a stratified systematic sample across the forest area.

Recommended approaches for most natural resources include systematic sampling, simple random sampling, and stratified random sampling (Cochran 1977). *Systematic sampling* distributes the sampling units in a fixed manner, usually as a grid, across the sampling frame. Technically, this means that the precision cannot be computed accurately, but experience indicates that this is not a problem. The systematic sample is easy to understand, design, and implement. Systematic spatial arrangement of samples allows analysis on multiple scales and variable boundaries (Smith 1997). The systematic location of plots provides a sampling of strata proportional to their size. It permits field work to begin before mapping is complete. By far, systematic sampling was the most frequently used design for MRIs based upon our MRI questionnaire survey and literature review (see Table 2-9). Case studies 3.3 and 3.4 in Chapter 3 provide examples of systematic sampling.

For rare products, however, it is more difficult to use general purpose sampling alone to provide accurate estimates. Other means of gathering data may need to be employed.

Increasing demand for information quality/quantit

Sources of information and collections techniques	Year	Requirements and technologies affective forest inventory
Maps of areas of forests	1800	Perceived shortage of fuelwood (Central Europe)
Visual estimation of timber over small areas	1825	
Random and strip line surveys. Tree volume tables developed	1850	
Statistically sound surveys developed	1875	
Forest mensuration relationships increasingly used, e.g. volume : basal area	1900	Increased demand for information over large areas in North America and Australia
Stratified sampling, aerial survey	1925	Major advances in technology including aircraft devices and computing devices
Textbooks on statistically based survey methods. Variable probability sampling (plotless cruising)	1950	Increasing demand for multiple resource information, and information to aid large industry developments
Sophisticated models (e.g. taper models), use of laser and sonic technology	1975	Microcomputers and GIS become freely available
Multi-phase, multi-stage inventories. Linear and non-linear regression models. Expert systems	2000	Increasing concern over biodiversity and ecologically sustainable development
	2025	

Increasing cost of labour. Decreasing cost of technology

Figure 2-8: A time line of major developments and requirements for collecting forest information (Brack 1977).

With *simple random sampling*, individual plots are located randomly across the sampling frame. This permits simple computations of both the estimates and their precision. Finally, *stratified random sampling* uses maps or imagery to divide the population into strata of known area. Simple random sampling is conducted within each stratum, then the stratum's estimates are combined into a single estimate for the population. Results are almost always more precise with stratified random sampling, but this requires classification and some good maps. The estimators and their variances are the same for systematic and simple random sampling. They are a bit more complicated for stratified random sampling (Cochran 1977).

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.

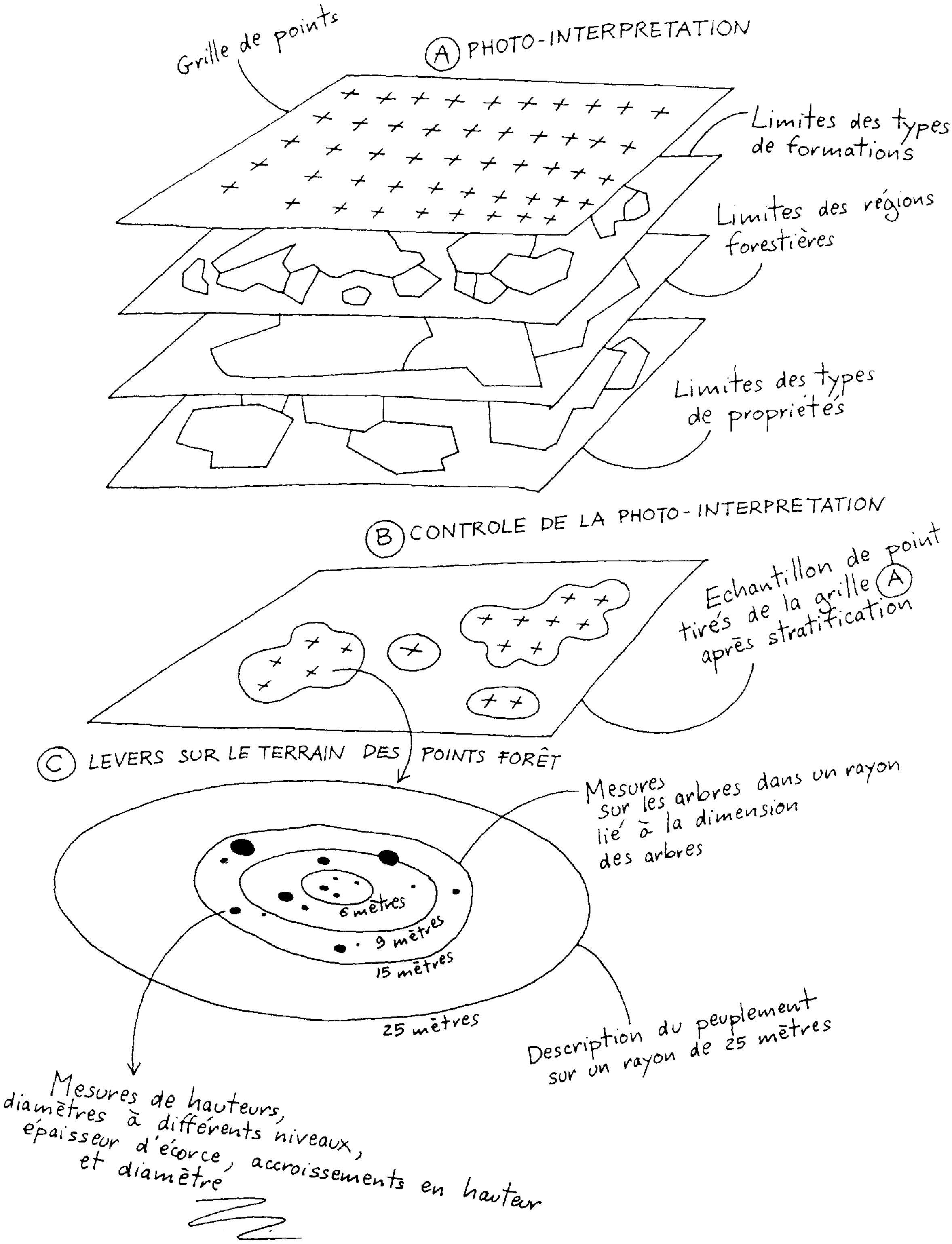

Figure 2-9: Example of an MRI inventory design. Even though it is in French, it may be easily understood. Having a simple and effective design that all partners can understand is fundamental for developing a successful MRI. Source: Inventaire Forestier National 1995.

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
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).

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

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

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).

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 α-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-β) 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 α-level and β-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.

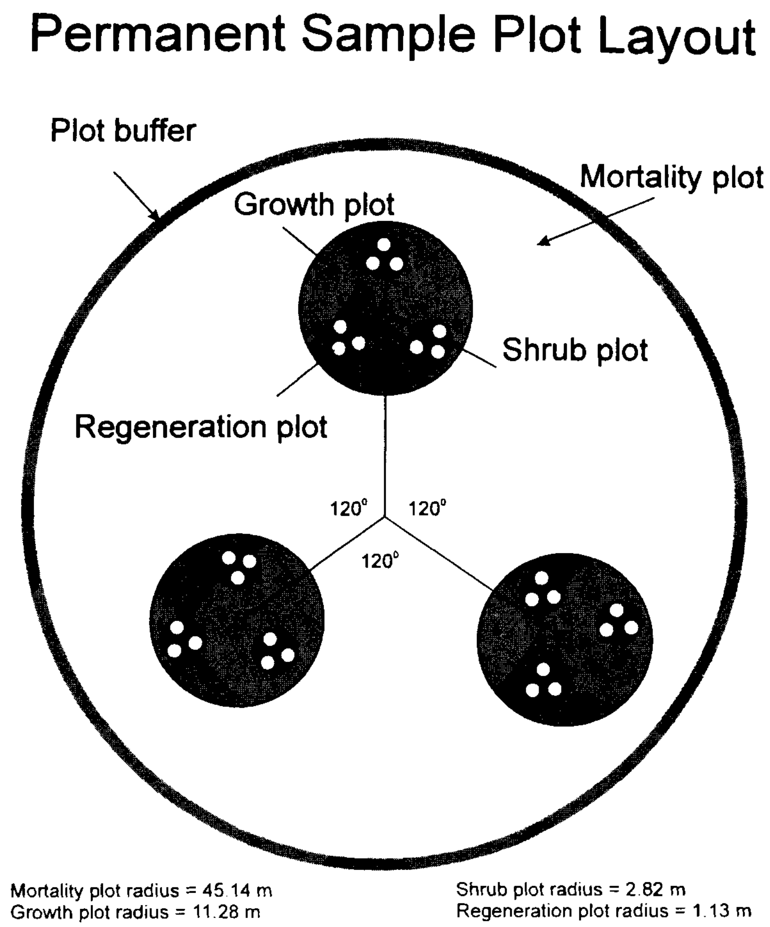

Figure 2-10: A plot design useful for measuring and monitoring vegetation for multiple purposes. Source: Hayden *et al.* 1995.

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, $\bar{Y}$), 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:

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

thus,

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

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.

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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 1. Government takes decision to sell concessions, etc.; 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: 1. Data about valuable species lead to illegal use by outsiders; 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 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; 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 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 trainingsessions; 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 (±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 teamcan 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

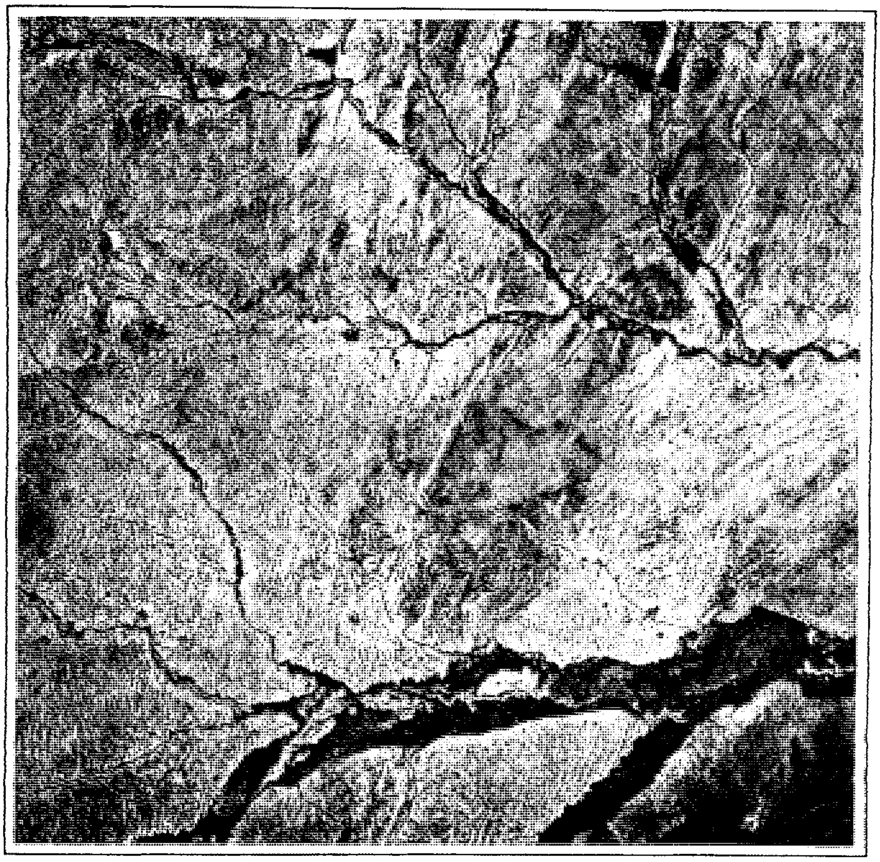
Inventory schedules address how data are to be collected, compiled, and used and how the results are to be documented, disseminated, and maintained. The schedule should cover inventory development through reporting that includes:

- 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.

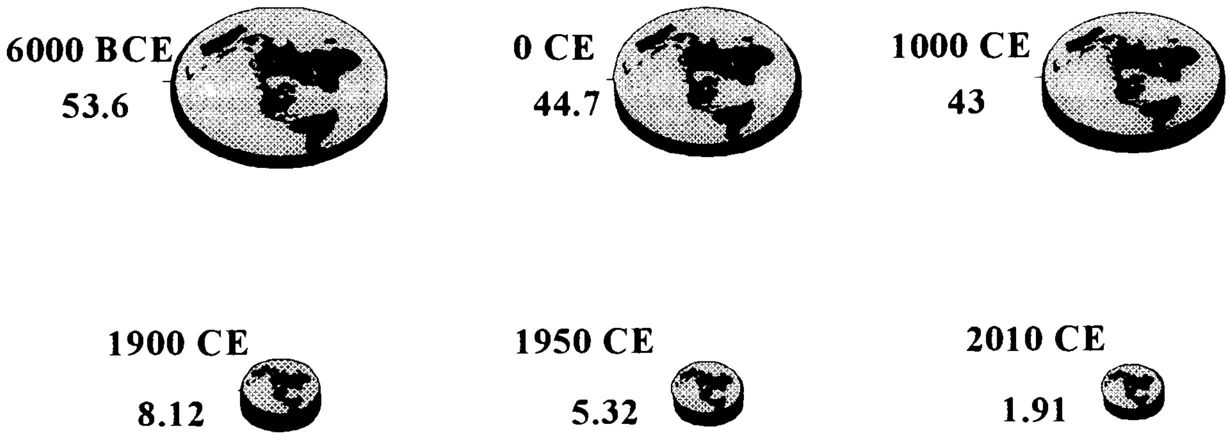


Figure 2-19: Shrinking biosphere (land area - ha per person) for selected years. Source: Lund 1997b.

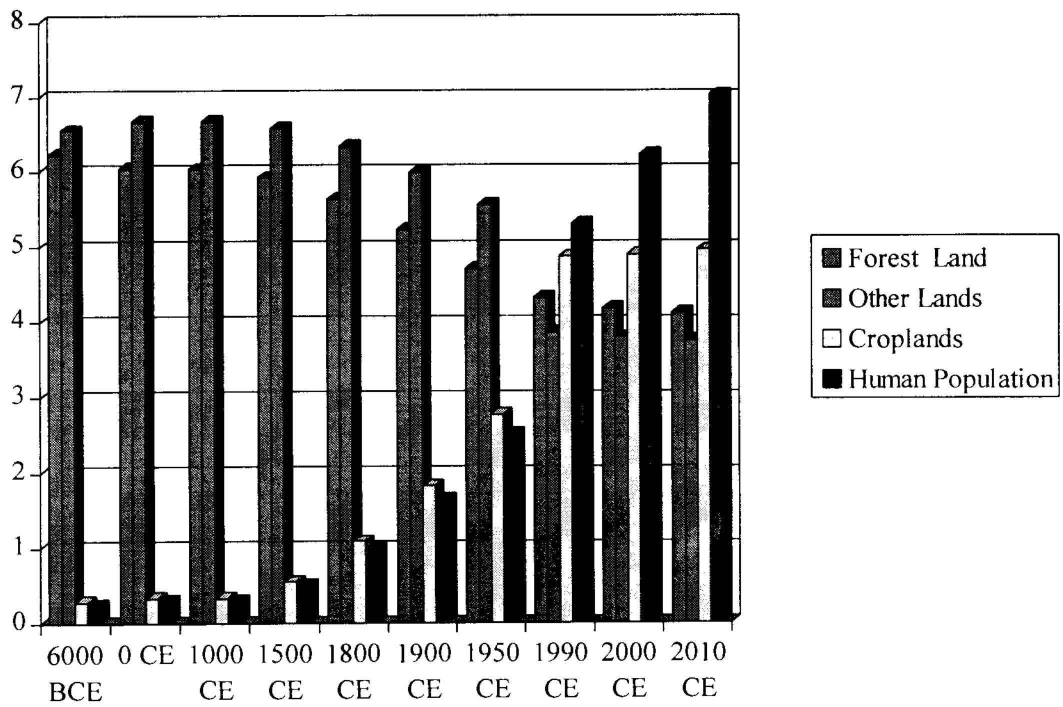


Figure 2-20: Changes in land use with increase in human population over time. Source: Lund 1997b.

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 modellingefforts (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.

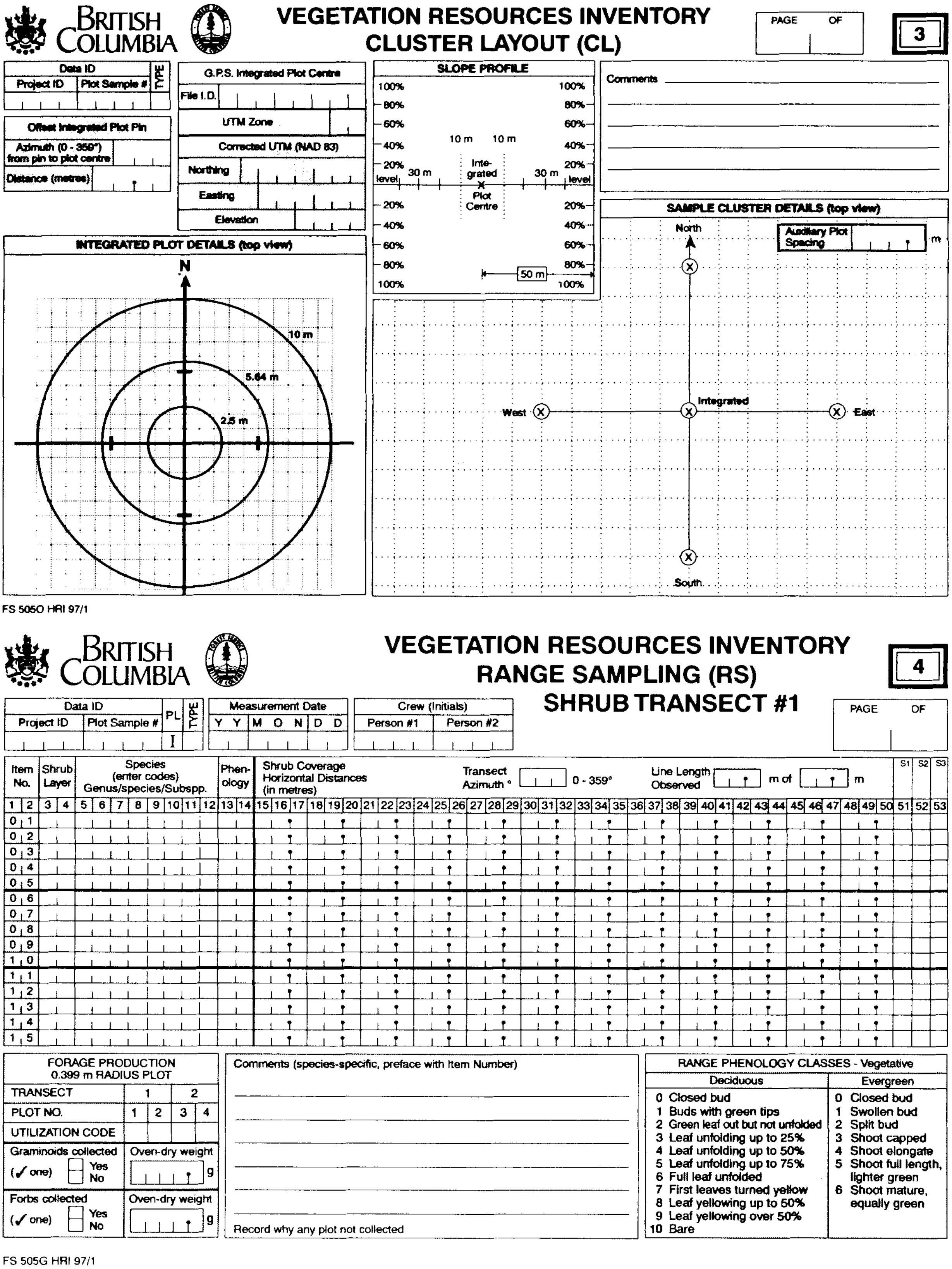
The vegetation inventory is based on a two-phase sampling design. Phase I involves subjective delineation and estimation of stands (polygons) using well-defined criteria and observable differences which can be recognised on aerial photographs on a scale of 1:15,000. Phase II involves establishment of 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 — Project ID | Plot Sample # | TYPE

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; 30 m; Integrated 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 505O HRI 97/1

BRITISH COLUMBIA

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

4

PAGE OF

Data ID — Project ID | Plot Sample # | PL | TYPE (I)

Measurement Date — Y Y M O N D D

Crew (Initials) — Person #1 | Person #2

Item No. | Shrub Layer | Species (enter codes) Genus/species/Subspp. | Phenology | Shrub Coverage Horizontal Distances (in metres) | Transect Azimuth ° 0 - 359° | Line Length Observed m of m | S1 | S2 | S3

Columns 1–53; Item No. rows 01–15

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.

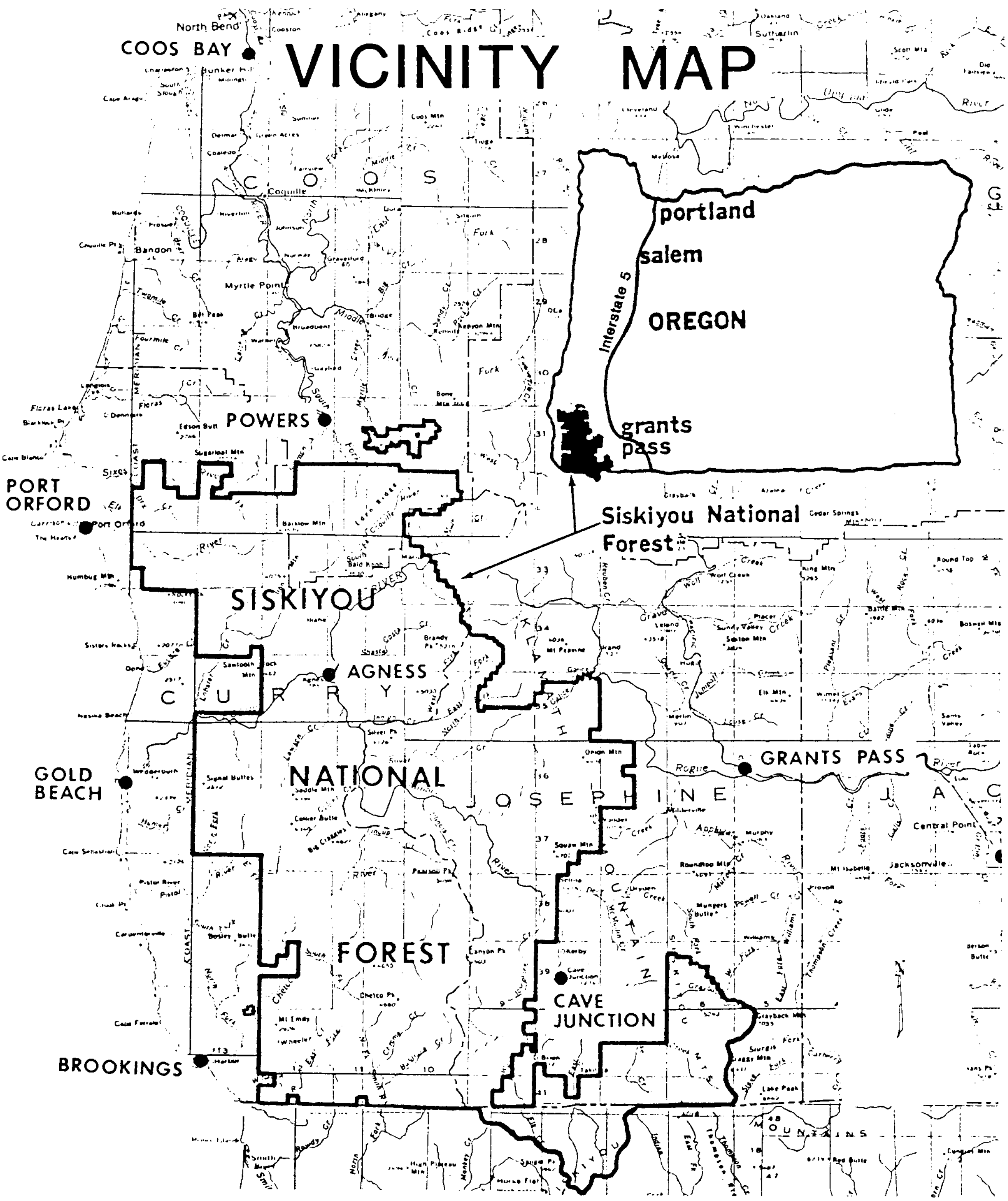
Most inventory information can be utilised for models. For example: the downed woody material items were collected to feed into a pine marten habitat model. Other items supported a pileated woodpecker model (Schroeder 1982) and the cover items supported a habitat effectiveness index (HEI) model that 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	HT RNGE	SLOPE POSITION	ELEVATION	SLOPE	ASPECT
OS							
				PLANT ASSOCIATIONS		WINDTHROW POTENTIAL	PLANTIBILITY PERCENT %
TOTAL OS				SOIL DEPTH	SOIL TEXTURE	COARSE FRAG.	PARENT MAT.
UPPER US							
				DUFF	DEER/ELK USE	HIDING COVER	STREAM/CLASS
TOTAL UPP US							
LOWER US							
				SNAG CLASS	DBH	HEIGHT	(1/5 ACRE PLOT)
TOTAL LOW US							
BC				S N A G S			
TOTAL BC							
G/F							
				DOWN WOODY MATERIALS (1/5 Acre Plot):			
				% GROUND COVER >3"			
				#STUMPS > 1'x7" DIA AND/OR # LOGS > 7"			
TOTAL GF				# 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.

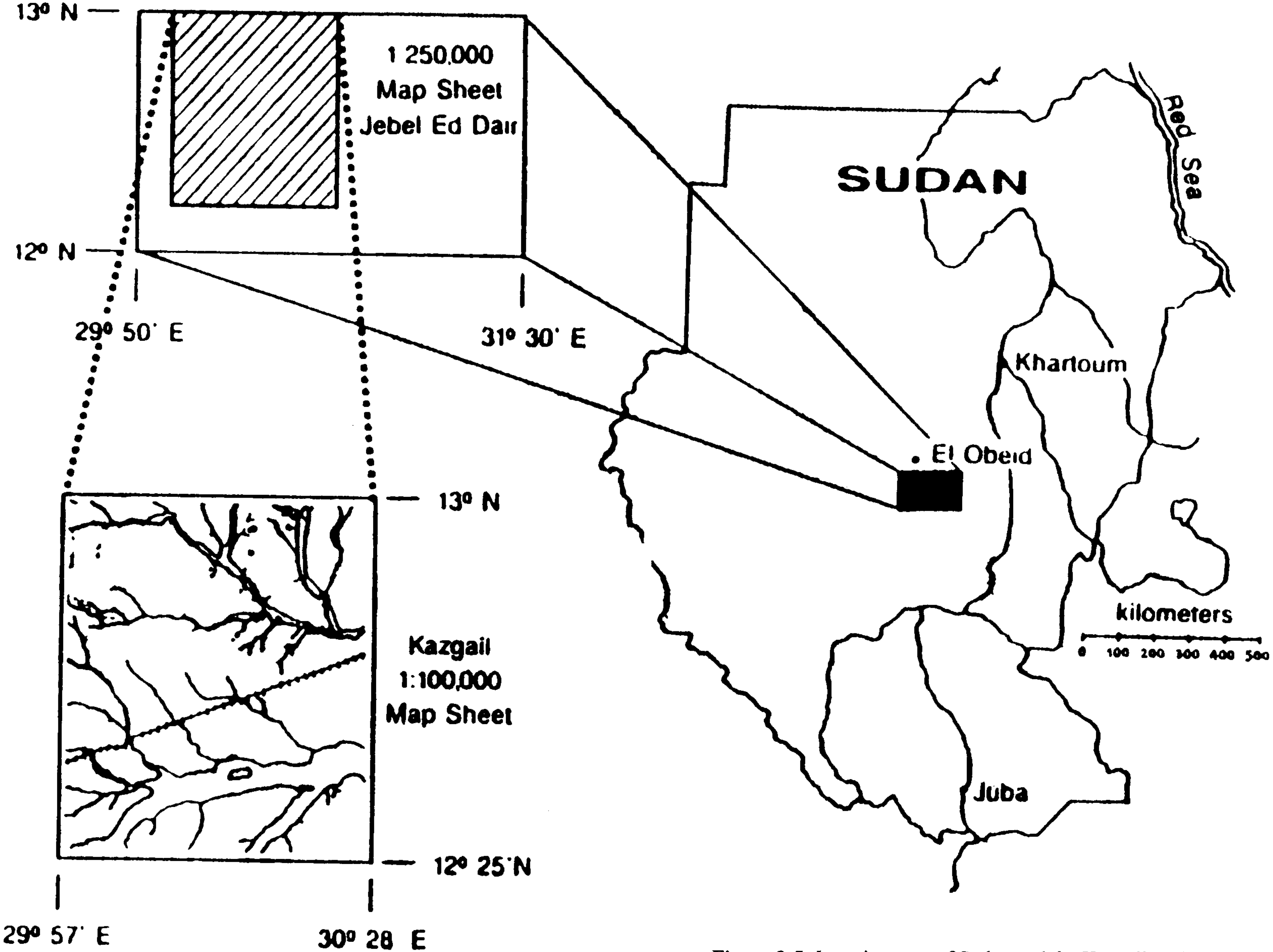


Figure 3-5: Location map of Sudan and the Kazgail Project Area.

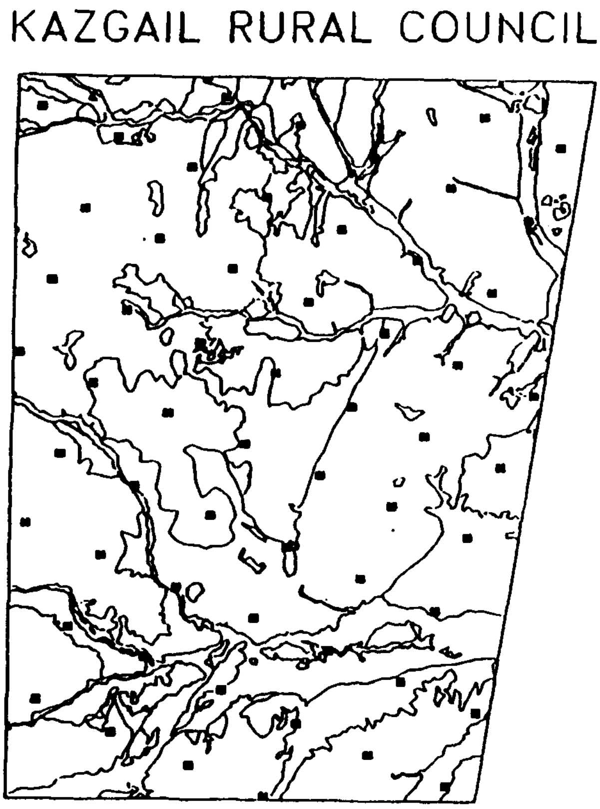


Figure 3-6: Distribution of sample plots in the Kazgail Project Area.

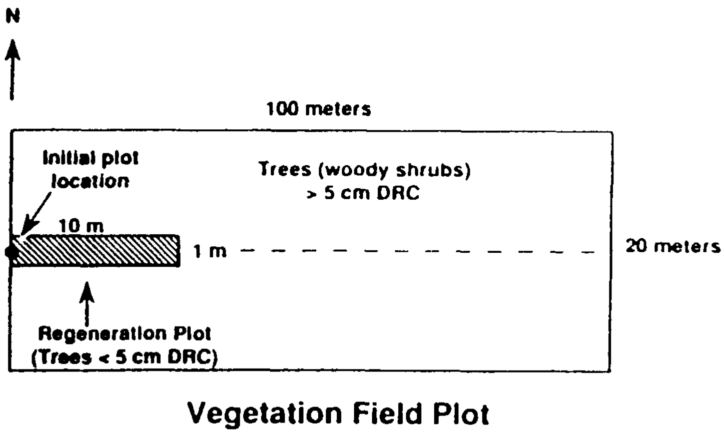


Figure 3-7: MRI field plot lay out. Herbaceous vegetation is measured along the centre line transect.

KASGAIL RURAL COUNCIL VEGETATION INVENTORY

PLOT NUMBER
PHOTO STRATUM
LAND COVER
LAND USE

LAND CONDITION
FOREST TYPE
TREE DENSITY
SOIL TYPE

PLOT WEIGHT
CREW
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 l'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.

Figure 3-9: Map of Indonesia showing the study areas.

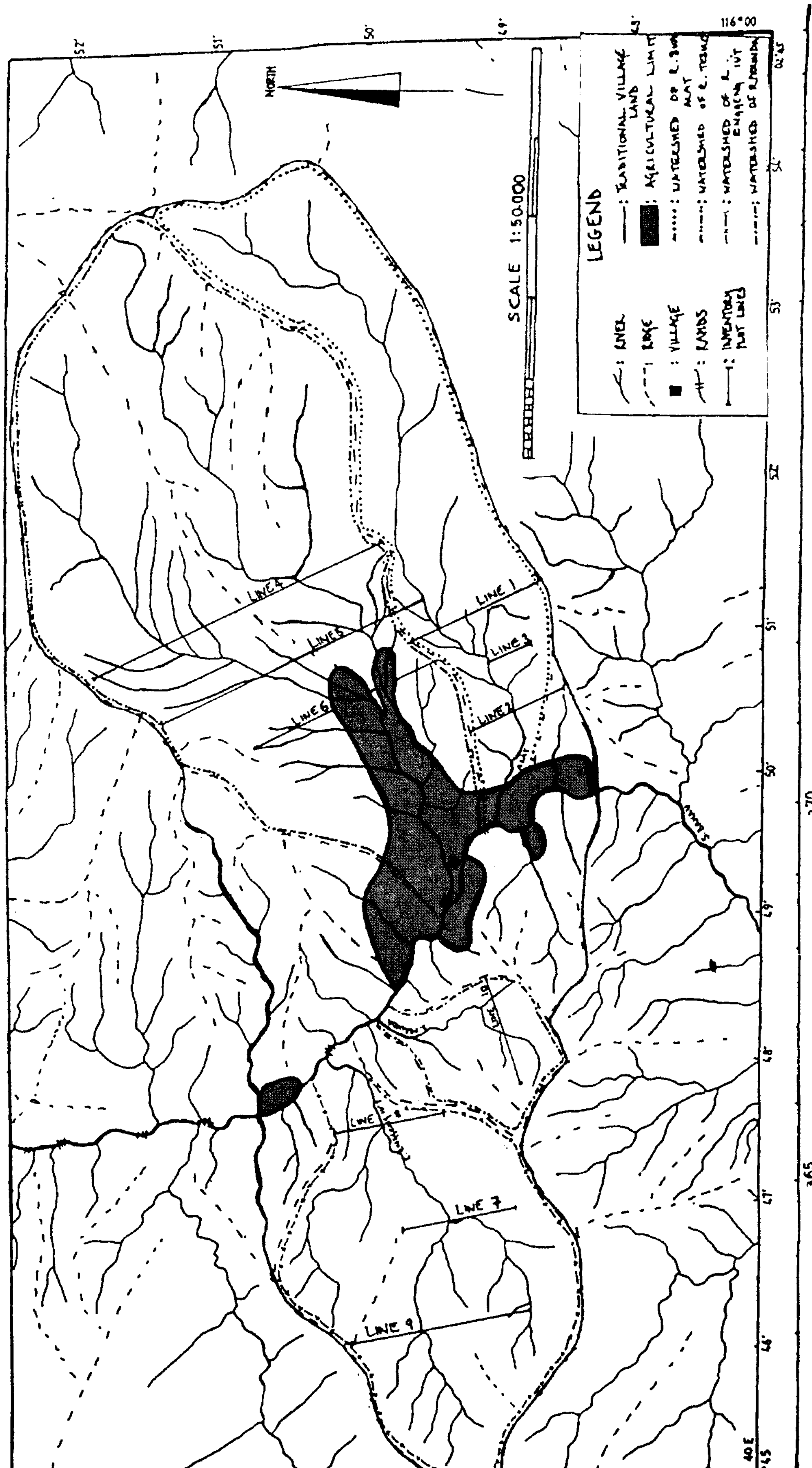


Figure 3-10: Inventory map of the Long Tebulo Village area.

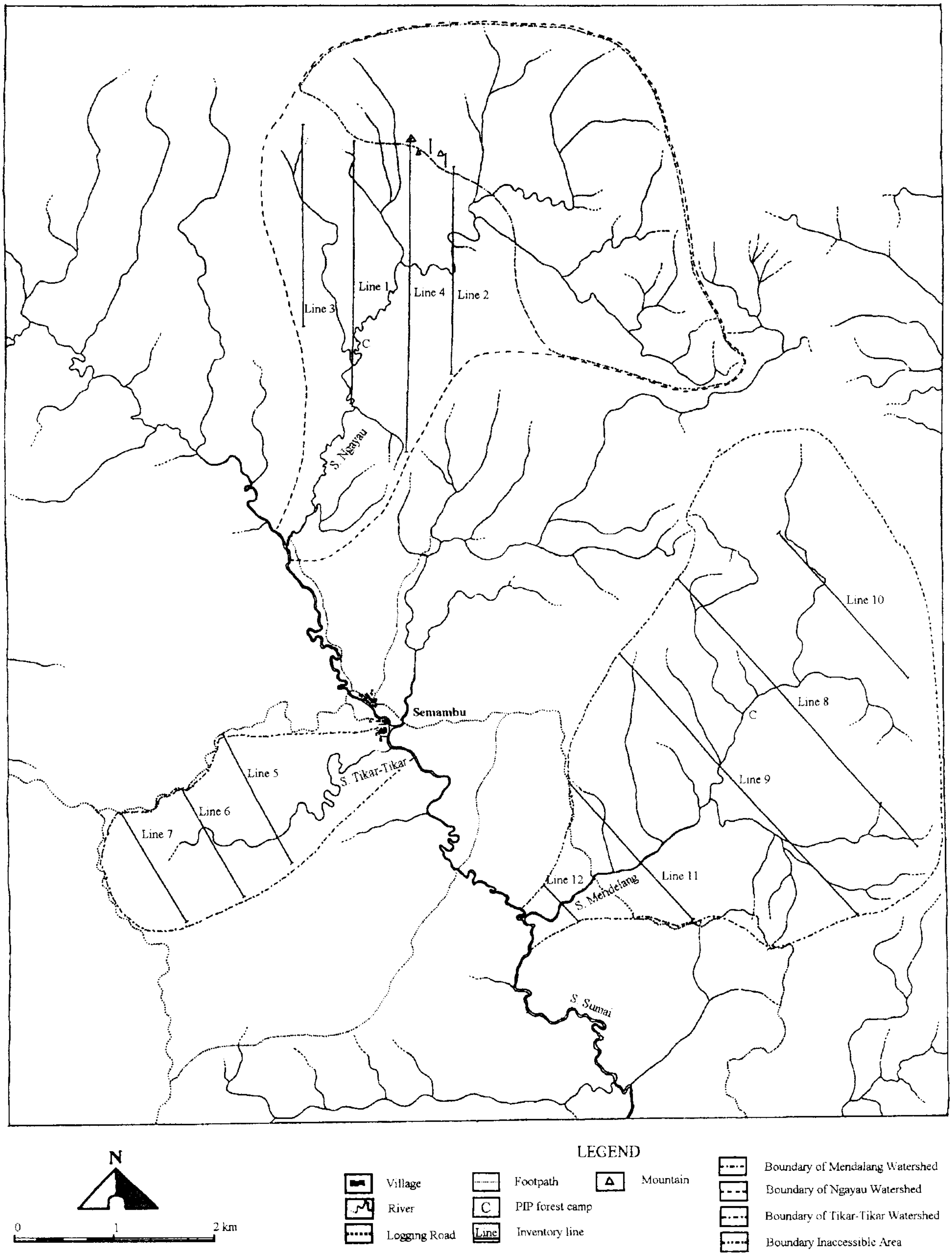


Figure 3-11. Inventory map of the Semambu Village area, Jambi Province, Sumatra.

Results from Semambu village. Some of the major results included:

- Evidence that Ngayau is the richest of the areas in most of the forest resources included in the inventory, such as timber trees, fruit trees, honey trees, *kemenyan* trees and bamboo. For this reason it is considered the area most important to the villagers. However, other areas in the inventory are also important because other resources are more common there; for example Tikar-tikar had the highest concentrations of *salak* and rattans and Mendalang had more *lipai*.

- Evidence that very few *durian* trees are regenerating. Unlike all other timber and fruit trees, there were more *durian* in the larger >31 cm d.b.h. class than in the 5-30 cm d.b.h. class. This spurred a discussion amongst the villagers about how their ancestors had originally planted the trees and resulted in a resolve to plant more trees in the near future to ensure a supply for future generations.

3.5.2.4 Lessons Learned

In addition to completing two trial inventories, members of the PIP team and villagers also evaluated the participatory mapping and inventory method. This evaluation was made using a number of techniques including: formal interviews of villagers after the community meetings, formal observations made during all meetings, informal feedback from villagers and PIP team members, analysis of precision, and analysis of the check data.

From this the following general observations have been made:

1. Were the inventory estimates precise? Tables 3-8 and 3-9 show, for Long Tebulo and Semembu villages respectively, the estimated overall mean number of plants per hectare for all of the chosen forest area together, the 90% confidence limits for this mean and the sampling error (the 90% confidence limits expressed as a percentage of the mean) for each of the chosen forest resources. The sampling errors were on the whole higher (or less precise) in Long Tebulo compared to Semambu. This is no doubt due to the lower number of plots established in Long Tebulo, where 347 plots were established, compared to Semambu, where 998 plots were established.

Tables 3-8 and 3-9 also show, for Long Tebulo and Semambu respectively, the sampling errors that can be achieved when the number of plots in the inventory are 2,500 and 10,000. If all forest resources which were considered extremely variable are excluded (i.e. those with a coefficient of variation (CV%) of greater than 700%), then a plot number of 2,500 is sufficient to bring the remaining nine resources in the Long Tebulo inventory and the remaining fifteen resources in the Semambu inventory to sampling errors of 20% or lower (at 90% probability). A plot number of 10,000 is sufficient to bring the same resources to sampling errors of 10% or lower.

The cost of achieving a desired sampling error is higher in Long Tebulo than in Semambu. In Long Tebulo, the steeper terrain only allows an average of 20 plots to be finished by one team in one day. Thus a sampling error of 10% or less for all but the most variable resources (which would require 10,000 plots to be established) would cost 500 team days, and a sampling error of 20% or less for the same resources (which would require 2,500 plots to be established) would cost 125 team days. In Semambu, an average of 30 plots could be finished per team per day. Here, a sampling error of 10% would cost 333 team days and a sampling error of 20% would cost 83 team days.

2. Were the inventory data accurate? Accuracy could not be measured directly as the "true" data values were not known, however, it was approximated by comparing the data gathered from the same plots by two different teams. Tables 3-7 and 3-8 show the results of three checks for Long Tebulo and Semambu, respectively. In Long Tebulo, there is no discernible trend over time in the differences between the original and the check data, perhaps a trend would have been observed had there been a larger number of plots revisited in each check. In Semambu the trend over time is a decrease in the differences between the original data and the check data. This improvement in accuracy is largely due to the information feedback to the teams from the check data. For this reason checks should be done at a higher intensity at the beginning of the field work, and lowered as the work progresses and fewer discrepancies between the original data and the check data can be seen.

The differences between original and check data were particularly large for some forest resources. These differences can be divided into four major types of errors. The teams found that some of these types of errors could be improved once discovered, whereas others continued to be a problem.

- *Small plants were often missed.* This error occurred for all small herbs, shrubs, saplings and seedlings, such as the <10 cm d.b.h. *sekau, bekai lanya, bekai lan* and *temaha* in the Long Tebulo inventory and *pasak bumi* in the Semambu inventory. The checks in Long Tebulo also showed that women focused on small plants because these often included resources of particular importance to them, such as the cooking herbs *bekai lan* and *bekai lanya*, whereas men tended to enumerate the trees only, therefore teams with no women often missed the smaller plants. There was no such gender difference in Semambu, where it seemed that this error occurred more often when individuals were tired, preoccupied with other tasks or simply less meticulous than their colleagues. This problem was difficult to rectify by discussion; perhaps one solution is to count small plants in smaller subplots, although this makes work in the field and later calculations more complex.

- *It was difficult to determine how to count clumped plants.* This difficulty was experienced for the rattans, the other palms and the bamboo enumerated in the two inventories. There were two types of error for these plants. One error was in determining whether all the size classes of plants should be included in the data. For example, in Semambu some people were counting the rattan clumps down to seedlings, at which stage it becomes very difficult to distinguish species, whereas other people were only counting rattan clumps that had already developed stems. This problem led to vast errors between teams in the first check, but was soon improved after discussion, following which the approach of the latter group of people was adopted. The other error was in determining whether a group of clumps in close proximity were all individual clumps or all one big clump. For example, in Semambu, *rotan udang* produces long underground stolons which lead to a much more spreading clump structure than those of *rotan sego* or *rotan jerenang*. Thus people differed much more in their judgement of what constitutes a clump when counting this species. This problem was difficult to rectify with discussion.

- *There were some differences of opinion about taxonomy.* Most older villagers were extremely good at identifying species, especially those included in the inventories since they were of particular importance to them. However, checks revealed some differences of opinion. In Semambu there was confusion over whether or not to include two types of *kulim*, a timber tree with an edible fruit. Although the two types of tree were from different genera the fruit tasted similar and both were referred to as*kulim*.

3. Were the important concepts underlying this method understood by the villagers?

- *Levels of understanding:* It was clear that not everyone in the villages understood all of the concepts underlying the mapping and inventory method to the same level. However, this was not so important as long as the concepts that are important for community decision-making (such as the potential purposes and objectives of mapping and inventory) are understood by all and as long as the other concepts, such as the technical aspects (including how to use a map or how to sample in order to estimate total quantities), are understood by at least some people, so that they continue to use the method and explain its products long after the PIP team has gone.

- *Who understands the concepts:* Understanding all concepts, particularly the technical ones, was easier for the younger, formally educated people in the village. However, the older, less educated people contributed a specialised knowledge of the area and the resources that was particularly useful when making the sketch maps, planning the objectives, finding the starting points of inventory lines, identifying the plants in the plots etc. Thus the knowledge and skills of the two groups together made for a formidable team, and meant that the maps and inventory data were produced efficiently and were of a higher quality than if outsiders such as the PIP team had tried to produce them by themselves.

4. Was this method participatory?

- *Within the village:* It is important to have participation from all sectors of the village community, as otherwise the decision-making, if made by a small group of villagers only, may be biased by their values and opinions alone. In this project, participation could be said to have been achieved in terms of actual numbers of villagers at meetings and representation of important sectors of society (such as men, women, youths) in all steps of the method; however participation in terms of equal involvement by all in decision-making was not achieved, as the older men tended to dominate the community discussions. This situation could not have been changed without major challenges to traditional institutions; at least this method provided an opportunity for the views of the less vocal groups to be brought forward.

Between villagers and outsiders: The mapping and inventory activities in this project were initiated and directed by outsiders (notably two researchers from the Oxford Forestry Institute), as part of a research project for testing and evaluating a new method. The focus of this project was on developing ways of involving the participation of the villagers in the mapping and inventory activities; the other stakeholders from the region who provided representatives to the PIP team (notably from WWF-Indonesia, the local timber concession and government) were not involved as equal participants.

It should be possible for villagers to initiate and direct the mapping and inventory process themselves. However, some assistance before and/or during the process may be needed from outsiders, in the form of thorough practical training with training materials that can be taken away to use as a basic reference, and equipment such as a base map, compasses and d.b.h. tapes.

The villagers are likely to be able to cover much of the inventory costs (such as labour, food supplies, etc.) if they feel that the products of the activities are of sufficient importance to be worth the expense. However, in most cases it might be unrealistic to expect that the village alone could obtain or pay for the training or equipment mentioned above.

It should also be possible for villagers to conduct this mapping and inventory work as part of a larger team of stakeholders, which might include members from government, non-government or commercial organizations. Mechanisms for involving these other stakeholders as full participants still need to be sought. For various reasons, there is often a high degree of mistrust by villagers of the motivations of outsiders; for this reason an emphasis on transparency in the involvement of all stakeholders is very important. Furthermore, to ensure that the participation of the villagers does not become restricted to a token presence on the team, it is important to try to maintain the villagers' full involvement in the planning of the mapping and inventory activities, in the collecting, compiling and analysis of data and in the implementation of results.

5. Was this method acceptable to the villagers? The ideals of ensuring full participation from all groups in the community at times clashed with culturally accepted norms. For example, in one of the villages the men did not see the need for the participation of women in the meetings and field work. This is a difficult and value-laden issue.

In general, however, the method met the approval of the villagers, although not without some suspicion of ulterior motives on the part of members of the PIP team. The involvement of villagers in the method from start to finish had the effect of decreasing suspicion and raising enthusiasm as time progressed. The feedback from both villages at the end was positive, with villagers commenting that they felt more confident to discuss issues with outsiders or within the village, now that they were armed with written documents to illustrate their statements.

Table 3-6: Forest resources chosen for the Long Tebulo inventory

Lepo Ke' name	Latin name	Uses	Information required
Sekau	*Aquilaria malaccensis (Thymelaceae)*	Aromatic incense with international market value	1. Trees <10 cm trees 2. Trees ≥10 cm trees
Bekai Lanya	*Coscinium miosepalum (Menispermaceae)*	Cooking herb with local market value	All shrubs
Bekai Lan	*Pycnarrhena cauliflora (Menispermaceae)*	Cooking herb with local market value	All shrubs
Sang	*Licuala sp. (Palmae)*	Leaves for roofing and hat making	All clumps
Da'a	*Pandanus sp. (Pandanaceae)*	Leaves for hat and basket making	All clumps with at least one stem
Wai Seka	*Calamus caesius (Palmae)*	Cane for construction and basket making	All clumps with at least one stem
Temaha	*Memecylon garcinddes (Melastomataceae)*	Stem for hunting spears and boat poles	Trees 3-10 cm d.b.h.
Kayu Merang	*(Rubiaceae)*	Timber for house foundations	1. Trees 30-59cm d.b.h. 2. Trees 60-89cm d.b.h. 3. Trees ≥90cm d.b.h.
Kayu Tenak	*Shorea spp. (Dipterocarpaceae)*	Timber for boards and boat building	1. Trees 30-59cm d.b.h. 2. Trees 60-89cm d.b.h. 3. Trees ≥90cm d.b.h.
Kayu Tumu	*Agathis borneensis (Araucariaceae)*	Timber for boards and furniture	1. Trees 30-59cm d.b.h. 2. Trees 60-89cm d.b.h. 3. Trees ≥90cm d.b.h.
Kayu Pung Ubi	*Ochanostachys amentacea (Olacaceae)*	Timber for house foundations	1. Trees 30-59cm d.b.h. 2. Trees 60-89cm d.b.h. 3. Trees ≥90cm d.b.h.
Kayu Kapun	*Dryobalanops lanceolata (Dipterocarpaceae).*	Timber for boards and joints in house construction	1. Trees 30-59cm d.b.h. 2. Trees 60-89cm d.b.h. 3. Trees ≥90cm d.b.h.
Kayu Nyeliwai	*Quercus argentea (Fagaceae)*	Timber for shingles	All trees ≥30 cm d.b.h.

Table 3-7: Forest resources chosen for the Semambu inventory

Jambi Dialect name	Latin name	Uses	Information required
Sialang	Canopy emergents (many species)	Honey from hives	All trees ≥50 cm d.b.h.
Kayu Kulim	*Scorodocarpus borneensis* and *Ochanostachys amentaceae (Olacaceae)*	Timber for construction and fruit for food	1. Trees 10-49 cm d.b.h. 2. Trees ≥50 cm d.b.h.
Kayu Tembesu	*Plectronia dydima (Rubiaceae)*	Timber for construction	1. Trees 10-49 cm d.b.h. 2. Trees ≥50 cm d.b.h.
Kemenyan	*Styrax benzoin (Styracaceae)*	Resin for smoking	Trees ≥5 cm d.b.h.
Durian	*Durio spp. (Bombacaceae)*	Fruit for food	1. Trees 5-29 cm d.b.h. 2. Trees ≥30 cm d.b.h.
Bedaro	*Nephelium eriopetalum* and *Paranephelium nitidum (Sapindaceae)*	Fruit for food	1. Trees 5-29 cm d.b.h. 2. Trees ≥30 cm d.b.h.
Petai	*Parkia spp. (Fabaceae)*	Seed for food	1. Trees 5-29 cm d.b.h. 2. Trees ≥30 cm d.b.h.
Cempedak	*Artocarpus spp. (Moraceae)*	Fruit for food	1. Trees 5-29 cm d.b.h. 2. Trees ≥30 cm d.b.h.
Salak	*Salacca spp. (Palmae)*	Fruit for food	All clumps
Lipai	*Licuala spp. (Palmae)*	Leaves for hat and basket making	All clump
Bambu Mayan	*(Graminae)*	Stems for fence, tool and, raft building and construction	All clumps with stems
Bambu Mumpo	*(Graminae)*	Stems for fence, tool and, raft building and construction	All clumps with stems
Rotan Sego	*Calamus caesius (Palmae)*	Cane for construction and household items	All clumps with stems
Rotan Udang	*Korthalsia echinometra (Palmae)*	Cane for household items	All clumps with stems
Rotan Jerenang	*Daemonorops propinqua and D. didymophylla (Palmae)*	Seed skin gives red dye with international market value	All clumps with stems
Pasak Bumi	*Eurycoma longifolia (Simarubaceae)*	Root for medicinal tonic	Shrubs

Table 3-8: Precision and accuracy of the data from the Long Tebulo inventory

Resource Name	**Precision**					**Accuracy**								
	Mean	*Conf Limits*	*CL/Mean %*	*CL/Mean %*	*CL/Mean %*	*1st Check*			*2nd Check*			*3rd Check*		
	Plants per ha	*Plants per ha*		if n = 2500	if n = 10000	*Orig*	*Check*	*Diff*	*Orig*	*Check*	*Diff*	*Orig*	*Check*	*Diff*
Sekau	20.63	±4.01	19.5	7.3	3.6	8	5	**3**	65	13	**52**	0	16	**16**
Bekai Lanya	0.06	±0.09	164.5	61.3	30.6	0	0	**0**	1	0	**1**	0	0	**0**
Bekai Lan	3.98	±1.74	43.9	16.3	8.2	7	10	**3**	0	0	**0**	0	0	**0**
Sang	12.68	±4.31	34.0	12.7	6.3	8	22	**14**	0	0	**0**	22	75	**53**
Da'a	2.07	±2.78	133.9	49.9	24.9	51	2	**49**	0	1	**1**	0	0	**0**
Wai Seka	1.84	±0.98	53.3	19.8	9.9	0	0	**0**	0	0	**0**	0	1	**1**
Temaha	12.05	±3.73	30.9	11.5	5.8	15	3	**12**	0	0	**0**	4	11	**7**
Merang	0.06	±0.09	164.5	61.3	30.6	0	0	**0**	0	0	**0**	0	0	**0**
Tenak	6.86	±1.23	18.0	6.7	3.3	8	3	**5**	9	14	**5**	8	3	**5**
Kapun	2.36	±1.25	53.0	19.8	9.9	0	0	**0**	0	0	**0**	4	4	**0**
Tumu	0.12	±0.13	116.2	43.3	21.6	0	0	**0**	0	0	**0**	0	0	**0**
Pung Ubi	0.69	±0.35	50.6	18.9	9.4	0	2	**2**	0	0	**0**	2	0	**2**
Nyeliwai	7.49	±1.47	19.7	7.3	3.7	21	4	**17**	0	3	**3**	5	2	**3**

Table 3-9: Precision and accuracy of the data from the Semambu inventory

Resource Name	Precision					Accuracy								
	Mean: Plants per ha	*Conf Limits: Plants per ha*	*CL/Mean %*	*CL/Mean % if* n = 2500	*CL/Mean % if* n = 10000	*1st Check*			*2nd Check*			*3rd Check*		
						Orig	*Check*	*Diff*	*Orig*	*Check*	*Diff*	*Orig*	*Check*	*Diff*
Sialang	2.38	±0.43	18.0	11.4	5.7	19	9	**10**	2	6	**4**	4	4	**0**
Kemenyan	4.55	±0.86	18.9	11.9	6.0	8	4	**4**	25	0	**25**	0	1	**1**
Kulim	12.38	±1.33	10.7	6.8	3.4	22	0	**22**	20	0	**20**	19	5	**14**
Tembesu	3.85	±0.72	18.6	11.8	5.9	24	2	**22**	17	3	**14**	1	0	**1**
Durian	5.29	±0.86	16.3	10.3	5.1	12	14	**2**	31	0	**31**	2	1	**1**
Bedaro	9.10	±1.47	16.2	10.2	5.1	34	132	**98**	14	3	**11**	0	0	**0**
Petai	3.69	±0.58	15.8	10.0	5.0	3	5	**2**	10	1	**9**	15	5	**10**
Cempedak	1.56	±0.34	21.9	13.9	6.9	1	0	**1**	2	0	**2**	0	1	**1**
Pasak Bumi	18.82	±1.63	8.7	5.5	2.7	36	24	**12**	20	24	**4**	60	86	**26**
Lipai	94.63	±11.77	12.4	7.9	3.9	7	11	**4**	27	43	**16**	370	440	70
Salak	3.79	±1.12	29.6	18.7	9.3	4	3	**1**	0	0	**0**	3	2	**1**
Bambu Mayan	1.28	±0.60	47.1	29.8	14.9	31	30	**1**	0	0	**0**	1	1	**0**
Bambu Mumpu	7.82	±2.51	32.2	20.3	10.1	153	164	**11**	0	0	**0**	0	0	**0**
Rotan Sego	2.77	±0.81	29.1	18.4	9.2	248	3	**245**	0	3	**3**	3	2	**1**
Rotan Udang	10.70	±2.31	21.6	13.6	6.8	178	3	**175**	1	2	**1**	42	17	**25**
Rotan Jerenang	10.68	±1.95	18.2	11.5	5.8	174	30	**144**	1	189	**188**	2	10	**8**

3.6 MEASURING AND MODELLING NATURAL DISTURBANCES IN NEW YORK STATE

The study compares and contrasts the impacts of a large-scale natural disturbance and the impacts of selective timber harvesting on focal fauna and flora of mixed northern hardwood – spruce forests in Adirondack Park, New York (Fimbel and Fimbel 1997). Lessons learned from response of the biological community to the natural disturbance will be translated to recommendations for silvicultural practices which minimise differences between the natural (windstorm) and anthropogenic (logging) disturbance regimes.

☺ Case Study Synopsis

Area of Concern: Adirondack Park, New York, USA. The Adirondacks are a 6 million acre (2.4 million ha) reserve comprised of totally protected lands interspersed with managed, private forest holdings.

Problem: A paucity of information to promote the conservation of biodiversity within mixed northern hardwood-spruce forest types targeted for sustainable forest management.

Organization/Infrastructure Created: Research team from Wildlife Conservation Society.

Methods: Variety of schemes to sample both flora and fauna.

Results: Data were collected and analyses are in progress.

The study program addresses the following specific aims:

1. To provide baseline data to assess similarities/dissimilarities in the composition of the flora and fauna of virgin old growth forests subject to periodic landscape-scale natural disturbances and lands managed for timber production;

2. To identify silvicultural practices that mimic natural disturbance and maximise the conservation of biodiversity across the landscape, while remaining sensitive to economic considerations.

3.6.1 Project Design and Methodologies

To meet the first specific aim described above, the following experimental design and field sampling methods have been employed. The recommendations for silvicultural prescriptions, as indicated in specific aim #2, are subject to the identification of significant differences between old-growth and managed stands of similar seral states (to be derived from specific aim # 1)

3.6.1.1 Experimental Design

Within the western Adirondacks of New York, 12 hardwood-spruce sites were identified for field data collection: 6 in the virgin old-growth Five Ponds Wilderness Area, and 6 sites in production forests on private property. See Figure 3-12. The study plan includes 3 stands (replicates) in each of the following 4 'treatments': 1) old-growth, not blown down; 2) old-growth, with moderate blow down; 3) production forest nearing 'maturity' and slated for selective timber harvest in 1998; and 4) production forest nearing 'maturity' that will not be selectively cut for the duration of the study. The four sites in treatment #3 will convert to 'post-harvest' sites in subsequent years of the study.

Nested within each 20 acre (8 ha) study site, are replicated flora and fauna sub-plots. Each site is visited two times per year, first in late spring, and then again in mid-summer. Data have been collected using standardised methods applicable to studies in the region, on the following taxa: trees, shrubs, herbs, grasses, bryophytes and above-ground fungi (flora group); and, large mammals, small mammals, herpetofauna, birds, ground beetles, and spiders (fauna group). Characteristics of the habitat, including cover, soil types, slopes, and aspects, were also noted. A detailed description of the field sampling methods, which began in the spring of 1997, appears below.

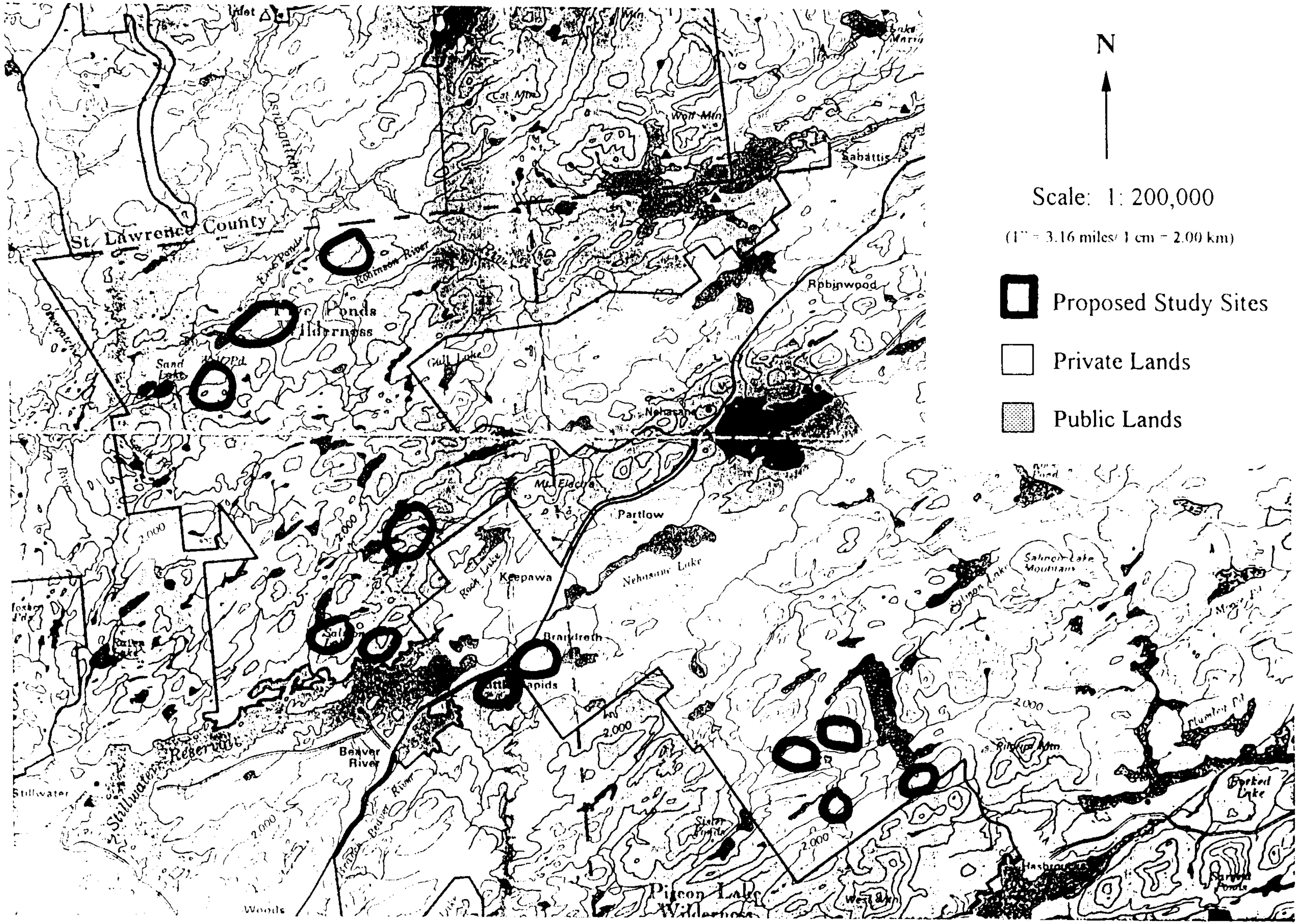


Figure 3-12: Location map of the Adirondack Park study area.

3.6.1.2 Field Data Collection Protocols

See Figure 3-13 for sampling layout and Figures 3-14 and 3-15 for sample forms.

Vegetation Plots - Vascular Plants: A series of overstory, understory, and regeneration sample plots are nested within each study site. Twenty circular overstory plots, 0.125 acres (0.05 ha) each, were systematically located across the area at ca. 200 foot (60 m) intervals. On sloping terrain, plots were corrected to a horizontal dimension. Within each of these plots, all stems greater than 4 inches (10 cm) d.b.h. were measured and permanently marked using aluminium tags. Variables noted on each tree included: 1) diameter; 2) canopy position; 3) estimated height; 4) general health (following guidelines in Allen *et al.* 1992); and 5) den site availability. Plot centres were permanently staked, and physical attributes noted (slope, aspect, proximity to streams, gaps, etc.).

Sapling stems, 0.25-4 inches (1-10 cm) d.b.h., were measured within 40-0.025 acre (0.01 ha) circular plots per site. Half of the plots were established within the 20 overstory plots, with the balance located between them. Sapling parameters measured include: 1) diameter; 2) estimated height; and 3) general health. Coarse woody debris (CWD), $\geq$4 inches (10 cm) in diameter, were measured and classified within each plot following protocols described by Tyrrell and Crow (1994). Finally, canopy closure over the plot was quantified using a point quadrat method (Greig-Smith 1983). Canopy cover at four height classes (0-7, 7-33, 33-66, 66+ feet or 0-2, 2-10, 10-20, 20+ m) was measured for 60 points distributed across each plot.

Regeneration was measured within 80-10.75 ft^2 (1 m^2) circular plots; two nested within each sapling plot. Seedlings of woody species <0.4 inches (1 cm) d.b.h. were recorded by 0-1, 1-3, 3+ foot (0-30, 31-90, 91+ cm) height classes. General health and evidence of animal browse were noted. The percent ground cover by herbaceous species, rock, soil, and litter in the plot, were also recorded. Where the identification of a species was in question, voucher specimens for that species were collected from outside of the regeneration plots. Regeneration plots were sampled two times/year; once for spring ephemerals (mid-May to mid-June), and again in mid-summer (early July to mid-August).

Above-ground Fungi & Bryophytes: Systematic surveys using a standard measure (counts, frequency, or biomass) during different parts of the season (and preferably over several years) are required to fully characterise fungal communities at different sites (Pilz and Molina 1996). Fungi are planned to be sample 2-3 x during the 1998 growing season, using macro-characteristics (fruiting bodies and mycelium), within all CWD plots. The percentage cover by bryophyte species was assessed one time during the spring growing season, in all regeneration plots.

Data from the vegetation surveys are being used to develop density (basal area and stems per acre/hectare for woody species), percent cover (herbaceous vascular plants and bryophytes), and measurements of ecological diversity (diversity and similarity indices for all plant groups), for use in comparisons of similarities/differences between 'treatment' areas.

Large Mammals: Line transect sampling between vegetation plots was employed to record large mammal sign (primarily deer, rabbit, and other large mammal dung), and live animal observations of deer, rabbits, squirrels, etc. The length of transect sampled per study site varied between 0.75-1.0 mile (1.2-1.6 km), depending upon the configuration of vegetation plots in the study site. Transects were walked at an average speed of 1 km/hr, adhering to the general guidelines for line transect sampling described by Burnham *et al.* (1980), Barnes and Jensen (1987), and Rudran *et al.* (1996). Data recorded for each observation included: time of day, distance along transect, perpendicular distance from transect to animal or sign observed, and direction of travel if the observation was a live sighting. Data are being used to calculate relative abundance of animals or sign per study site.

Small Mammals: The composition of the small mammal community was evaluated using Sherman live traps to capture small terrestrial mammal fauna such as rodents and insectivores. Parallel trap lines, approximately 540 feet (165 m) in length, were located in the central core area of each study site. Two large size Sherman traps (9"x 3.5"x 3"/ 23cm x 9cm x 7.5cm) were placed at each trap station, and stations were spaced 50 feet (15 m) apart along the 2 census trap lines for a total of 50 trap stations (100 traps) per study site. Traps were placed on the ground along natural features such as fallen logs or runways, but avoided sites with potential for flooding. Traps were baited with a mixture of peanut butter and rolled oats, and remained open for three consecutive nights. A fibre wadding was placed inside the traps to provide bedding and insulation for captured individuals. All traps were checked either one or two times daily, depending upon initial capture composition (where shrews were captured, traps were checked two times daily because these insectivores were at risk of mortality due to their exceptionally high metabolism). Each study site was sampled one time (equal to a period of 3 consecutive days) during the summer sample period. This yielded a total of 300 trap nights per study area. Although this number falls short of the 500 trap-night minimum recommended by Jones *et al.* (1996), when all three replicate stands of a single treatment (see overall study design) are considered together, this yielded data from 900 trap-nights to describe the small mammal fauna for a given treatment.

Captured animals were transferred to plastic bags to facilitate weighing and body measurement procedures, along with general observations of specific anomalies. Animals were identified to species with the aid of field guides, recording information on age and sex categories and breeding condition. Each animal was removed from the plastic bag by gripping the nape of the neck. The animal were marked by a dorsal fur clip (cutting dorsal fur in one of 6 places) which did not harm the animal in any way, and subsequently released.

<u>Bird Community</u>: There is a wide variety of field methods described for monitoring land birds, but point counts are the most efficient and data rich method of counting birds (Ralph *et al.* 1993). Point counts are most effective for passerine birds during breeding periods, but do not generally provide reliable data for quiet birds, large soaring birds such as hawks, nor waterfowl.

The composition of the bird communities in each of the study stands was evaluated using fixed-radius intensive point counts. Each stand contained 4 points, or sampling stations. Following the standardised recommendations outlined in Ralph *et al.* (1995), an experienced observer recorded the identification of all birds seen and heard within a radius of 164 feet (50 m) onto a point location mapping data sheet. The observer spent 15 minutes at each point, and separated data for birds detected during segments of 3 min., 2 min., 5 min. and 5 min. (= 15 minutes total). Birds detected at distances greater than 164 feet (50 m) from the observer but within the study site were recorded separately. Points were systematically located with a random starting point, and separated by a distance of 656 feet (200 m) to minimise repeat countings of the same species. All points were located at least 165 feet (50 m) from the stand border. Point counts were conducted within five hours of dawn, generally 05:30 h to 10:30 h, during the diel period of maximum vocal activity. Samples were not conducted during severe wind or rain storms when vocalisations or observations may be obscured by rustling leaves. Each stand was sampled twice early in the breeding season (mid-May to mid-June), and twice during the late breeding season (late June to mid-July) to maximise opportunities for recording all breeding birds, regardless of their time of breeding.

<u>Herpetofauna</u>: Sightings of reptiles and amphibians during visual encounter surveys along transect lines, and leaf-litter quadrat searches, were used to describe the herpetofauna community at each study site. Sites were sampled two times during the summer field sampling period.

- Visual Encounter Surveys: As a refinement of the visual encounter surveys described in Heyer *et al.* (1994), the line transects described for large mammals above were used for sampling herpetofauna. One observer walked 0.75-1.0 mile (1.2-1.6 km) of transect line in each study site, recording observations of amphibians and reptiles, especially frogs and toads, seen from the transect line. This procedure included searches within and under CWD one meter to either side of the transect. By sampling a straight line of measured distance, the data obtained allows comparison of relative abundance and species composition between treatment areas.

- Leaf Litter Quadrats: Twenty square leaf litter quadrats, 9.85ft x 9.85ft (3m x 3m) in size, were placed in a systematic random array in each study site, in close proximity to the vegetation plots. This quadrat size represents a compromise between the large 26.3ft x 26.3ft (8 m x 8m) and small 3.3ft x 3.3ft (1 m x 1 m) quadrats recommended by Heyer *et al.* (1994). Although the larger size is preferred, use of this large quadrat is constrained in the Adirondacks by relatively uneven terrain, and the limits imposed by a field crew size of only two individuals. Two field technicians recorded the starting time, and then begin to search slowly through leaf litter and ground detritus, sifting through the layers to locate amphibians, especially salamanders. A general sweep was conducted by each technician on their respective side so that layers of leaf litter are brushed from inside the plot to the outside, for example, from in front of the technician, to behind him/her. When animals were located, they were captured and immediately transferred to a plastic bag. When the two technicians finish, the end time was noted and the captured individuals were identified, measured, weighed, and subsequently released.

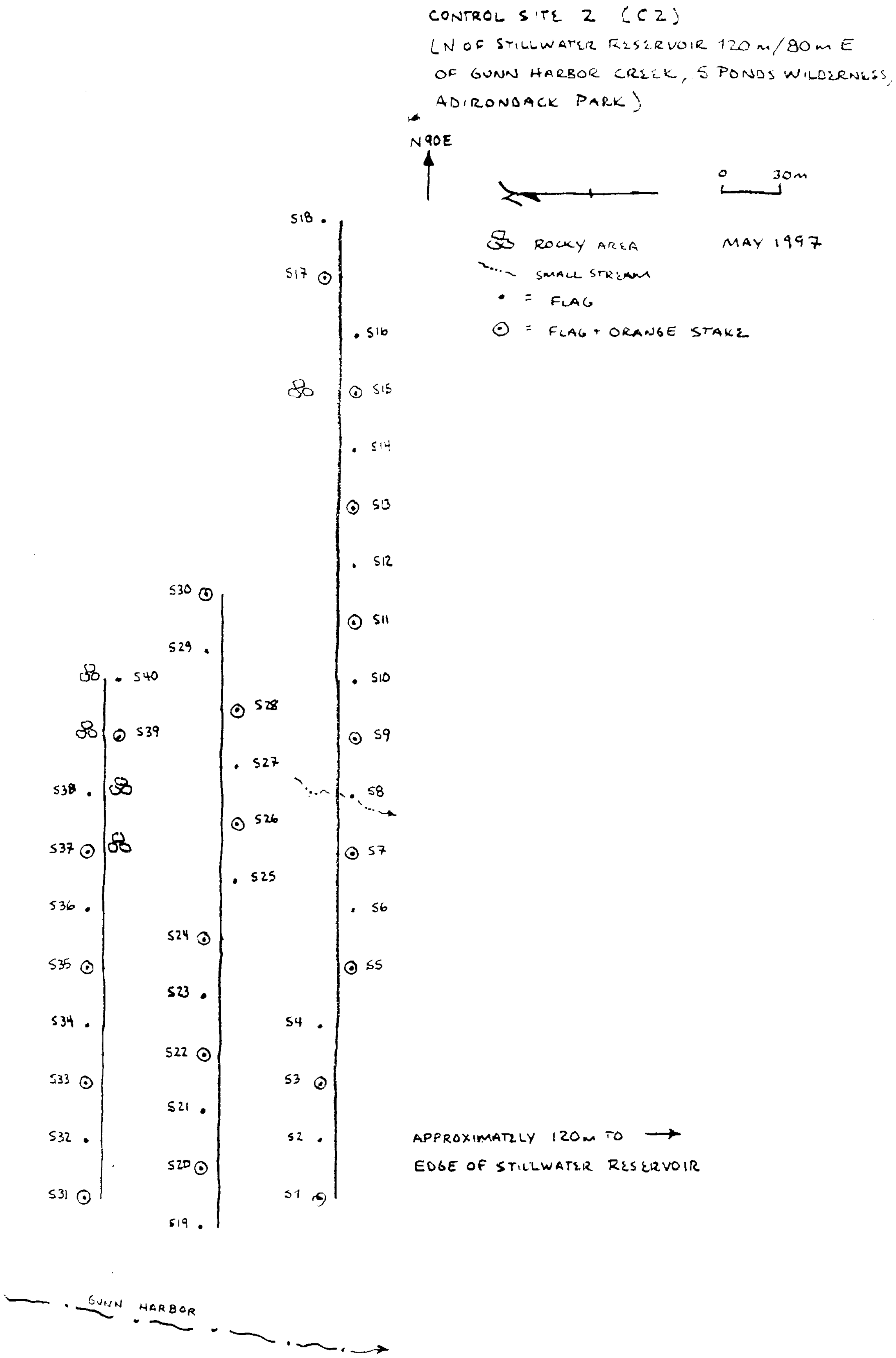


Figure 3-13: Example transect and plot layout.

ADIRONDACK BIODIVERSITY STUDY **Site:** ____________ **Crew:** ____________
Overstory Tree Plots (12.62 m/41.38 ft radius)

Slope: _____° Aspect: ______ Comments:

Tag #	Species	Diam (cm)	Diam Ht (m)	Stem Angle	Canop Posit	Vigor	Den Qual	Comments

Slope: _____° Aspect: _____ C

Tag #	Species	Diam (cm)	Diam Ht (m)

ADIRONDACK BIODIVERSITY STUDY **Site:** ____________ **Date:** ____________
Understory Sapling Plots (5.64 m/18.51 ft radius) **Crew:** ____________

Plot:

Species	Diam (cm)	Diam Ht (m)	Stem Angle	Vigor	Comments

Plot:

Species	Diam (cm)	Diam Ht (m)	Stem Angle	Vigor	Comments

ADIRONDACK BIODIVERSITY STUDY **Site:** ____________ **Date:** ____________
Regeneration Plots (0.56 m/1.85 ft radius) **Crew:** ____________

				Cover			Seedlings			
T	R	P	Q	Species	%Cov	Comments	Species	Ht	#	Browse

				Cover			Seedlings			
T	R	P	Q	Species	%Cov	Comments	Species	Ht	#	Browse

ADIRONDACK BIODIVERSITY STUDY **Site:** ____________ **Date:** ____________
Down CWD Plots (5.64 m/18.51 ft radius) **Crew:** ____________

Trmt	Rep	Plot	Species	Sm Dia (cm)	Lg Dia (cm)	Lenght (m)	Decay	Comments

Trmt	Rep	Plot	ments

WCS AP Blowdown-Biodiversity Study

Site: **Date:**

Trmt: **Rep:** **Plot:** **Quad:**

Habitat:

Form:
type: woody / herb / fern-grp size (cm): ______
form: upright / trailing stem: single / multiple

Leaves:
arrangement: alternate / opposite / sub-opposite
form: simple / compound / whorled / basal
compound: imparipinnate / paripinnate leaflets: ______

Twig:
spines: stipules: bt: odor:

Flowers:
form: regular / irregular
stamen: #: ____
pistil: superior / inferior chambers: ______
petals: #: ____ color:
sepals: #: ____ color:

Fruits:
arrangement: size (cm): ______
color: seeds:

Name: Common:
Family:
Genus/Species:
WCS Adirondack BBS#

ADIRONDACK BIODIVERSITY STUDY **Site:** ____________
Ground Cover Transects (10m @ 0.1m intervals) **Crew:** ____________
Treatment: _____ **Replicaton:** _____ **Plot:** S_____

Transect __________ **Transect** _____

Species of Vegetation Observ.

Dist. (m)	0.5 - 1.0m	0.3 - 0.5m	0 - 0.3m	Grnd cond.	Dstrb class	Comments
0.0						
0.5						
1.0						

Species of

Dist. (m)	0.5 - 1.0m
0.0	
0.5	
1.0	

Adirondack Biodiversity Study **Site:** ____________
Canopy Cover Plots (50 point-samples/sapling plot)

Plot: ____________
Ht(m) Ctr 45° (NE) 2.5° (SW)
20+ _ _ _ _ _ _ _ _ _ _
10-20 _ _ _ _ _ _ _ _ _ _
2-10 _ _ _ _ _ _ _ _ _ _
0-2 _ _ _ _ _ _ _ _ _ _

Maximum gap size (2+ m high): ______m^2 (10+ m high): ______m^2 Comments: ________

Figure 3-14: Portions of the vegetation data forms.

WCS Transect Data Summary 1997

Observers:	Date:	Transect location:
Habitat: Wilderness or Private	Blow-Down or Intact	Transect length:
Time Begin:	Time Finish:	Weather:

Distance	Species	Sign	Age	SIGN P/dist	Habitat	Comments

WCS SMALL MAMMAL TRAP DATA SUMMARY 1997

Observers:

study plot # (1-12)	W... or P...	B-D or I...	Date	night weather	trap #	species	recapture?	age	sex	mass total	mass bag	mass net	bod len	tail len	Comments

WCS Bird Summary Data Form - 50 m radius points 1997

OBSERVER:

study plot # (1-16)	Wild or Priv	B-D or Intac	Date	point #	Time	Species	< 50 m 0-3 min	< 50 m 4-5 min	< 50 m 6-10 min	< 50 m 11-15 min	fly- overs 0-3 min	fly- overs 4-5 min	fly- overs 6-10 min	fly- overs 11-1 min	> 50 m 0-3 min	> 50 m 4-5 min	> 50 m 6-1 min	> 50 m 1-1 min

Herpetofauna Transect Summary

WCS Adirondack Biod., 1997

Observer(s):_______________

month	day	Study Area	Wild. or Private	30 m segment	rock	wood	species	found in r or w

Figure 3-15: Portions of fauna data collection forms. WCS stands for Wildlife Conservation Society.

Basic habitat parameters were also be noted, including slope, cover, air temperature, soil moisture, depth of leaf litter, and special features in or near the plot such as streams, spring seeps, rock outcrops, etc. Litter was redistributed across the disturbed site at the close of the search. These data are being used to describe the species composition and estimate the absolute density of the more common amphibians in each study site.

Ground Beetles and Spiders: Ground beetles and spiders can be captured readily in pitfall traps arrayed across the forest floor (Bell 1990). Based on our conversations with Dr. Ross T. Bell, a noted Carabidologist at the University of Vermont, we constructed five trap sets, each consisting of five pitfall traps within each of the 12 - 8 ha stands studied. The pit traps were small, clear, disposable plastic "martini" glasses, which can be purchased inexpensively at local supermarkets. For each pitfall, a small hole was dug in the ground so that the lip of the cup was level with the ground surface. A second cup was then nested within the first and filled with 1 inch (2.5 cm) of water to which a few drops of formalin were added. The formalin was added to discourage omnivorous mammals from eating the contents of the traps and to kill the captured invertebrates quickly and prevent them from damaging other specimens. The trap was overlain with a plastic plate to protect it from flooding by rainfall. Traps were checked weekly for four weeks in mid-summer, at which time the contents were sieved, and captured individuals were deposited into 70% ethanol solution in collection vials for preservation and identification.

3.6.2 Data Analysis

A variety of simple and sophisticated statistical analyses are being used to contrast community structure of the various groups assayed in the different forest treatments. Data from the randomised block design for the study sites are being subjected to Analyses of Variance (ANOVA's) to identify significant differences in plant and animal populations, species assemblages, and habitat parameters between 'treatments' (Chambers and Brown 1983, Zar 1984, Magurran 1988). Of particular interest will be the extent to which community shifts are similar or different among groups, especially between invertebrates and vertebrates, and among herbaceous plants, bryophytes, and fungi. Minimally, we are calculating measures of species richness, diversity, evenness and dominance, and examining relationships among sites and treatments using clustering techniques, multidimensional scaling, and rarefaction techniques (Michaels and McQuillan 1995, Pettersson 1996). Among invertebrate groups, we are also characterising communities or guilds based on body size, dispersal ability, foraging tactic, and special habitat needs. Lastly, our data are being digitised and geo-referenced, and thereby serving as a baseline for future monitoring.

3.6.3 Anticipated Outputs

Comprehensive outputs will be available at the close of the first phase of the study, early in the year 2000. A first progress reports is slated for March, 1998, and will provide summaries and interpretations of data collected during the 1997 field season. The following outputs are related to the two specific aims of the study.

Specific Aim #1: To provide baseline data to assess similarities/dissimilarities in the flora and fauna of virgin old growth forests subject to periodic landscape-scale natural disturbances and lands managed for timberproduction.

- A description of the structure and composition of woody and herbaceous vegetation, fungi and bryophytes, and CWD, for each stand, and summarised at the treatment level.

- A description of the composition and relative abundance of the carabids, araneae, herpetofauna, avifauna, and non-volant mammal communities for each stand, and summarised at the treatment level.

- Estimates of measures of diversity for each stand and treatment category.

- Statistical comparison of taxonomic and community level parameters, including composition and diversity, using indices of similarity, across treatments.

- Analyses of habitat parameters, as an aid to identification of environmental factors responsible for significant differences in the biotic composition between treatments (where differences exist).

Specific Aim #2: To identify silvicultural practices that mimic natural disturbance and maximise the conservation of biodiversity across the landscape, while remaining sensitive to economic considerations.

- An evaluation of current silvicultural practices and their influences on biodiversity, including an assessment of ways to improve the conservation of biodiversity across hardwood-spruce forest landscapes (based upon the above analyses) through the use of silvicultural habitat modification techniques.

☺ This approach of describing and contrasting the dynamic nature of northern forest lands, overcomes biases associated with historical evaluations based on relatively static, mature old growth stands as the standard for comparison with stands managed for timber production. The information generated by this undertaking will provide innovative standards for the assessment and modification of efforts to promote the conservation of biodiversity in sustainably managed forest landscapes.

APPENDICES

APPENDIX 1. REFERENCES AND ADDITIONAL READING

We encourage the readers to consult the following documents for more details on how to develop and implement multipurpose resource inventories.

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APPENDIX 2. ABBREVIATIONS AND ACRONYMS

Abbreviation /Acronym	Meaning
A21	Agenda 21
AHP	Analytic Hierarchy Process – AHP is a multi-criteria decision analysis tool that involves choosing from a number of alternatives based on how well those alternatives rate against a chosen set of criteria. The criteria are weighted by importance to the decision-maker. The overall "score" of an alternative is the weighted sum of its rating against each criterion (Peterson, *et al.* 1994, Schmoldt, Peterson, and Smith 1994, and Schmoldt, Peterson, and Silsbee 1994).
AIFM	ASEAN Institute of Forest Management
ANOVA	Analysis of Variance
AR/GIS	Active Response Geographic Information System – AR/GIS is a multi-user GIS tool used for place-based negotiations. The tool serves as a linkage between electronic meeting systems and GIS. Meeting participants interact with laptop computers to assess the current status, develop decision criteria, and propose geographically based proposals and scenarios. The GIS simulation models used in the negotiations are site specific. AR/GIS requires the use of a trained facilitator and a skilled ArcView operator (Fox and Faber 1995).
AUM	Animal Unit Month
BC	British Columbia, Canada
BCE	Before Current Era
BPHUT	Badan Inventarisasi Pemetaan Hutan (Forest Mapping and Inventory Organization - Indonesia)
CBD	Convention on Biological Diversity
CE	Current Era
CL	Confidence Limits
COD	Convention on Desertification
CRII	Corporate Resource Inventory Initiative
CWD	Coarse Woody Debris
d.b.h.	Diameter Breast Height
DFID	Department for International Development (U.K.)
d.o.b.	Diameter Outside Bark
d.r.c.	Diameter at Root Collar
DPC	Desired Potential Community
ECE	Economic Commission for Europe
EROS	Earth Resources Observation Satellites
FAO	Food and Agriculture Organization of the United Nations
FAQ	Frequently Asked Questions
FCCC	Framework Convention on Climate Change

Abbreviation /Acronym	Meaning
FNC	Forests National Corporation (Sudan)
FNIC	First Nations Inventory Committee (British Columbia)
FIA	Forest Inventory and Analysis
FP	Forestry Principles
FRA	Forest Resource Assessment
FRAGSTATS	FRAGSTATS is a spatial pattern analysis program for quantifying landscape structure. Two versions of FRAGSTATS exist: one for vector images and one for raster images. FRAGSTATS generates a variety of area metrics, patch density, size and variability metrics, edge metrics, shape metrics, core area metrics, diversity metrics, and contagion and interspersion metrics. The raster version also computes nearest neighbour metrics (McGarigal and Marks 1995).
FVS	Forest Vegetation Simulator – FVS (formerly PROGNOSIS) simulates the future state of primary vegetation (growth and yield). FVS also includes various extensions to represent shrubs, insects, disease, and fire-behaviour. FVS has model variants for throughout the United States. FVS is used in forest planning to predict vegetation through time. Data from FVS are used in Spectrum models. (Teck *et al.* 1996 and Wykoff *et al.* 1982).
GIS	Geographic Information System
GOS	Government of Sudan
GPS	Global Positioning System
HEI	Habitat Effectiveness Index
HTML	Hypertext Mark-up Language – The World Wide Web's text-based coding system, as scripting language that is used to write World Wide Web pages. Hypertext allows a document to be linked to an unlimited number of other documents on the Web.
IMPLAN	IMPact analysis for PLANning – IMPLAN tracks regional economic impacts of project, program, and policy decisions. Using input-output analysis, IMPLAN builds profiles of regional economic linkages under different scenarios posed by the analyst. IMPLAN is applicable throughout the United States. An analyst uses it to construct input-output models for any county or groups of counties (USDA Forest Service 1993b).
ICFR	Institute for Commercial Forestry Research (South Africa)
IRG	International Resources Group
ISAFA	Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura (Italy)
IUCN	The World Conservation Union
IUFRO	International Union of Forestry Research Organizations.
KPHP	Kesatuan Pegusahaan Hutan Produksk (Production Forest Management Unit - Indonesia)
MAGIS	Multi-Resource Analysis and Geographic Information System - MAGIS is a tactical planning model for planning land management and transportation-related activities on an area or project. The user operates MAGIS in both optimisation and simulation modes. For strategic planning, the user builds MAGIS models for representative projects to test spatial feasibility and other site-specific constraints. The user then applies a better estimate of these constraints to the strategic forest plan model (Zuuring *et al.* 1995).
MMRC	Mensuration and Modelling Research Consortium (South Africa)

Abbreviation /Acronym	Meaning
MOA	Ministry of Agriculture
MRI	Multipurpose Resource Inventory
NFMA	National Forest Management Act (U.S.A.)
NFS	National Forest System (U.S.A.)
NIJOS	Norsk Institutt for Jord- Og Skogkartlegging (Norwegian Institute of Land Inventory)
NSO	National Statistics Office
NTFP	Non-Timber Forest Product
NWGS	Non-Wood Goods and Services
ODA	Overseas Development Administration (United Kingdom)
P.L.	Public Law
PIP	Pemetaan dan Inventarisasi Partisipatif (Participatory Mapping and Inventory)
PNC	Potential Natural Community
PRA	Participatory Rural Appraisal
PT.IFA	Industries et Forets Asiatiques (Asian Industries and Forests Companies)
RELMDSS	Regional Ecosystem and Land Management Decision Support System – RELMDSS is an integration, analysis, and display tool for the generation and implementation of forest and land use plans. The tool evaluates the effects of various existing or proposed allocations, standards and guides, and treatment schedules related to meeting multiple objectives or desired future conditions across several time periods and scales (Church *et al.* 1994).
RIC	Resource Inventory Committee (British Columbia)
RICTG	Resource Inventory Co-ordination Task Group (USDA Forest Service)
RHV	Range of Historic Variation
RPA	Renewable Resources Planning Act (United States)
RRA	Rapid Rural Appraisal
SAF	Society of American Foresters
SIMPPLLE	Simulation of Patterns and Processes at Landscape Scales – SIMPPLLE simulates change in vegetative states by using processes (insects, diseases, wildfire) and management treatments. SIMPPLLE addresses only the existing vegetative component of landscapes. Application of SIMPPLLE requires adjusting the vegetation and processes to a specific area (Chew 1993 and 1997).
SMART	Simple Multi-attribute Rating Technique – SMART is another multi-criteria decision analysis tool. In SMART, the user assigns ratings of alternatives directly in the natural scales of the criteria. SMART is more appropriate to use if the user is likely to add new alternatives to the model later. Information on AHP and SMART software can be found on the World Wide Web (WWW).

Abbreviation /Acronym	Meaning
SNAP	Scheduling and Network Analysis Program – SNAP assists in scheduling and transportation planning for resource management projects. For strategic planning, the user builds SNAP models for representative projects to test spatial feasibility and other site-specific constraints. The user then applies a better estimate of these constraints to the strategic forest plan model (Sessions and Sessions 1991).
SPECTRUM	Spectrum is a linear programming model designed to schedule management treatments to achieve ecosystem management, financial, or other goals. Use Spectrum to examine trade-offs and to evaluate alternative management scenarios for strategic planning. Spectrum has the ability to do goal programming. The user enters all data into Spectrum. Analysis requires inventory data and the results of simulation models such as FVS (Sleavin and Camenson 1994, USDA Forest Service 1997).
SRAAD	Sudan Reforestation and Anti-Desertification Project
SSD	Sudan Survey Department
TM	Thematic Mapper
TETF	Terrestrial Ecosystem Task Force (British Columbia)
TITF	Timber Inventory Task Force (British Columbia)
TRIM	Terrain Resource Information Management (British Columbia)
UNCED	United Nations Conference on Environment and Development
URL	Unique Resource Locator - The naming convention computers use to locate pages or documents on the World Wide Web.
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geologic Survey
VDDT	Vegetation Dynamics Development Tool – VDDT simulates successional pathways and examines the potential effects of disturbance agents on the vegetation (Beukema and Kurz 1996).
VIWG	Vegetation Inventory Working Group (British Columbia, Canada)
WAG	World Agriculture Assessment
WAIS	Wide Area Information Service. The WAIS system is a collection of programs which provide for convenient information distribution over wide area networks).
WCS	Wildlife Conservation Society
WFUD	Wildlife/Fisheries User Day
WSL	World Species List
WWF	World Wide Fund for Nature or World Wildlife Fund
WWW	World Wide Web or more simply, the web. The graphical part of the Internet. A system that allows a user to search for related "pages" across the Internet.
😐	Tip – generally for information only
☺	Tip showing some recommended action
☹	Tip - things to avoid

APPENDIX 3. GLOSSARY

Accuracy – The ability of a method to obtain the "correct" or "true" value. The success of estimating the true value of a quantity. Accurate estimates have low bias and high precision.

Administrative Unit – The basic geographic management area within a land management organization.

Adverse Effects of Climate Change – Changes in the physical environment or biota resulting from climate change, which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare (FCCC).

Anadromous Fish – Fish which are born in fresh water and spend part of their lives in the ocean and then return to fresh water to spawn.

Animal (Deer/Elk) Sign – Indicators of wildlife that include the animals themselves, scat, trails (well used only), tracks, elk wallows, antler rubs, bed grounds, calving areas, mineral licks, or browse.

Aquatic Habitat Types – The classification of instream habitat based on location within channel, patterns of water flow, and nature of flow controlling structures. Riffles are divided into three habitat types: low gradient riffles, rapids, and cascades. Pools are divided into seven types: secondary channel pools, backward pools, trench pools, plunge pools, lateral scour pools, dammed pools, and beaver ponds. Glides, the third habitat type, are intermediate in many characteristics between riffles and pools. It is recognised that as aquatic habitat types occur in various parts of the country additional habitat types may have to be described. If that becomes necessary it will be the responsibility of the regional fishery biologist to describe and define the additional habitat types (Bisson *et al.* 1989).

Arid, Semiarid and Dry Sub-humid Areas – Areas other than polar and subpolar regions in which the ratio of annual precipitation to potential evapo-transpiration falls within the range from 0.05 to 0.65 (COD).

Assessment – The act of officially estimating the value or character of property. It is the process of estimating or determining the significance, importance or value of something.

Attribute – A trait, quality, inherent characteristic, or property describing or belonging to a specific thing or required to describe a variable (such as 'species' and 'height' are attributes of the variable 'tree').

Authorised Use – Specific activity or occupancy, such as ski area, historical marker, or oil and gas lease, for which a special authorisation is issued. Observed from the source document authorising the use.

Bark Thickness – A measure of the thickness of the bark at d.b.h., unless otherwise specified. Radial bark thickness is determined at a level slightly below the d.b.h. to prevent callusing. It is measured from the inside of the cambium layer to the outside of the exterior bark. At least two measurements of bark thickness should be taken in order to obtain an average reading. Avoid areas of abnormal bark thickness (callous, scars, etc.). A bark thickness gauge should be used whenever possible.

Basal Area – The cross section area of the stem or stems of a plant or of all plants in a stand, generally expressed as square units per unit area.

Bed Grounds – Exposed, bare mineral soil areas of 10 to 225 square meters which show persistent use by deer or elk. Generally, bed grounds often occur in stands consisting of an overstory and understory having greater than 70% crown cover. Bed grounds are often observed on cooler, heavily timbered ridge tops, and north slopes. Bed grounds are also areas in which grass/forbs are matted, but these may not be used on a continuous basis.

Benefit – Something that promotes well being.

Bias – Systematic distortion of a statistic as a result of sampling, measurement, or estimation procedures.

Biological Diversity – The variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD).

Biological Resources – Genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity (CBD).

Biomass (Tree) – The oven dry weight of all trees to a minimum d.b.h. of 10 cm, above ground only, and includes main stems, branches, twigs, leaves, and fruits (FRA).

Bole Top Diameter – The diameter outside bark (d.o.b.) of the tree stem at a point on the bole above which no merchantable product section exists. See BOLE LENGTH.

Browse – New growth on shrubs and hardwood sprouts or conifer seedlings that can be or has been eaten by big game animals.

Butt Log Grade – The condition of the bottom log in a sawlog tree, or estimate of potential sawtimber quality for hardwood poletimber.

Calving Areas – Areas where cow elk give birth to calves and maintain them during the first few days or weeks. Calving sites are usually associated with upland topographic land types of mid to lower elevations. Habitat characteristics of calving sites include warm exposures, associated benches or areas of gentle terrain, in close proximity to hiding cover and adjacent to succulent forage.

Canopy Cover – The percent of a fixed area covered by the crown of an individual plant species are delimited by the vertical projection of its outermost perimeter; small openings in the crown are included. Measured on fixed plots or transects. Estimate in percent (or class group by percent) by *plant species*. May also be computed from *crown width*. If foliage is not present because of seasonal variation or temporary defoliation, visualise the amount of live crown that would normally be present. The sum of the canopy cover across individual plant species may exceed 100% in a given area.

Canopy Layer – A roughly horizontal stratum of more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth. Canopy layers may be distinguished and used to describe the vertical position of a group of trees related to other trees in a stand. A multi-storied forest stand will have a canopy layer associated with each story. Three layers are often recognised for tropical forests – emergents, main canopy, and understory.

Cation Exchange Capacity – The sum of exchangeable cations that a soil, soil constituent, or other material adsorbs at a specific pH. Cation exchange capacity is a laboratory analysed value.

Cause of Death/Injury – The nominal most obvious cause of death for mortality trees or the most important cause of injury to live trees. To be judged as important, the injury must be serious enough now or in the future to (1) ultimately cause death, (2) predispose the tree to fatal attack by another agent, or (3) significantly reduce diameter or height growth.

Caves – Underground chambers that are open to the ground surface. These also include chambers in cliff faces or rock outcroppings.

Channel Depth – The average depth of channel from mean high water mark to mean high water mark. Used to define STREAM TYPE, instream flow calculations, and riparian management. Measured in the field or from maps or aerial photographs.

Channel Stability Rating – A rating of a stream channel's resistance capacity to the detachment of bed and bank materials.

Channel Substrate – The composition of the channel substrate (stream channel bed materials). Categorisation of substrate is accomplished by visual analysis or by sieving samples obtained by the manual or freeze core sampling methods. Visual categorisation of the surface is usually adequate for basic habitat analysis.

Channel Roughness – A channel roughness coefficient (Manning Coefficient: symbol, n) used in the equation proposed in 1889 by Manning to determine stream flow velocity (Barnes 1967).

Channel Gradient – The slope of the stream channel expressed on a percent of rise per unit length. A measure of the drop in water surface elevation per unit length of channel. Used in model building, channel hydraulics and flow response water yield, water use, instream and flood hazard. Measure channel elevations for a representative channel length. Channel gradient is an important variable in regulating stream velocity. Stream gradient is the difference in water surface or streambed elevation of two study sites on a stream divided by the distance between the study sites.

Channel Entrenchment – A measure of channel confinement and entrenchment of the channel within a valley. Used to define STREAM TYPE, riparian management, flood forecasting, etc. Categorisation of the entrenchment and confinement is accomplished by visual analysis or by aerial photos.

Chemistry, Atmospheric – The chemical composition of ambient air. Ambient levels of fine particulates in the size ranges Total Suspended Particulate, less than 10 microns and less than 2.5 microns and ozone.

Chemistry, pH Dry Deposition – The pH of particles and aerosols deposited at the surface.

Chemistry, pH Wet Deposition – The pH of precipitation.

Chemistry, Snowpack – Chemical composition of undisturbed accumulated snow.

Chemistry, Water – This variable includes all the chemical constituents of water, including BOD, DO, nutrients, trace metals, and other organics and inorganics. Used to measure and evaluate suitability of water for various beneficial uses.

Classification – The process of assigning objects to categories based on their natural affinities to one another.

Cliffs – Steep vertical or overhanging faces of rock.

Climate Change – A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (FCCC).

Climate System – The totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions (FCCC).

Climate Type – The classified prevailing weather condition of a region.

Comparability – The ability to combine data collected from different methods, from different locations, or different instruments.

Completeness – The amount of valid, useful data points that a method provides.

Co-ordinated Inventories – Data collection efforts by different sectors but done so effectively. Collecting information needed by a number of resource functions co-ordinated either spatially or temporally or both.

Correction – The analysis and interpretation of data quality information collected during prevention, assessment, and appraisal to modify any aspect of the measurement process to ensure data quality requirements.

Cost Effective – Achieving specified outputs for objectives under given conditions for the least cost or maximising outputs or their precision for a specified cost.

Criterion – A category of conditions or processes by which sustainable forest management may be assessed. A criterion is characterised by a set of related indicators which are monitored periodically to assess change.

Crown Class – The relative position of the tree or shrub crown with respect to competing vegetation surrounding the tree or shrub. Crown class for each tree or shrub is judged in the context of its immediate environment; that is, those trees or shrubs which are competing for sunlight with the subject tree. Differentiation into crown classes is intended for application in even-aged stands and within small even-aged groups in which trees of an uneven-aged stand are often arranged. Although crown classes were originally conceived to classify trees in even-aged or storied stands, they can be a useful descriptor of competitive status of trees in all structural types of stands. Crown class is essentially a classification of competition for light and is aimed at separating trees that are growing freely from those that are not. It designates trees or shrubs with crowns of similar development and occupying similar positions in the crown canopy. This is an ocular classification of trees or shrubs based on dominance in relation to adjacent trees or brush as indicated by crown development and amount of sunlight received from above and on the sides.

Crown Closure (Cover) – The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants. See also CANOPY COVER. Used to map and stratify stands of vegetation and as a measure of protection of a site or stream. Use a line intercept or observe on a plot or area basis. Size and number of plots and/or length and number of line intercept transects vary according to the kind of vegetation measured and the precision required. May be also estimated from aerial photographs or other remotely sensed images. Small openings in the canopy are included. The total coverage on an area may not exceed 100%. Overlapping plants are only counted once. Crown closure above streams requires special techniques. A concave spherical densitometer model B is used on permanent points to estimate relative crown closure.

Crown Foliage Density – A visual index of the amount of foliage per unit of crown. Used to calculate foliage structure and a measure of the severity of defoliation and disease.

Crown Form (Shape) – The configuration crown of a standing tree or shrub. Used to model vegetation structure and to determine foliage volume and percent growth cover by height.

Crown Length (Depth) – The vertical distance from the top of the leader to the base of the crown, measured to the lowest live branch-whorl with live branches in at least three quadrants, and continuous with the main crown. This information is used to develop horizontal-vertical profiles and biomass estimates. Crown length is used in a number of growth and yield simulation models. Irregular crowns must be ocularly "adjusted" to estimate the corresponding position of the base of a normally formed crown of the same volume.

Crown Ratio – The percent of the compacted portion of the tree bole or shrub supporting green, live, healthy foliage when compared to the total length or height. Used to develop horizontal-vertical profiles and phytomass estimates, estimate relative vigour of tree species, and some growth and yield simulation models. Crown ratio is usually ocularly estimated but may be calculated. Ocularly transfer lower branches to fill in large holes in the upper portion of the tree until a full, even crown is visualised. Compressing the crown because the crown appears sparse is not appropriate. Do not compact branches to form an unnaturally dense crown.

Crown Width (Diameter) – The span of the crown of a tree or shrub. Used to determine foliage area, foliage structure, and phytomass. Also, useful in studies of competition. First measure the maximum crown width through the plant centre. Measurements can be made using a tape or poles. Measure through the geographic centre of the plant if multi-stemmed. Then measure the "minimum" crown width at a right angle to the maximum crown width. Finally, average the maximum and "minimum" crown widths and record this as the crown width.

Crown Volume Percent – The percentage of a given space occupied by live foliage. Used for phytomass estimates, calculation of foliage structure, vegetation classification foliage stratum volume and space occupancy. Usually an ocular estimate, but may be computed from *crown length, height to crown, canopy cover*, and *crown foliage density*. Assess all or a portion of each individual plant occurring within the plot from both the horizontal and vertical standpoint. Without compressing or packing the foliage, try to put an imaginary box around each plant. Add all the space taken up by all the plants in a zone and express this as a percent of the total volume in the plot.

Cultural Sites – Areas showing the presence of indicators of cultural resources. These may include chips/flakes of chert, trails, shelters, cabins, homesteads, good or likely camping areas, springs, telephone lines/insulators, tree blazes, charcoal lenses in cutbanks, chert outcrops. Root wads and rodent burrows/gopher mounds are good places to look.

Data Element – A basic unit of information built on standard structures having a unique meaning and distinct units or values.

Database – A collection of interrelated data, often with controlled redundancy, organised according to a scheme to serve one or more applications. The data are stored so they can often be used by different programs with little or no restructuring or reorganisation of the data. A successful database is one that provides the principal users and stakeholders with the economic, social, and environmental information that they need to make sound and timely decisions and in formats they understand and use.

Depth to Mottling or Water – Mottling is the occurrence of small spots of color which contrast with the general matrix color of the soil. These spots of color, or mottles, commonly appear as small spherical splotches. Mottle colours are either: (1) grey on a matrix subsoil color of yellowish-brown, or (2) reddish-brown on a matrix subsoil color of grey or greyish-brown. The shorter the depth to mottling, the more poorly drained the soil. Measure and record to the distance from the base of the organic layer to the highest point that obvious mottling is observed in the soil and to standing water in soil bore hole, if present.

Depth to Bedrock or Restriction – The vertical distance from the mineral soil surface to unbroken solid rock or restriction. Measure and record the depth of the soil beginning at the base of the organic layer (O layers), to bedrock (lithic contact, R horizon).

Deforestation – The removal of tree cover and change of land use to non-forestry purposes. Deforestation, in itself, may not necessarily be undesirable. The clearing of land for agricultural purposes, for example, may be needed and may justify deforestation.

Desertification – Land degradation in arid, semiarid and dry sub-humid areas resulting from various factors including climatic variations and human activities (COD). Desertification is the continuous and sustained decline in the amount and quantity of biological productivity of arid and semiarid lands generally stimulated through land-use practices such as deforestation, devegetation, over-grazing, and cultivation.

Detrimental Soil Disturbance – The condition where established threshold values for soil properties are exceeded and result in significant change.

Devegetation – The removal of vegetation and exposure of bare soil throughout at least one growing season. Both deforestation and devegetation may lead to desertification.

Diameter, Basal (Diameter at Root Collar) – The straight line passing through the centre of a cross section of a bole measured at the root collar of a shrub or tree. Used for calculation of total phytomass and volume of shrubs or deliquescent trees.

Diameter, Stump – The diameter of a tree inside or outside bark at stump height. Used to determine d.b.h. for cut trees and to develop volume equations for uncut trees. Use in conjunction with *stump height.*

Diameter at Breast Height (d.b.h.) – Tree d.b.h. is outside bark diameter at breast height. Breast height is defined as 1.37 m above the forest floor on the uphill side of the tree. Note that the location of tree d.b.h. varies by jurisdiction. In some places it may be 1.3 m above the forest floor and in others 1.37 m. For the purposes of determining breast height, the forest floor includes the duff layer that may be present, but does not include unincorporated woody debris that may rise above the ground line.

Domesticated or Cultivated Species – Species in which the evolutionary process has been influenced by humans to meet their needs (CBD).

Down Material Condition – The deterioration of state trees lying on the ground or across a stream. Used for the determination of wildlife habitat potential and fire hazard.

Drought – The naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems (COD).

Duff – Fresh or partly decomposed organic material on the surface of the mineral soil, including needles, leaves and twigs. These materials usually form an intertwined mat whose depth can be determine.

Ecological Status – The degree of similarity between the present community and the potential natural community on a site. Ecological status is rated irrespective of management objectives. Ratings are based on the floristic similarity of the current vegetation to the potential natural community. The similarity can be expressed on a relative scale ranging from zero to 100 with adjective ratings assigned as low, moderate or high similarity.

Ecological Type (Habitat Type) – A category of land having a unique combination of potential natural community; soil, landscape features, climate, and differing from other ecological types in its ability to produce vegetation and respond to management. Classes of ecological types include all sites that have this unique combination of components with the defined range of properties.

Ecological Unit – The map unit developed for an *ecological type* or types. This unit often includes a complex of small and intricately associated ecological types too small to delineate separately.

Ecosystem – A dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit. A dynamic complex of plant, animal, fungal and micro-organism communities and the associated nonliving environment with which they interact. The interacting system of a biological community and its nonliving environment; a biological community, together with its environment.

Ecosystem/Cover Type – The native vegetation ecological community considered together with nonliving factors of the environment as a unit and, the general cover type occupying the greatest percent of the stand location.

Effective Rooting Depth – The depth of the soil that accounts for 80 percent of the roots. These data will help to identify the presence of a water table or hardpan or other root limiting layers, which severely restrict site productivity. Measure and record the depth of the soil beginning at the base of the organic layer (Oi, Oe, and Oa), to the level that accounts for 80% of the roots in the soil pit.

Elk Wallows – Disturbed areas present during the rut and in moist areas. Wallows are used primarily by mature rutting bulls and may also be associated with antler rubbing on nearby trees. Bulls dig up moist ground with front hooves and will also "horn" the ground with antlers. Wallows are used by the bulls to spread mud and urine over their body and thus wallows receiving use will likely smell of urine.

Embeddedness – A rating of the degree that larger substrate particles (boulder, rubble, or gravel) are surrounded or covered by fine sediment. A parameter used in model building and monitoring. Embeddedness measures the amount of surface area of the larger particles (boulder, rubble, or gravel) that are surrounded or covered by fine sediment. This aids in evaluation of the channel substrate's suitability for spawning and egg incubation, and as habitat for aquatic invertebrates and young overwintering fish (Platts *et al.* 1983).

Emissions – The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time (FCCC).

Erosion Severity – The degree of erosion taken place on the site. Indicate the class of eroded soils including whether eroded by wind or water.

Ex-situ Conservation – The conservation of components of biological diversity outside their natural habitats (CBD).

Fire Evidence – Any visible evidence of fire, including charred logs/trees/stumps/soil surface debris.

Fisheries Classification – Water bodies and streams classed as having either a cold water or warm water fishery (USDA Forest Service 1989).

Forage Utilisation – The proportion of current year's forage production that is consumed or destroyed by grazing animals. Forage is all browse and herbage that is available and acceptable to grazing animals.

Forest (Tree Land) – Land with tree crowns (or equivalent stocking level) of more than 10 percent and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. May consist of either closed forest formations where trees of various stories and undergrowth cover a high proportion of the ground, or of open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10 percent. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 percent or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily non-stocked as a result of human intervention or natural causes but which are expected to revert to forest. Includes: forest nurseries and seed orchards that constitute an integral part of the forest, forest roads, cleared tracts, firebreaks and reserves and other protected areas such as those of special environmental, scientific, historical, cultural or spiritual interest, windbreaks and shelterbelts of trees with an area of more than 0.5 ha and a width of more than 20 m. Rubber plantations and cork oak stands are included. Excludes lands predominantly used for agricultural practices (UN-ECE/FAO 1997).

Forest Floor (Litter) And Humus – The freshly cast (Oi), partly decomposed (Oe), and fully decomposed (Oa) vegetative material on the soil surface.

Forest Type – A category of forest defined by its vegetation, particularly composition, and/or locality factors, as categorised by each country in a system suitable to its situation.

Fuel Model – Mathematical descriptions of fuel properties (such as fuel load and fuel depth) that are used as inputs to calculations of fire danger indices and fire behaviour potential.

Fuel Moisture – The extent to which fuel will burn is largely determined by the amount of water in the fuel. Fuel moisture is a dynamic variable controlled by seasonal, daily and immediate weather changes. Fuel moisture is used for the development of fire prescriptions, for estimating expected fire behaviour and for calculating fire danger indices. Fuel moisture, expressed as a percent, is computed from the weight of contained water in fuel divided by the oven dry weight of the fuel.

Genetic Resources – Genetic material of actual or potential value (CBD).

Genetic Material – Any material of plant, animal, microbial or other origin containing functional units of heredity (CBD).

Geologic Formation – A mappable body of rock identified by distinctive characteristics, some degree of internal homogeneity, and stratigraphic position. The name normally consists of two parts. The first is the name of the geographic locality where the formation was first identified and described. This is followed by a descriptive geologic term, usually the dominant rock type. General use is to provide a common reference for a "time-lithologic" unit used in mapping.

Geologic Hazards – A natural condition that poses some risk to human health or safety. Used to identify lands that may require special management to protect human safety or capital investment.

Geologic Time Unit – A division of time traditionally distinguished on the basis of observable changes in world-wide life forms as represented in the fossil record in sedimentary rocks.

Goods – Things that are useful, beneficial, and has intrinsic value. Things that have economic utility or satisfy an economic want. *Forest goods* include all flora and fauna, mineral, and water resources occurring on or originating from the forest. The use of the term *goods* implies that the resources will be used for economic needs and includes direct consumption, barter, and gift exchanges as well as buying and selling in the market place. The resource will be consumed directly or used for economic needs.

Greenhouse Gases – Those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation (FCCC).

Ground Water Aquifers –A geologic formation that is sufficiently permeable to conduct ground water and has the potential to yield economically significant quantities of water to wells and springs. Used to identify areas important to the proper management, including protection of quality and quantity, of the ground water resource. Recorded from drill logs.

Habitat – The place or type of site where an organism or population naturally occurs (CBD).

Height Growth – The increase in height over five years or the period between measurements. Compute by subtracting previous height from current height on remeasurement plots or measure internodes if the species is suitable and the situation allows (USDA Forest Service 1989).

Height to Crown, Compacted – The vertical distance in feet from the ground to the base of the compacted live crown. Use to compute *crown ratio*. Measure from the ground up to the point where live, clustered, green branch material is found. Disregard single limbs of forks below the main crown.

Height to Crown, Uncompacted – The vertical distance in feet from the ground to the base of the live crown, measured to the lowest live branch-whorl or lowest live branch excluding epicormics. This information is useful for determining browse availability, crown phytomass, and foliage structure. Measure up to the point where the first live limb is found.

In-situ Conditions – Conditions where genetic resources exist within ecosystems and natural habitats, and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties (CBD).

In-situ Conservation – The conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties (CBD).

Indicator – A measure (measurement) of an aspect of the criterion. A quantitative or qualitative variable which can be measured or described and which when observed periodically demonstrates trends. Key actions, functions, elements, or objects which, by virtue of their physical, biological, economic, or organizational attributes, are so closely associated with the system in which they are found as to be indicative of the state or trends (improvement or deterioration) of the system (Weber 1991).

Instream Cover – The amount of vegetation and organic debris within a stream channel capable of providing protection for fish (Platts *et al.* 1983).

Integrated Inventories – Data collection efforts designed to link multi-sectors, data collectors, and decision levels over time (Lund 1986). Data collection efforts may be separate, but are designed and implemented so the resulting information can be brought together. An inventory or group of inventories designed to meet multiple needs for information. Integrated inventories are planned as a whole and the various functions rely on one another.

Inventory (Survey) Unit – The land unit containing the population of objects or attributes for which information is to be summarised and analysed. For national assessments and land and resource management planning, the inventory unit is usually the planning area, Forest, or State. For local projects or other planning needs, the unit may consist of any area of land such as grazing allotments, compartments, watersheds, lakes, 10 hectare, or discrete vegetative stands.

Inventory – An accounting of goods or services on hand. An inventory may establish a baseline for monitoring. We conduct inventories to provide decision-makers with the information they need to secure or maintain a healthy and sustainable flow of goods and services for the people they represent.

Internet – A world-wide "networks of computer networks" presently connecting more than 40,000 networks and 40 million users. Common applications include electronic mail.

Land – The terrestrial bio-productive system that comprises soil, vegetation, and other biota, and the ecological and hydrological process that operate within the system (COD).

Land Cover – That which overlays or currently covers the ground, especially vegetation, permanent snow and ice fields, water bodies, or structures. Barren land is also considered a 'land cover' although technically it is lack of cover. The term land cover can be thought of as applying to the setting in which action (one or more different land uses) takes place.

Land Degradation – The reduction or loss, in arid, semiarid and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or a process or combination of processes, including processes arising from human activities and habitation patterns, such as: soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation (COD).

Land Use Class – The predominant purpose for which an area is employed.

Landforms – Any physical feature of the earth's surface having a characteristic, recognisable shape and produced by natural causes. A criterion to be used in determining the capability and suitability of lands to produce resources and accommodate management activities.

Lithologic Unit – A system of rock classification based on manner of origin, composition, and texture (or grain size).

Macroinvertebrate Biotic Condition Index – An index that compares the tolerance or sensitivity to pollution of an existing community of macroinvertebrates, to the predicted potential tolerance of a community in undisturbed conditions for a given stream. An indication of macroinvertebrate community tolerance which reflects the condition of the aquatic ecosystem. Used in model building and monitoring.

Map Unit – See Sampling Unit.

Mapping – The process of determining and graphically portraying the distribution of variables in geographic relation to one another.

Market – The number of potential customers which have in common one or more easily identifiable characteristics that affects their wants. A market results whenever the forces of supply and demand operate.

Mass Stability – The existing condition of the soil mantel related to the potential for land mass failure such as landslides, mud flows, and debris slides.

Mean Water Depth – A measure of the average vertical height of the water column from the existing water surface level to the channel bottom. A parameter used in model building and monitoring. Depth is the vertical height of the water column from the existing water surface to the channel bottom. Depth is measured along each cross section at five locations: the two margins, and one-fourth, one-half, and three-fourths of the width across the stream or habitat unit. The total of the measurements is divided by a five, even when depth is zero at one or both margins (Platts *et al.* 1983).

Mineral Licks – Exposed soil and/or rock used by animals (such as ungulates) as a mineral source, Likely will occur in moist areas such as seeps, and the immediate area will probably be tracked up. Rocks may be somewhat smoothed from licking.

Mineral Resource – A known or undiscovered concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Mistletoe Infection Rating – The relative abundance of mistletoe in the crown of a tree or shrub (Hawksworth 1977).

Mixing Height – The height above the surface (m) defining a boundary layer, within which pollutants are free to mix.

Modelling – The development of formulas that predict the variables found under certain conditions or predict responses to natural or human-induced disturbances.

Monitoring – The periodic and systematic measurement and assessment of an indicator to detect changes in resources or environmental trends. The process of detecting change over time with the intent of recommending management adjustments if needed.

Most Hazardous Pest – The principal natural agent operating in the vicinity of the sample point, which presents the greatest threat to realising stand goals of stocking, growth and structure.

Multi-product Inventory – A cataloguing or listing of geographic areas for different commercial commodities, for example, an inventory of forest land for commodity products such as timber, pulp, and fuel wood or non-timber products such as edible plants, nuts, medicinal plants, genes, floral products, animal and animal products, fodder, cork.

Multipurpose Inventory – A cataloguing or listing of geographic areas for different uses, for example, an inventory of forest land for timber production and for watershed stability.

Multipurpose Resource Inventories (MRI) – A cataloguing or listing of geographic areas for different resources. Data collection efforts designed specifically to meet all or parts of the information requirements for two or more products, services, functions, or sectors such as forestry and wildlife. The objective is to collect the needed information at least cost and present it in such a way so it is available and useful to the maximum number of decision-makers. An inventory designed to describe two or more components of the total resources (1) in a single data collection effort (co-ordinated inventory) or (2) with a sample design which permits the description of two or more resources (integrated inventory).

Odour Type and Concentration – The threshold ambient concentration at which certain pollutants are odoriferous to humans.

Output – The product (goods, services, or on-site use) from forest and rangeland resources.

Ownership – The identification of the legal owner/administrator (Federal, State, Local, Private) on both the surface and subsurface estates.

Overstory – The uppermost canopy layer.

Overstory Canopy Closure – The total canopy closure of the overstory layer, all species included, determined by ocular estimation.

Paleontological Resources – Any remains, trace, or imprint of a plant or animal that has been preserved in the Earth's crust since some past geologic time.

Parameter – A quantity (as a mean or variance) that describes a statistical population.

Parent Material – The unconsolidated organic and mineral material in which soil forms. Some soils have formed from the weathering of bedrock in place; however, other soils have formed from material that has been transported from the site of the parent rock and redeposited at a different location through the action of glacial ice, water, wind or gravity.

Particle Size – The effective diameter of a particle measured by sedimentation, sieving, or micro metric methods. Particle size distribution is the percent by weight of sand, silt, and clay in a soil sample of a soil horizon excluding coarse fragments. Used for erosion hazard models, soil classification, and moisture holding capacity. Determine percent composition by weight for each size class for specific soil horizons. Use established laboratory procedures.

Partnership – A co-operative effort among two or more survey programs or data sources to which all stakeholders contribute and from which all stakeholders benefit based upon common needs or goals.

Permanent Sample – A plot or transect established and documented so as to permit repeated measurements of the same variables at the same exact places.

Plant Species – The major subdivision of a genus or subgenus of a plant being described or measured.

Plantability – A percent of plantable area for the plot or stand. If there are no obstructions (such as rock outcrops, heavy concentrations of downed woody material, or soil less than 0.5 m deep) to the planting of at least one tree in a quadrant, the quadrant may be considered plantable.

Plot – The earth cover area for which a sample observation or measurement is made.

Pollutant Loading – Amount of pollutants in a unit volume of air.

Pool Quality – A rating of the capability of a pool to provide fish survival and growth requirements. Pool quality estimates the capability of a pool to meet requirements for survival and growth of fish. The rating system requires that direct measurement of the greatest pool width and depth be combined with a cover analysis (Platts *et al.* 1983).

Pool-riffle Ratio – The ratio of the length or percent of pool habitat divided by the length or percent of riffle habitat. To calculate the pool-riffle ratio, sum the length of pool habitat within a stream reach and divide by the length of riffle habitat within the same reach (Platts *et al.* 1983).

Pond – Any standing body of water, either seasonal or permanent, natural or manmade.

Potential Natural Community – The biotic community that would be established if all successional sequences of its ecosystem were completed without additional human-caused disturbance under present environmental conditions. Grazing by native fauna, natural disturbances, such as drought, floods, wildfire, insects and disease are inherent in the development of potential natural communities which may include naturalised non native species. The potential natural community and its environmental characteristics provide a reference standard to which existing serial communities can be related.

Precipitation, Average Annual – The amount of rainfall (or equivalent snowfall) expected in the area over a calendar year.

Precipitation, Hourly – Hourly amount of liquid equivalent precipitation. Precipitation measurements made using a tipping bucket or weighing rain gauge.

Precision – The ability of a method to reproduce the same value within a narrow range. The clustering of sample values about their own average.

Prevention – The major activity that attempts to ensure that "good" data are collected prior to the collection of actual data.

Principal Defect – The most significant defect that reduces *tree volume* and *tree class*.

Product – Anything produced or obtained as a result of some operation of work, as by generation, growth, labour, study, or skill. One may derive products from animal, vegetation, mineral *resources*, or a combination. Thus the term *forest product* is a sub-category of *goods* and *resources*. We may use the resources directly or we may have to do some processing before use. The conversion of plant or animal material into a form suitable for human use constitutes an example of production. Products usually have an economic implication.

Non-timber products – Any from forest lands other than those used for building or structural purposes. Non-timber products may include those parts of trees used for fuelwood, roots, limbs, as well as things that are not woody.

Non-wood forest products – Products which exclude timber and all other potential wood products. This includes large-scale industrial plantations that supply either primary consumer goods or raw materials for further processing using non-wood forest resources (Leakey *et al.* 1996).

Production, Forage – Annual production of herbage, shrubs, woody vines, and trees which may provide food for grazing animals or harvested for feeding.

Property – The quality or trait belonging and especially peculiar to an individual or thing (such as a tree's height).

Protected Area – An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN 1994). The World Conservation Union (IUCN) has defined a series of protected area management categories based on management objective as follows. Where the site does not meet the internationally recognised definition of a protected area, application of a management category is not appropriate.

Strict Nature Reserve – Area managed mainly for science. Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.

Wilderness Area – Area managed mainly for wilderness protection. Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.

National Park – Area managed mainly for ecosystem protection and recreation. Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.

Natural Monument – Area managed mainly for conservation of specific natural features. Area containing one, or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.

Habitat/Species Management Area – Area managed mainly for conservation through management intervention. Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.

Protected Landscape/Seascape – Area managed mainly for landscape/seascape conservation and recreation. Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.

Managed Resource Protected Area – Area managed mainly for the sustainable use of natural ecosystems. Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

Protocol – A fixed set of rules to specify the format of an exchange of data.

Public Access – An indication if the property is posted or restricted from public use.

Quality Assessment and Appraisal – The activities conducted during data collection (measurement) process that monitor and document data quality.

Radial Growth (Increment) – The increase in tree radius over a period of time (such as 10 years or period between measurements) at breast height or occasionally at the base.

Rangeland – Open expanses of land over which animals (such as livestock) may roam and feed.

Recreation Use – The primary type of recreation use observed in the vicinity of the sample unit.

Recreation Opportunity Class – An assessment of the potential of a site for a range of outdoor recreation experiences from few to many conveniences, such as motor vehicle access, human control.

Relative Humidity – A ratio, expressed in percent, of the amount of moisture in a volume of air to the total amount which that volume holds at the given temperature and atmospheric pressure. Used for developing fire prescriptions, calculation of fire danger rating indices in predicting fire danger, and for making fire behaviour predictions.

Reservoir (Greenhouse Gas) – A component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored (FCCC).

Resource – An object valued because it is important to an influential group of people, such as government agencies, nongovernment organizations, and it is used and consumed by the public. A source of supply or support. An asset or material used to accomplish a goal or task.

Natural resource – Things occurring in nature that can be used as wealth.

Renewable resource – A resource that will replenish itself over time. This may be in a natural situation or in a plantation.

Resource Inventory – The planning and collection of data for description and analysis of the status, condition, production, or quantity of resources for planning and implementing protection and management activities. Inventories usually include some descriptive data, numeric data, and some means of relating that information to specific geographic locations.

Resources – The elements of supply inherent to an area within the scope of responsibilities and authorities of the agency including lands, soils, timber, forage, water, air, fish and wildlife, aesthetics, recreation, wilderness, and energy and minerals. Natural resources are often divided into two categories, renewable and non-renewable.

Sampling Error – The standard error (square root of the variance) of the sample estimate, expressed either absolutely or as a percentage of the estimate.

Sampling Unit – The basic unit of observation. The inventory unit is divided into sampling units such as a prism point, line transect, a fixed-area plot, or a mapped unit such as a stand. Each sampling unit is regarded as individual and indivisible when the sample selection is made. By knowing the probability of selection, data collected from the sampling unit can be expanded to the inventory unit.

Sawlog Top Diameter – The span of the tree stem outside bark (d.o.b.) at the top of the sawlog length of the bole. Used to determine sawtimber volume. Use relascope, callipers, or other devices to measure the diameter outside bark. Measure to the point on the bole where the sawlog limit occurs. If the sawlog length is taken to the bottom of a fork or the flare from a limb, the smallest diameter immediately below the swell is recorded.

Seeps/bogs – Discharges smaller than springs are called seeps or bogs. Riparian vegetation is a good indicator.

Serpentine – A dark, greenish rock that is usually fairly soft and rather greasy looking in appearance. Many specimens feel soapy because they contain some talc. Plant communities are distinctive where serpentine exists.

Service – A contribution to the welfare of others. *Forest services* include the roles or functions forests play. These may be economical, environmental, ecological, cultural, or political.

Economical Services – The production of goods or products that one consumes directly or sells.

Environmental Services – Functions that maintain or protect the general stability of the landscape. They include such things as watershed protection, soil stabilisation, and carbon sequestration. We can maintain environmental functions naturally or through plantations of many kinds of vegetation. These things are vital to human survival.

Ecological Services – Functions providing of biodiversity and maintaining of ecosystems. Management requires maintaining a naturalness to the forest.

Cultural Services – Include recreation, spiritual uplifting, and just peace of mind in knowing that some wild and natural places exist on Earth. These most frequently take place in *natural areas*, but we can find beauty and recreation in human-influenced areas as well.

Political Services – These are the roles that natural resources play in helping to get people elected or kept in power. Very often our natural resources are political pawns at times of re-elections. People may take a certain stance on natural resources because it looks good rather than because it is ethically or morally the right thing to do.

Shore Depth – A measure of the water depth at the shoreline. The water depth at the stream shore is measured on each cross section at the shoreline or at the edge of a bank overhanging the shoreline. If the angle formed by the bank as it meets the stream bottom is greater than 90 degrees the reading for shore depth is always zero. If the angle is 90 degrees or less, the water column goes under the streambank and the measurement of the shore depth is greater than zero (Platts *et al.* 1983).

Single-function (Resource) Inventory – An inventory describing only one component of the total resource available, such as a stand examination or a timber cruise.

Sink (Greenhouse Gas) – Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere (FCCC).

Sinuosity – The ratio of the channel length to valley length. Use for channel classification, fisheries, and channel morphology.

Site Index – Height of a tree at a specified index or base age. Used as an indicator of site quality.

Site Productivity Class – A classification of forest land's inherent capacity to grow crops of industrial wood. The class identifies the potential growth and is based on the age of culmination of mean annual increment of fully stocked natural stands.

Site Tree Quality – A classification of sample tree according to how well the tree reflects the productive potential of the site.

Smolt – A stage of downstream migration for fish such as salmon. Fish are usually 10-15 cm in length and one to two years old.

Snag Condition – A description of the deterioration of a standing dead tree (Thomas 1979).

Soil Bulk Density – The mass of undisturbed or disturbed dry soil per unit bulk volume. The bulk volume is determined before drying to a constant weight at 105° c. The value is expressed in grams per cubic centimetre (g/cc).

Soil Cover – The type of cover on the soil surface.

Soil Drainage Class – Natural soil drainage refers to the rapidity and extent of the removal of water from the soil, in relation to incoming water. This is especially true of water by surface runoff and by flow through the soil to underground spaces. Soil drainage, as a condition of the soil, refers to the frequency and duration of periods when the soil is free of saturation or partial saturation.

Soil Erosion Type – Soil erosion is the process of removal of soil material by running water, wind or gravitational creep. Factors that affect soil erosion are climate, nature of the soil, slope, vegetation and cultivation practices.

Soil Structure – Structure is described by grade, class and type. Terms are used to describe natural aggregates in the soil called peds in contrast to clods caused by disturbance, fragments by rupture of peds, and by local concentrations of compounds that irreversibly cement the soil grains together.

Soil Texture – Texture refers to the relative proportions of clay, silt, and sand (less than 2 mm in diameter). Clay particles are the smallest, silt particles are intermediate, and sand particles are the largest. Loams contain various mixtures of the three basic particle sizes. Rock fragments in the soil modify textural names depending on size and amount. Stones and boulders on the surface affect use and coverage should be estimated.

Source (Greenhouse Gas) – Any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere (FCCC).

Species Percent Composition – The percent composition of each species in any given layer of the stand or area. The sum of all percent values within a given layer must equal 100%. Generally obtained by ocular estimation.

Spring – Any surface discharge of water large enough to flow in a small rivulet.

Stand Age – The mean age of the dominant and co-dominant trees in the stand.

Stand Condition – A classification of forest stands based upon the age of maturity and structure of the overstory and understory (Delfs 1986).

Stand History – The kind of disturbance (prior to plot establishment) on the sample location.

Stand Origin – The apparent source of vegetation on the location whether natural, seeded, or planted.

Stand Size Class – A classification of land based on the stocking of all live vegetation of various sizes. This is usually computed from other field data, but it may be estimated in the field.

Stand Structure – A description of the distribution and representation of *stand age* and *stand size classes* within a stand. An ocular classification reflecting the form of the stand rather than its actual composition by age groups.

Stand Year of Origin – Year the stand was planted or created. Determine from historical records where available.

Statistically Valid Design – An inventory design with known probabilities of selection which permits the calculation of sampling error.

Stream Azimuth – Direction of streamflow, looking downstream.

Stream Gradient – The percent slope of the streambed, average for both upslope and downslope.

Stocking Percent – The amount of live trees on a given area in relation to what is considered the optimum. A calculation using either the total number of trees, total basal area, or total volume per unit area divided by the optimum total number of trees, optimum total basal area or optimum total volume for a particular species and management objective, expressed as a percent.

Stratification – The division of an inventory unit into homogeneous subunits to improve the efficiency of the inventory, and can be used to ensure certain segments of the population are sampled.

Stream Channel-bank Angle – A measure of the angle formed by the downward sloping streambank as it meets the more horizontal stream bottom (Platts *et al.* 1983).

Streambank Undercut – A measure of the furthest point of protrusion of the bank to the furthest undercut of the bank (Platts *et al.* 1983).

Streamflow – Measure of the volume of water passing a given point in a stream channel at a given point in time (Buchanan and Sommers 1969).

Stump Height – The vertical distance from the ground on the uphill side to the top of the stump on cut trees. Vertical distance from the ground to a stump height set by study objectives or local utilisation practice for uncut trees.

Suspended Sediment – Sediment which remains in suspension in water for a considerable period of time without contact with the bottom. Depth integrated water samples are collected. Sediment content is measured in the Laboratory and reported as parts per million or milligrams per litre.

Sustainable Use – The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations (CBD).

Talus – Dislodged rock fragments that accumulate at the base of steep slopes of cliffs.

Temperature, Water – A measure of water temperature heterogeneity.

Temperature, Ambient – The hourly air temperature of the surrounding area.

Time since Disturbance – The number of years between when the most recent disturbance took place (*stand history*) and the time of plot measurement.

Tolerance – The maximum permissible range of variation in an individual measurement or observation (USDA Forest Service 1989).

Tree – An erect woody perennial having generally one well-developed main stem (except in coppice management systems) and of a species, which is usually capable of reaching a height of 5 meters at maturity in most of its distribution areas (ECE/FAO 1993).

Tree Age: The total age of the above ground stem of the tree in years (not the age of the rootstock or the total age from seed). Total age is usually the annual ring count to the pith of the tree at breast height plus an estimate of the number of years it took the tree to reach breast height. This must be an estimate based on local knowledge.

Tree Class – The overall quality of live trees.

Tree History – A classification of the change in status (living or dead) of a tally tree. Determined by comparing previous status with current status.

Tree Length (Height) – The total span of a tree from ground level along the bole to tip of tree. Height measurements are necessary for access to volume references. Errors in measurements will have a direct effect on final volumes. Total height measurements are used in many growth and yield models, and site estimates are increasingly being based on height-diameter curves and diameter distributions rather than selected individual site trees.

Tree Top Condition – An indication as to whether or not the top of the tree is intact.

Tree Volume – The amount of wood in a tree. It may be gross volume or net volume (gross less defects). For most trees, volumes are computed via existing equations using *d.b.h.* and *tree length.*

Trend – The direction of change in ecological status observed over time.

Turbidity – A measure of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines.

Update – A method used to make inventory estimates current by manipulation of the inventory database through accounting procedures or projection models, or by taking a subsample and estimating the current values for the whole.

Utility – The ability of a good or service to satisfy human wants.

Value – The monetary or relative worth, utility or importance of something. It is the quality of an asset which people think as being desirable, useful, and important. In short, value is the worth of direct consumption or the sum of money a buyer is prepared to pay for a product or service.

Variable – A quantity that may assume any one of a set of values.

Vegetation Density – Number of individual plants of a given species in a unit of area. The relative density of a species is the number of its individuals as a percentage of the total number of individuals of all species in the sample. Count of individuals of a species by plot or transects.

Vegetation Height – The vertical distance from ground level to the top of an individual plant or canopy. Usually measured with ruler, poles, or clinometer. May be done for individual plants or groups of plants.

Visibility Sensitivity – The determination of how rapidly visibility can be reduced.

Visual Quality – Degree of obstruction or contrast degradation of viewing scene due to air contaminants or weather.

Visual Range – The distance at which a large (half a degree) black or a dark object disappears from view. Visual range is normally measured directly using a teleradiometer or indirectly by scanning 35 mm slides of a scene using a scanning densitometer.

Water Flow Velocity – The average velocity of water flowing through a cross-section of a stream. Used in calculating stream flow, engineering design, and almost all evaluations of hydrology, channel morphology and fisheries. Measured in the field by using a velocity meter, surface float, vertical float, or tracer.

Wildlife & Fish Habitat Capability – The ability of a specified area to support a species expressed in terms of numbers of an animal or habitat capability index. Wildlife and fish habitat relationships program models are used to predict habitat capability. For wildlife, the predictive models estimate capability considering vegetation, structure, arrangement, succession, and composition.

Wildlife/Fish/Threatened & Endangered Abundance – The population levels of wildlife, fish, and threatened or endangered (T&E) species for a given geographic area.

Wind Speed – The wind speed at the height of interest (surface, plume height, or upper air). Wind speed may be measured directly or indirectly in any of a variety of ways. These parameters may also be estimated using a power law relationship dependent on height above the surface and the surface wind speed. Direct measurements include the use of sensors on towers, tethered balloons, free rise balloons, constant volume balloons, and aeroplanes. Indirect measurements include the use of Doppler acoustic soder, Doppler lidar tracking of aerosols and profilers.

Withdrawals – Lands that have been removed or segregated from the operation of some or all of the public lands through Executive or Congressional action.

Windthrow Potential – An assigned low, medium, or high rating. Windfall potential may be considered high where stands are near ridgetops or ridge saddles, near large adjacent openings or harvest areas, where evidence of blowdown occurs near the stand, on extremely shallow soils, in wet areas, or on steep slopes exceeding 90%. A low rating is assigned on flat topography, in areas protected from direct effects of wind, at a low slope position, or when well within a stand. All other locations are rated as medium.

APPENDIX 4. LETTER AND QUESTIONNAIRE FOR MRI SURVEY

INTERNATIONAL UNION OF FORESTRY RESEARCH ORGANIZATIONS
WORKING PARTY 4.02
MULTIPLE RESOURCE INVENTORY GUIDELINES PROJECT

12 May 1997

Dear Friend:

As you may know, the International Union of Forestry Research Organizations (IUFRO) Working Party on Forest Resource Inventory and Monitoring is in the process of developing a World Series Report – ***IUFRO Guidelines for Designing Multipurpose Resource Inventories***. This work is a follow-up to recommendations made at the IUFRO Monte Veritá' Conference on Forest Survey Designs for Non-Timber Resources held in Ascona, Switzerland 2-4 May 1994 and from the International Conference on Multiple Resource Inventory and Monitoring of Tropical Forests held in Seremban, Malaysia, 21-24 November 1994. The project is supported in part with grants and in-kind services from the City of Joensuu, Finland, the European Forest Institute, and the USDA Forest Service.

Multipurpose resource inventories (MRI) are data collection efforts designed to meet all or part of the information needs for two or more products, functions, or sectors - e.g., forestry and agriculture, wildlife and forestry, wildlife and grazing, etc. In theory, MRI should reduce inventory costs and provide more comprehensive and complete information needed by today's land manager.

In order to complete the Guidelines, we are conducting a survey of World Forestry Organizations to learn what kinds of multipurpose resource inventories are being conducted. Would you please take a few minutes to complete the enclose questionnaire and return it to me in care of the European Forest Institute, Torikatu 34, FIN 80100 Joensuu, Finland? Responses are desired by 15 July 1997. Your contribution will be acknowledged in the final report. Thank you in advance for your kind cooperation.

Sincerely,

H. GYDE LUND
MRI Project Leader

Enclosure

IUFRO 4.02.02 QUESTIONNAIRE ON MULTIPUFROPSE RESOURCE INVENTORIES

The International Union of Forestry Research Organizations (IUFRO) Group 4.02.02, the European Forest Institute (EFI), and the USDA Forest Service are developing a proposed IUFRO World Series Volume - IUFRO Guidelines for Designing Multipurpose Resource Inventories. As part of that project we are doing a survey and comparison of existing multiple resource inventories (MRI). For purposes of this survey, *a multipurpose resource inventory is a data collection effort that is designed to meet all or part of the information requirements of two or more resource products, functions or sectors such as forestry and wildlife, forestry and range, and forestry and agriculture.* If you have completed or are conducting such a survey, would you please take a few minutes to answer the following questions? Your contribution will be acknowledged in the Guidelines.

1. Are you conducting multipurpose resource inventories?
   If yes, please complete rest of form.

   If no and you are interested in receiving information about the IUFRO Guidelines for Designing Multipurpose Resource Inventories once they are complete, please complete part 2 and return.

2. Your Name:
   Organization:
   Street Address:
   City, State:
   Country:
   Telephone number:
   Fax number:
   Email:

3. What area is surveyed (geographic location - state, province, country)?

   3.1 What is the size of the area (inventory unit) in hectares?

   3.2 What is the primary purpose (objective) of the inventory?
   Local land management
   State/Provincial assessments
   International assessments
   Other - please specify

   3.3 What resources are being surveyed? Check those that apply
   Agricultural Crops
   Grazing/Range
   Non-timber Forest Products, Goods, and Services (fruits, forage, biodiversity, etc.)
   Recreation
   Timber
   Water
   Wildlife
   Other - please specify

   3.4 What attributes are being assessed?

   3.5 What groups are involved in the design/ data collection/ interpretation?
   3.5.1 Who has leadership, how and why?
   3.5.2 How are decisions reached?

4. What is the sample design?
   Systematic sample
   Stratified sample (what are the strata?)

Enumeration
Remote sensing/mapping based
Other - please specify

4.1 Is remote sensing used?
4.1.1 What type (scale, media) and in what way?
4.1.2 What information is obtained from the remote sensing?

4.2 If field plots are used, what is the plot configuration (fixed area, variable radius, combination, nested plots)? Please describe or provide a diagram with dimensions, etc.
4.2.1 What is the sampling intensity (number of plots established in the inventory unit)?
4.2.2 What data are collected on the plots? Please provide definitions of variables.

5. Were the objectives of the inventory met? If no, why not?

5.1 What are the advantages of the inventory?

5.2 What are the obstacles?

5.3 What are your recommendations for changes?

6. Are copies of the following documentation available? Please enclose copies if possible. If you cannot enclose, how can we obtain copies?
Inventory/monitoring plan
Remote sensing interpretation instructions
Field measurement procedures
Forms for recording data
Glossaries, definitions, standards
Analytical procedures
Final reports on the outcomes or results of the inventories

Please send your responses to the following address NO LATER THAN 15 JULY 1997:

H. Gyde Lund
European Forest Institute
Torikatu 34
FIN 80100 Joensuu, Finland
Tel: 358-13-252-0241, Fax: 358-13-124-393, Email: gyde.lund@efi.joensuu.fi

Thanks in advance for your kind cooperation.

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