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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).

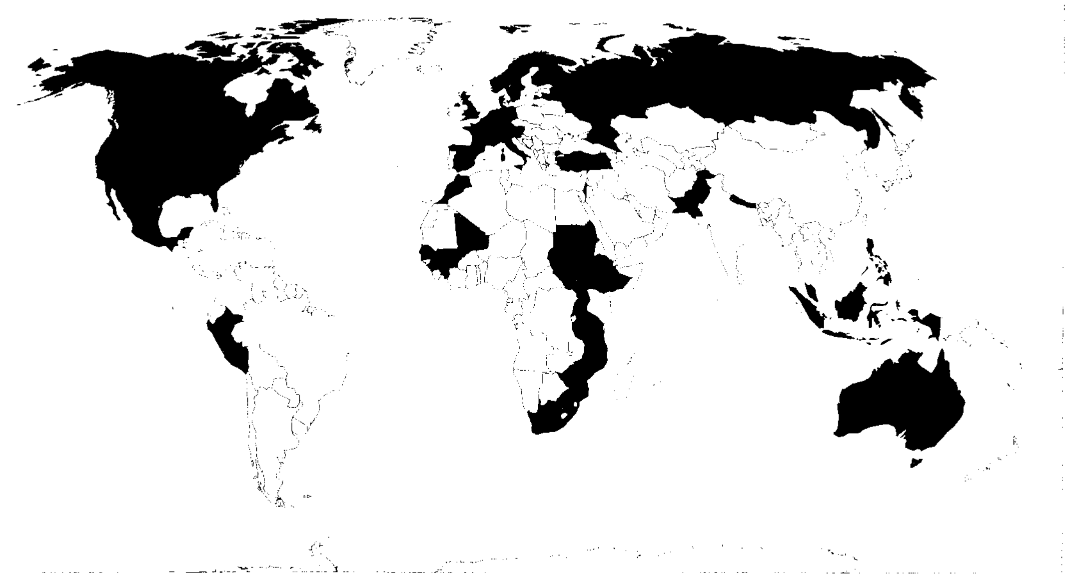

Figure 1-2: World map showing countries (darker shade) reporting MRIs.

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).

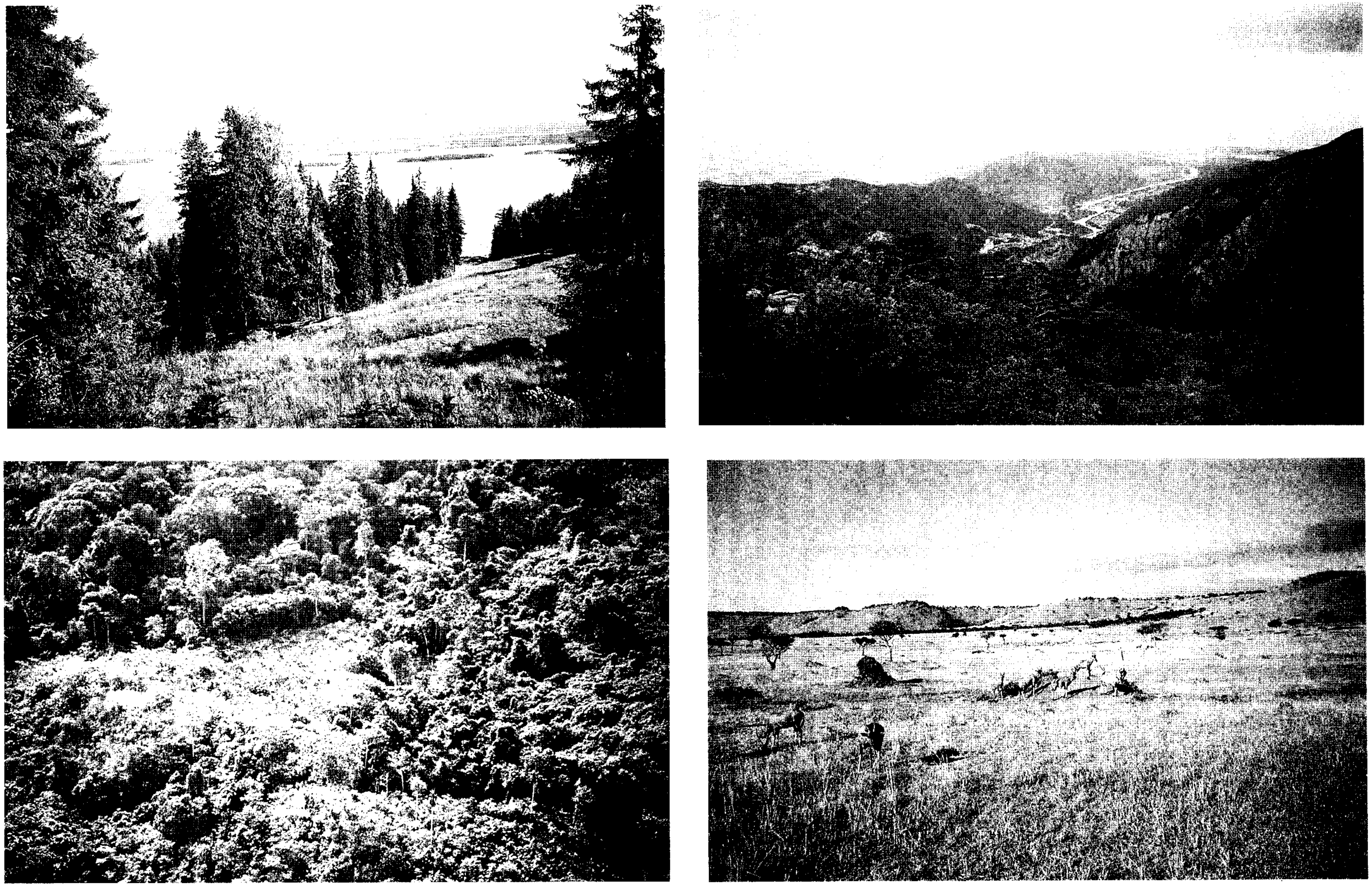

Figure 1-3: Sample situations where MRIs may be useful. Upper left – Forests used for recreation and timber production (Finland). Upper right – Forests used for watershed protection, recreation and timber production (Korea). Lower left – Lands where land uses are interspersed – agriculture and forestry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

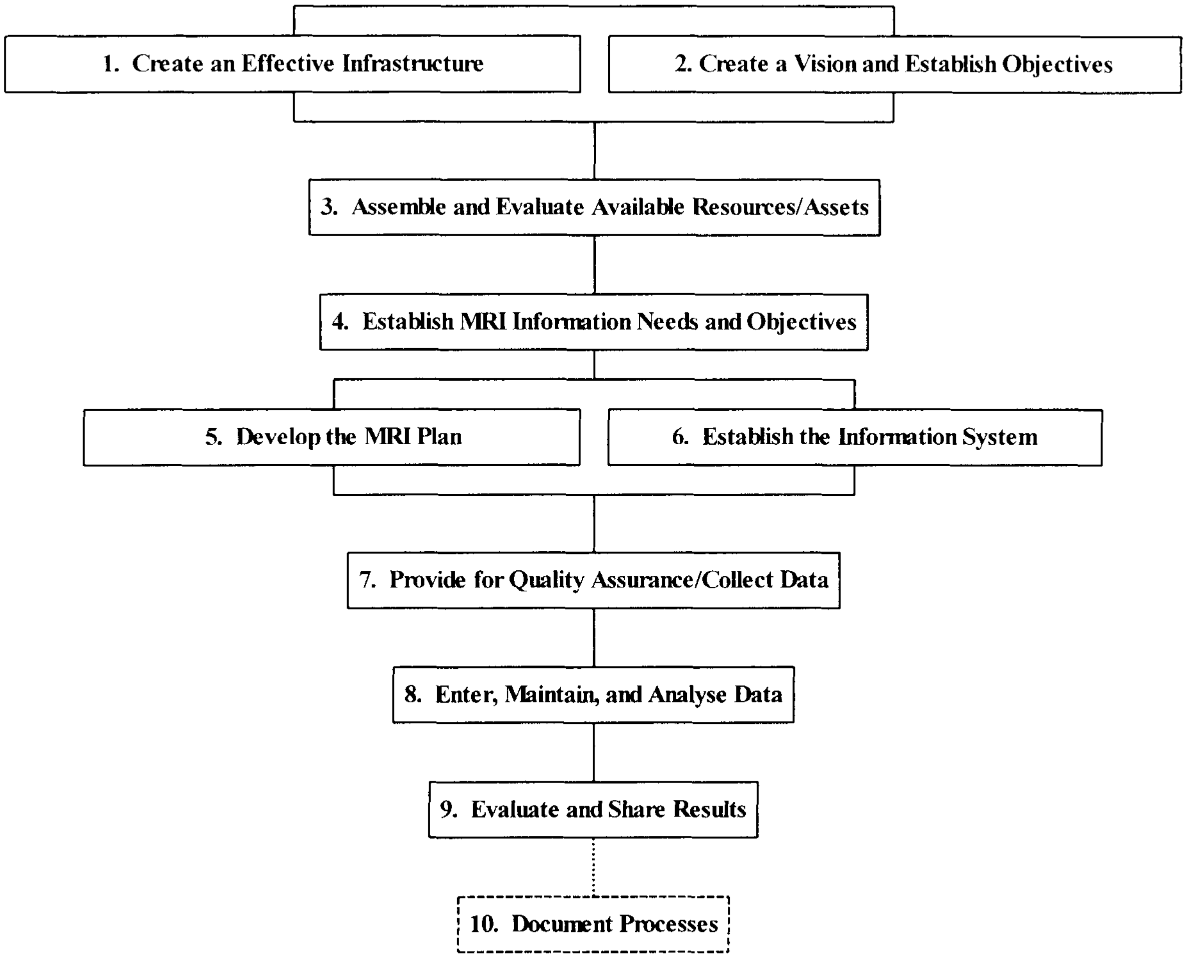

Figure 2-1: Steps in implementing an MRI.

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 greatest ease 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 users without 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 2f^{t} 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 appraisak:

- 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 timber inventory 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:

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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.

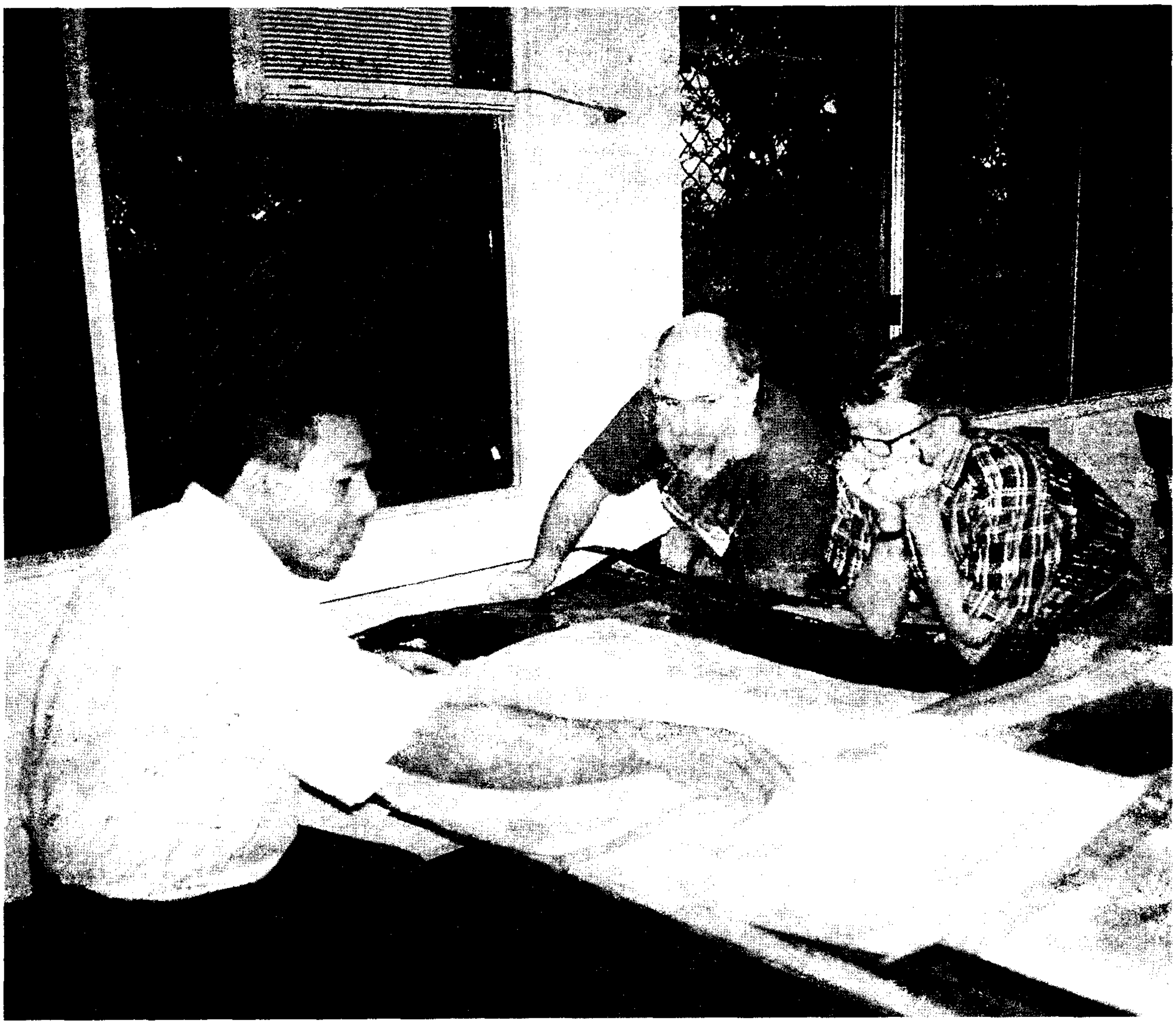


Figure 2-3: Reviewing existing maps and imagery in preparation for a forest inventory in Papua New Guinea. Such a review saves unnecessary expenditure of funds on information that may already exist.

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.

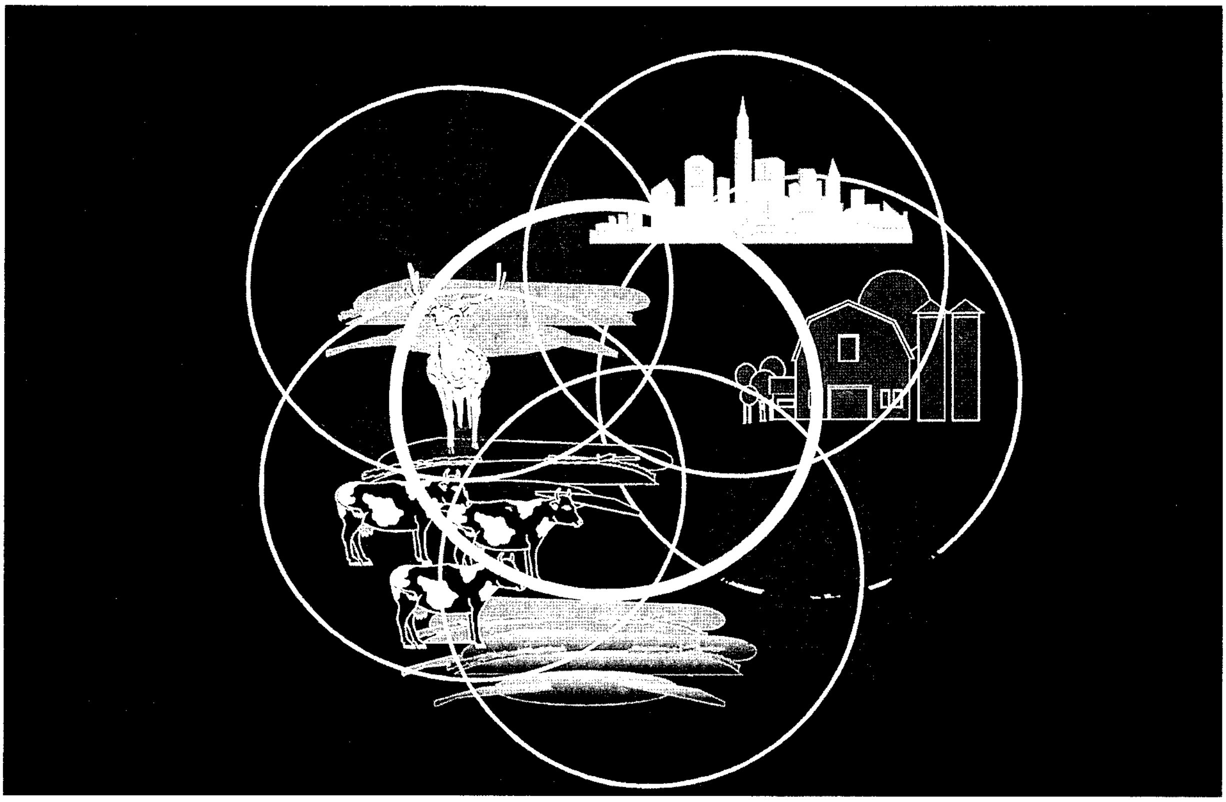


Figure 2-4: Each resource has a sphere of information requirements (upper drawing). Where they overlap are opportunities for integration of data collection (lower drawing).

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).

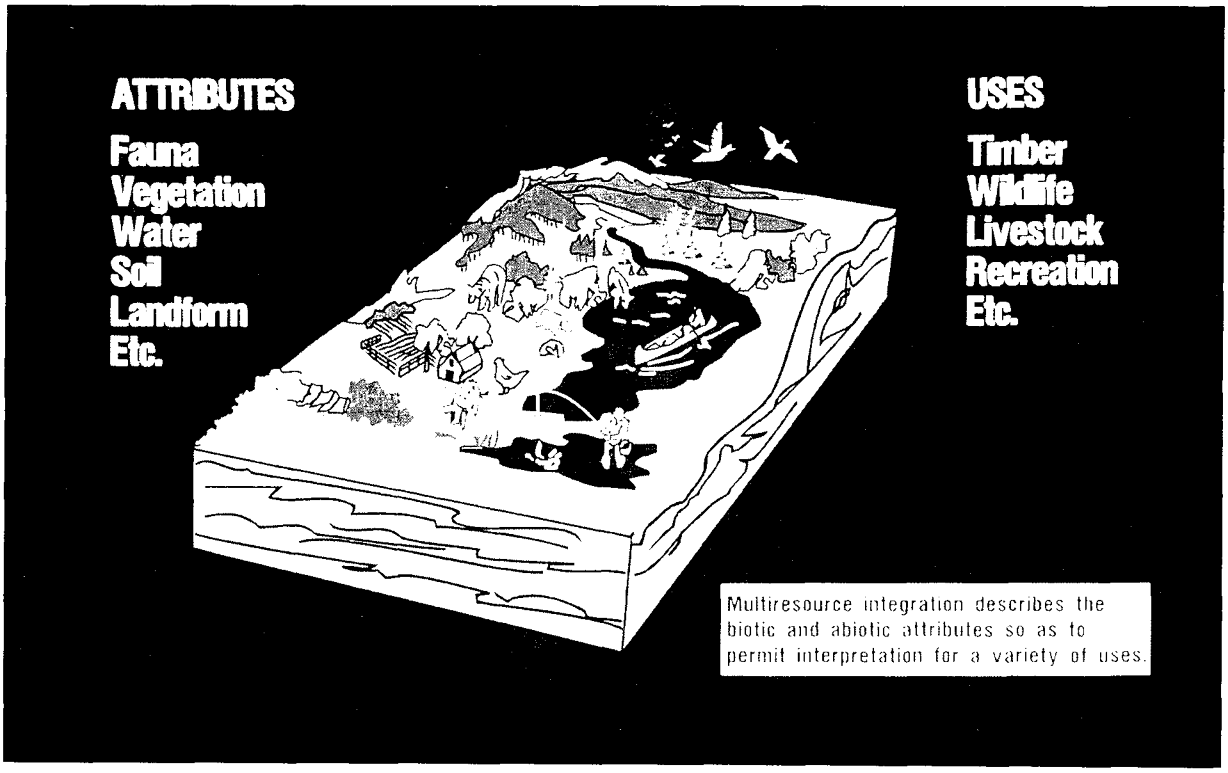


Figure 2-5: Describing the resource database so that it can be used by a number of people is fundamental to MRIs.

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 users must 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 modellingand 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:

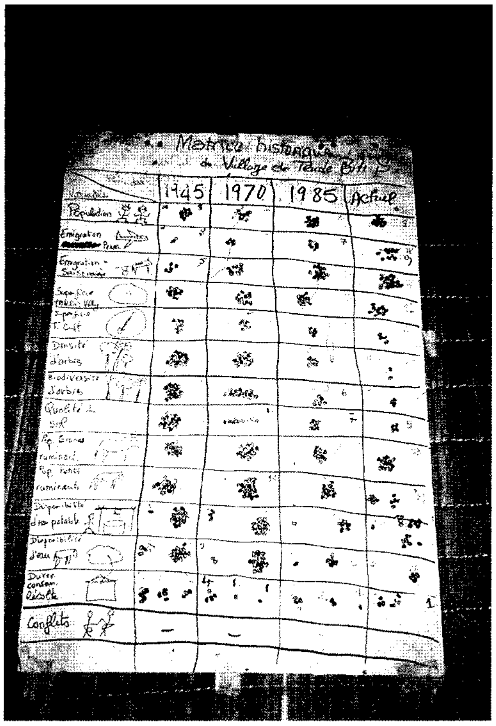
- Variations between elements of the population are large and sampling is expensive.

- 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.



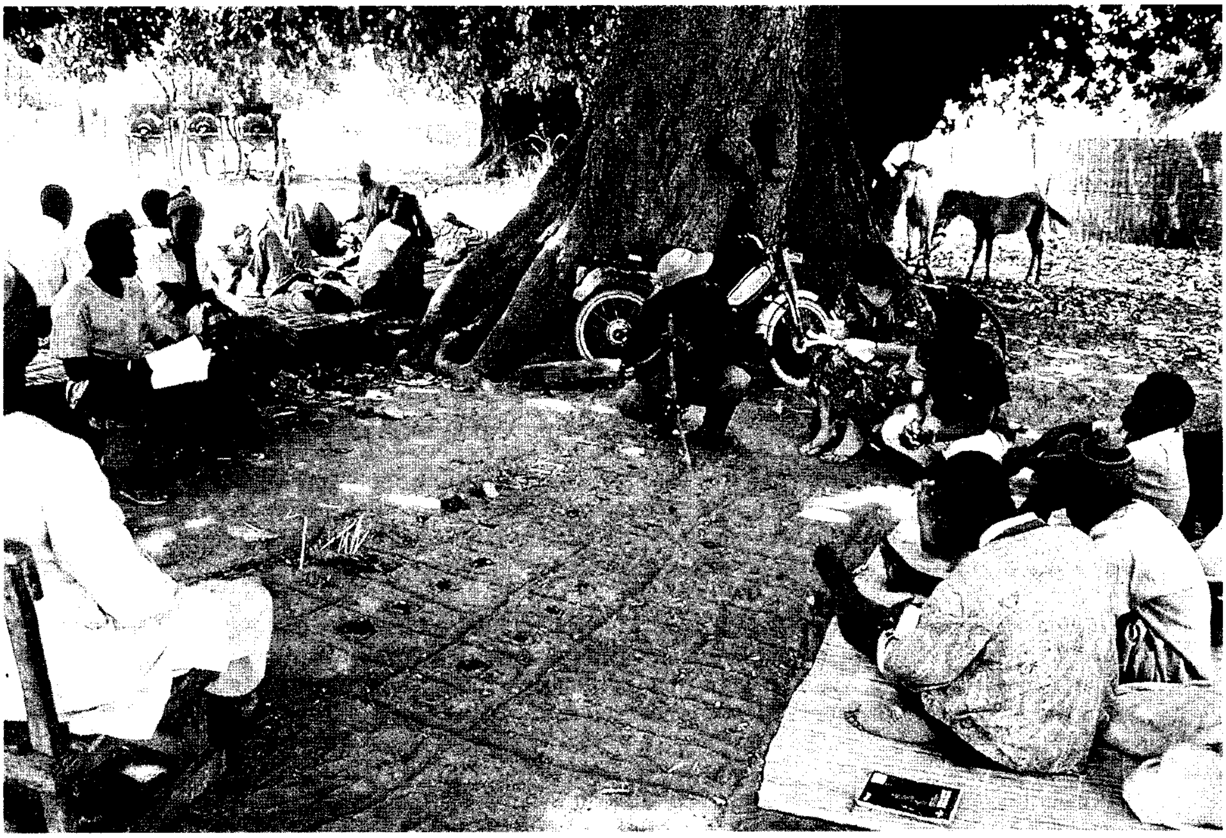


Figure 2-7: Innovative ways of recording data in the field. Upper photo shows a data recording 'form' etched in the soil that local farmers are using to record perceived changes in their village in Senegal. This photograph is the 'hard copy' of the form. Lower photograph, a similar innovative form. Here, 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

Increasing cost of labour. Decreasing cost of technology

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	

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).