PART III

CROSS CUTTING ISSUES IN SUSTAINABLE FOREST MANAGEMENT
8 Forest Assessment for Changing Information Needs

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Abstract: Forest assessment aims to meet the information needs of forestry for management decisions. It was introduced more than 500 years ago, when an increasing demand for continuous wood supply led to the idea of sustainable forest management. Since then, along with the evolution of planning from timber maximization to holistic ecological management, several changes in paradigms have occurred in the evolution of forest assessment. Today, forest assessment has been implemented worldwide with different intensities and at different scales, ranging from the stand level to the national, multinational and global scale. Paradigms are changing to differing extents in most of these forestry systems. Multinational systems based on collations of national results, as well as on harmonized transnational monitoring grids, assess indicators on forest health, climate change, carbon sequestration, biodiversity and sustainable forest management. However, even basic quantitative information on the forests of many developing countries and nations with large territories is founded on estimations. Remote sensing can contribute to closing gaps in knowledge, especially when combined with terrestrial assessments. Harmonization of assessment methods, standards and reporting systems among different countries enhances the comparability of results. This is a precondition for multinational assessments, utilizing synergies and avoiding duplications. Any forest assessment system must have clearly defined objectives, must rely upon a statistically sound survey design and must be subjected to strict procedures of data quality assurance.

Keywords: Forest assessment; forest inventory; information needs; sustainable forest management; remote sensing; quality assurance.

8.1 Introduction

Forest inventories and assessment aim at providing the basic information needed in forestry. The first documented systematic collections of forest information were carried out in Central Europe as a result of an increasing demand for fuel wood and timber, e.g. for mining and ship-building. One of the first known forest assessments is that of a forest area in Austria, from 1499 to 1510, under Emperor Maximilian I (Zöhrer 1980). The demand for a continuous wood supply led to the idea of sustainable forest management, which was first mentioned in the 16th century in Saxonian forest law. H.C. von Carlowitz described the principle of sustainability in 1713 as follows (Speidel 1983):

“...Therefore the highest skills, science, efforts and planning will be founded on how the conservation and growing of wood has to be organized in order to achieve a continuous constant and sustainable utilization; this is an indispensable thing, without which the nation can not exist.”

From these beginnings, as other social values related to the forest such as recreation, aesthetics, conservation, and indigenous land management increasingly came to the fore, new information needs began slowly to evolve. Information is needed for various purposes, and varies over space and time. Strategy related information on the size, condition, and development of forest resources is needed for broad planning and investment considerations. Man-
management related information on specific properties and functions of forests is required for afforestation, thinning and harvesting. Problem related information on the presence and intensity of damage and risks is needed for such things as pest control, soil amelioration, and fire fighting. Information related to global issues such as forest health, effects of air pollution and climate change, carbon sequestration, growth, and biodiversity is demanded by international processes on environmental policies and sustainable forest management.

The present chapter analyzes the degree to which changing paradigms in forestry have influenced or are influencing existing forest assessment systems. Recommendations are given regarding the further development of forest monitoring to meet future information needs. Forest monitoring systems have been implemented world-wide in different intensities and at different scales, ranging from the stand level, to the national, multinational, regional and global level. Paradigms are changing in all of these forestry systems to differing degrees. This chapter focuses on the important global and multinational forest assessment systems. In some cases, national systems have been included as long as they cover large territories, such as continents or subcontinents, but even this approach does not permit covering the whole globe. For example, much of Eurasia, Asia and Africa are omitted. In many parts of the former Soviet Union substantial inventory systems are in use, but at the same time, there are considerable information gaps in the remote areas. Similarly, in India and China there are functioning national forest inventory systems, but they are beyond the scope of the present chapter. It is hoped that the selected examples of national to global level systems will help the reader to travel through the changing paradigms in forest inventory and assessment.

### 8.2 Changing Paradigms in Forest Assessments

Along with the evolution of forest management from timber maximization to holistic ecological planning, several paradigm changes in the evolution of forest inventories and assessments can be identified.
and the effects on carbon stocks and greenhouse gas of information needs related to changes in land use. A good example is the variety of information needs of the whole society, related especially to values in forest planning. The past 15 years have witnessed the development of multi-scale inventories may be considered a broad paradigmatic shift, from merely forestry related to information on forest area from around 1500 onwards, reflecting an increasing demand for fuel wood and timber. After 1700, the idea of sustainable timber supply created the need for information on standing volume and growth. Within the first half of the 20th century the most advanced national forest inventories compiled information on plant composition of forest stands and on the succession of species. In the second half of the century, these initial efforts evolved into full-fledged forest health monitoring, considering the effects of insects, diseases, fire, and air pollution. This development was fostered by growing concern about environmental pollution. Following the spread of the idea of sustainable development, towards the end of the 20th century information on inter-relationships between forests, other natural resources and society became ingrained in forest monitoring. Criteria and indicators for SFM were developed, and the necessary information is often aimed to be assessed within existing forest monitoring systems. At the heart of SFM is the consideration of social as well as timber values in forest planning. The past 15 years have witnessed the introduction of an ecological approach to SFM, which has gained increasing attention through international processes such as the Kyoto Protocol and the UN CBD. This new approach to planning considers social and economic values as well as the ecological functions and processes associated with the ecosystems under consideration. This highlights a broad paradigmatic shift from merely forestry related information needs to multisectoral information needs of the whole society, related especially to land use monitoring. A good example is the variety of information needs related to changes in land use and the effects on carbon stocks and greenhouse gas emissions in the IPCC (Penman et al. 2003).

As regards scales of space and time, the development of multi-scale inventories may be considered a paradigm change in the evolution of the scale of forest inventories. The first applied scale was the forest stand level approach, with aggregation of stand level inventories. The second entailed the development of sampling techniques that adequately depict the entire forestland base, and broadening the scope to national levels. In the last decade or so, inventories providing information at continental and global scales were carried out. A further changing paradigm is related to the interpretive time span of the inventories. One of the important aspects of forest assessment and ecosystem monitoring is change detection. Change detection is important for understanding human influences on the ecosystem. Initially, the inventories described the present status of the forest. In the 20th century, inventories were designed to estimate forest conditions a decade or two into the future. With issues such as global warming, future interpretive scenarios can span hundreds or thousands of years.

The paradigmatic shifts in the scope and scale of forest inventories have presented and continue to present major challenges for methodologies and assessment procedures in the interpretive integration of economic, ecological, social and cultural aspects. Concentrated on the supply of timber for ship building, for mining and for iron smelters, the earliest inventories focused on the immediate forests surrounding these industries. During the industrial revolution, more timber was needed for increased industrial purposes as well as for fuel wood. More precision was needed to assess the potential timber supply. The industrial revolution and the development of the pulp and paper industry were catalysts for national-level inventories in Europe. The need to inventory forests at the national level at lower costs led to the development of sampling-based inventories. At the same time, data requirements were increasing. For differing industrial uses more accurate information was needed not only on timber supply but also on the quality of timber.

With the advent of aerial photography in the mid-20th century, photo interpretation became a mainstay of forest inventories. Aerial photography and satellite based remote sensing are now integral to forest inventories (see Figure 1). Remote sensing can be adapted to various scales of management from broad overviews to stand level delineation. The development of the space-borne remote sensing methodologies makes it possible to monitor large areas and detect changes in forest landscapes. Remote sensing products include general forest maps on multinational areas. Such maps and multiple thematic maps based on detailed ground data can be converted into digital databases for modeling by means of GIS. Modeling, as well, has evolved over the last 25 years and has become an integral tool at different scales from tree level to stand and landscape levels. It is also invaluable as a predictive tool when considering various planning or operational scenarios. Criteria and indicators of sustainable forest development have evolved depicting the spectrum of forest ecosystem values. Many indicators of interest, e.g. carbon sequestration, cannot be measured directly, necessitating reliance on modeling and other interpretive techniques. Sophisticated modeling and expert systems, coupled with multi-phase and multi-stage inventories, are now required to address the abundant criteria and indicators that depict status and progress towards SFM.

Many developing nations anticipate that forestry will provide a change in livelihoods. Ecotourism, agroforestry, and non-timber forest products are just a few of the more recent benefits that have affected the livelihoods, and altered the value communities.
place on their forests. However, one of the more challenging tasks facing forest researchers is the lack of quantitative information and assessments regarding non-timber forest products. FAO forest resources assessment of 1990 noted the depressing state of forest inventory in the tropics, pointing out that no country had carried out a complete assessment on the status of NTFP resources. Moreover, the critical values for NTFP inventories differed from forest inventories that concentrated on wood volumes.

8.3 Forest Assessment Systems Worldwide

One of the most important and traditional periodic country level assessments of forest resources and their trends for the whole world is the Global Forest Resources Assessment (FRA) of the FAO. The parameters assessed globally are (FAO 2001):

- Forest area and its change;
- Wood volume and aboveground woody biomass;
- Extent and main species of forest plantations;
- Trees outside the forest;
- Biological diversity;
- Areas under forest management;
- Areas of forest in protected areas;
- Information on forest fires;
- Wood supply and removals;
- Non-wood forest products.

The ongoing harmonization of terms and definitions within FRA (or related to FRA) is a precondition for the presentation of consistent and comparable information from countries all over the world (FAO 2002). To assess the change in forests area of the tropical countries, remote sensing surveys were applied. Reflecting the development of the forest sector over the last decade, FRA is evolving into a more comprehensive collection of data and information required by several processes of international forest and environmental politics. Within the FRA system, information on countries of the temperate and boreal region is summarized by the Temperate and Boreal Forest Resources Assessment (TBFRA) of the United Nations Economic Commission for Europe (UNECE) and FAO (2000). TBFRA 2000 was compiled by means of a detailed inquiry within 55 participating countries, and all the information and necessary adjustments needed to achieve the comparability between national level information came from the countries themselves via National Correspondents.

Altogether there are more than 80 information tables available from the TBFRA. However, even with TBFRA, the availability and accuracy of the information varies considerably among countries, several countries did not reply to the last TBFRA 2000 questionnaire. The situation is even more diverse with the global FRA, even though the information required is limited. In Africa, Asia and Latin America the FRA information is based on expert evaluation if a functioning national forest inventory is not available. In the upcoming FRA 2005, the aim is to increase the amount of globally assessed information to 16 data tables, applying information on factors like employment to forest and other wooded land. In addition, the FRA 2005 will put more emphasis on capacity building for national forest inventories, and following the model of TBFRA it will be based more on country questionnaires. The tropical forest area changes will be assessed by remote sensing. A new part added to country questionnaires will be thematic reports addressing specific topics, such as mountain forests. In addition to FRA good examples of the global or regional mapping efforts are the global land cover and tree cover maps. These are based on globally available satellite imagery such as NOAA-AVHRR (NOAA-satellite – advanced very high resolution radiometer) or Spot Vegetation, and are commonly produced at 1 km resolution (e.g. Muecher et al. 1998). For forestry purposes, the 1 km resolution data set is available for tree cover percentage and broad forest classes (Defries et al. 2000). Global Land Cover 2000 including broad forest classes is another example of these types of mapping efforts.

Europe

The FAO forest assessments do not confine themselves to quantitative assessments, but are extending their scope to include qualitative assessments of forest resources. A good example is the inclusion of the large-scale results of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in TBFRA 2000. ICP Forests was established in 1985 under the Convention on Long-range Transboundary Air Pollution (CLRTAP) of the UNECE (Lorenz et al. 2003). Since 1986, it has been conducting continuous forest condition assessment in Europe jointly with the European Union (EU). With 40 participating countries, ICP Forests and EU are pursuing the following objectives:

- To provide a periodic overview of the spatial and temporal variation in forest condition in relation to anthropogenic and natural stress factors, in particular air pollution (achieved by means of a large-scale systematic network of low monitoring intensity, referred to as “Level I”);
- To contribute to a better understanding of the relationships between the condition of forest ecosystems and stress factors, in particular air pollution (achieved by means of intensive monitoring of a number of selected permanent observation plots spread across Europe, referred to as “Level II”);
- To contribute to the calculation of critical levels, critical loads and their exceedance in forests;
To collaborate with other environmental monitoring programs worldwide in order to provide information on other important issues, such as climate change and biodiversity in forests, and thus contribute to the sustainable management of forests;

To compile information on forest ecosystem processes, and to provide policy makers and the public with relevant information.

To achieve these main objectives, a systematic large-scale monitoring network (Level I) and an Intensive Forest Monitoring Programme (Level II) have been set up. The strength of the Level I network is the vast extent of its approximately 6000 permanent plots, arranged in a 16 x 16 km grid, throughout Europe. At Level I, annual crown condition assessments are carried out. In addition, soil and/or foliage surveys were conducted on many plots. A repetition of the soil survey is foreseen. For intensive monitoring, more than 860 Level II plots have been selected in the most important forest ecosystems of the participating countries. This intensive monitoring includes crown condition, soil condition, soil solution chemistry, foliage chemistry, tree growth, tree phenology, ground vegetation, meteorological conditions, ambient air quality and deposition. On 155 of the Level II plots, remote sensing methods are applied. All monitoring methods are described in a manual (UNECE 1998). The latest amendments to ongoing surveys include test phases for ozone measurements, injury assessments, and potential methods for forest biodiversity assessments. The data collected enable case studies on the most common combinations of tree species and sites. For ICP Forests, in accordance with its political mandate, air pollution effects are a priority.

Under its new Regulation “Forest Focus” EU plans to extend its monitoring activities towards questions of climate change, carbon sequestration, biodiversity and sustainable forest management.

The European Commission (EC) established the information system “Coordination of Information on the Environment” (CORINE) in 1985 to facilitate the planning and execution of the EU’s environmental policies. CORINE gathers information on the state of the environment for use in priority community applications. It strives for consistency of nomenclatures and definitions in order to ensure the comparability of data. Main results are procedures and methods for the collection, standardization, and exchange of data at the European level, as well as an information system capable of providing policy-relevant information on the European environment. Relevant for forest assessments are CORINE’s inventories on land cover, biotopes, soil quality, soil erosion, and water resources. The CORINE Land Cover (CLC) inventory is composed of 44 classes, covering the agricultural as well as the urban and natural sectors. Data are mainly acquired through satellite imagery, and evaluated by GIS. In contrast to the mapping approach of CORINE, the Land Use/Cover Area frame statistical Survey (LUCAS) produces harmonized land cover information based on systematic plot sampling (Bruyas 2002). LUCAS assesses data by means of annual field surveys and farmer interviews. Information related to forestry is provided by assessments of forest area (broadleaved, coniferous, and mixed), other wooded area, poplars and eucalypts, shrubland and grassland.

Figure 1. “Quickbird” satellite image utilized in a German pilot project evaluating the potential of remote sensing techniques for the national forest inventory. The photo allows a determination of land use and forest types such as unforested land (a), mixed deciduous forest (b), regeneration (c), and mixed conifer forest (d).
North America

As in Europe, forest assessment systems in North America are no longer confined to the quantification of forest area and timber supply, but have been widened by the factors of air pollution, climate change, biodiversity, and sustainable forest management.

In Canada, forest management is a provincial jurisdiction. Thus, all provinces carry out forest inventories at various management scales. Industry is also involved. Canada’s current national forest inventory is comprised of a periodic compilation of existing inventories from across the country. To address current weaknesses and to meet new demands, the Canadian Forest Inventory Committee (CFIC) – a group of inventory professionals from federal, provincial and territorial governments and industry – has developed a new approach for a national forest inventory. Instead of a periodic compilation of existing information from across the country, the CFIC decided on a plot-based system of permanent observational units located on a national grid. The Canadian Council of Forest Ministers has endorsed this system. The new plot-based National Forest Inventory (NFI) design will collect accurate and timely information on the extent and state of Canada’s forests, to establish a baseline of where the forests are and how they are changing over time. A core design has been developed with the following essential elements:

- A network of sampling points across the population;
- Stratification of the sampling points by terrestrial ecozone with varying sampling intensity among the strata;
- Estimation of most area attributes from remote sensing sources (photo plots) on a primary (large) sample;
- Estimation of species diversity, wood volumes and other desired data from a (small) ground-based sub-sample;
- Estimation of changes from repeated measurements of all samples.

The new inventory covers all of Canada. All potential sample locations reside on a countrywide 4 x 4 km network designed to survey a minimum of 1% of Canada’s land mass, which translates into approximately 20000 sample photo plots for Canada. Plots will be identified by conventional, mid-scale, aerial photography, and will be delineated and interpreted according to land cover classes and other forest stand attributes. Satellite imagery will be used as a surrogate for aerial photography to provide attribute data for areas otherwise not covered by photo or ground plots (e.g. Canada’s north). The flexibility of the design allows the sampling to be more intense to achieve regional objectives, or less intense for non-forested or remote areas, such as Canada’s north. The new NFI design also calls for a minimum of 50 forested ground plots per forested ecological zone. Attributes and data collected in ground plots will complement and enhance the attributes and data from the photo plots. A new related project, Earth Observation for Sustainable Development of Forests (EOSD), is designed to provide complete coverage of the forested area of Canada with satellite data at regular intervals, to produce information on land cover, biomass and change.

In Canada, provincial governments carry out forest health monitoring to varying degrees. Nationally, forest health attributes are being integrated into the new NFI. CFS is also taking an issue-based monitoring approach to forest health. For example, in the East there is the Forest Indicators of Global Change (FIGC) Gradient study. This study comprises 26 eastern Canadian, forested, permanent sample plots arranged across land characterized by both high levels of acidic deposition (sulfur/nitrogen) and ground-level ozone.

In the United States, there are several systems for forest assessments that pertain to or can provide information on forest air pollution impact. For the United States Department of Agriculture (USDA) Forest Service, a primary program is the Forest Inventory Analysis (FIA). The program covers forests on all forestlands within the United States. FIA consists of a nationally consistent core program that can be enhanced at the local, regional or state level to address special interests. The national core consists of three phases (USDA Forest Service 2002):

Phase one consists of remote sensing classification of the land into forest and non-forest, and spatial measurement of variables such as fragmentation, urbanization and distance. This phase has historically used aerial photography, but is changing to a satellite imagery based system. Phase two consists of a set of field sample locations distributed across the landscape, with approximately one sample location (FIA plot) in every 2500 ha. Field crews visit forested sample locations to collect a variety of forest ecosystem data. Non-forest locations are also visited as necessary to quantify rates of land use change. Phase three is a subset of the phase two plots (approximately 1 every 39 000 ha). These plots are visited during the growing season in order to collect an extended suite of ecological data, including full vegetation inventory, tree and crown condition, soil data, lichen diversity, coarse woody debris, and ozone damage.

Under a new approach, the FIA collects data on a subset of plots in all states every year. Ultimately the goal is to annually sample 205 field plots in every state. Another new approach is the FIA sister or companion program, Forest Health Monitoring (FHM). FIA and FHM aim to determine the productivity and health of forests through collection of a set of consistent core data and indicators, which can be compared across administrative boundaries and different land ownerships (e.g. federal, state, private) and provide meaningful analyses in a timely manner. FIA currently provides updates of assessment data every five years. FHM is a national program designed to determine the status, changes, and trends in indicators of forest condition on an annual basis. It uses data from ground plots and surveys, aerial...
surveys, and other biotic and abiotic data sources, and develops analytical approaches to address forest health issues that affect the sustainability of forest ecosystems.

Perhaps the largest and oldest monitoring network which applies to forest health and air quality in the USA is the National Atmospheric Deposition Program/National Trends Network (NADP/NTN), which incorporates approximately 200 cooperative sites that collect information on wet atmospheric deposition used in forest assessments. The objective of NADP/NTN is to determine atmospheric wet deposition trends and status in the United States in a manner scientifically defensible and useful to air quality policy decisions, scientific investigations, ecosystems management, and management of national parks and wilderness areas afforded special protection from air pollution effects (Clean Air Act Class I Areas). It collects data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. NADP/NTN provides baseline information that is often used in conjunction with short-term forest area studies to calculate critical loads and other forest health guidelines. For dry atmospheric deposition, the federal Environmental Protection Agency (EPA) has established the Clean Air Status and Trends Network (CASTNET), which has been extremely successful in helping to assess existing or potential forest impacts from large stationary sources.

Under the auspices of the North American Forestry Commission (NAFC) of the UN-FAO, Canada, the United States and Mexico are working together to develop North America-wide protocols for forest inventory, monitoring, assessment and reporting. A current NAFC initiative is the identification of a common set of compatible inventory and monitoring data to produce the first North American report on the nature and status of the major forest ecosystems of the continent. An ecological reporting framework (Ecoregions of North America) is being used, rather than a framework based on country jurisdictional boundaries. Recently, NAFC conducted a study to determine and demonstrate the capabilities of the three countries to create a North America database. Currently, however, NAFC has to rely on existing information, and some harmonization will be required until new inventories in Canada and Mexico are complete (Lund 2003).

**Latin America**

In Central and South America continent-wide forest assessment, information or monitoring systems are not yet established. Therefore, forest information for the entire continent comes from a compilation of national data and from other global assessment studies. The International Tropical Timber Organization supported projects to establish and implement forest information centers in four Latin American countries (Bolivia, Colombia, Panama, and Peru), and concluded that these activities “have added significantly to the ability of the countries to collect and analyze reliable forestry-related data” (ITTO 2003). Moreover, a regional FAO project, the Latin American Forestry Sector Outlook Study (LAFSOS), produced a “status of the forest information” report for 17 Latin American countries between 2001 and 2002. This report covers topics such as forest resources, land use change, forest management and trees outside the forest, timber and non timber forest products, energy wood, socioeconomic conditions with respect to forests and forestry, and forest information systems (FAO LAFSOS 2001–2002). Also, in a set of FAO FRA working papers, specific information is given on studies of forest cover change in 11 Latin American countries (FAO 2001).

FAO is also implementing national forest monitoring systems through its FRA program. The corresponding inventory activities are more closely linked to the national institutions, so that a higher level of “national appropriation” of the monitoring systems may be expected. In Latin America, FAO FRA carried out these projects to “Support National Forest Monitoring Systems” in Costa Rica and Guatemala (as of 2004). Other countries such as Honduras and Colombia are likely to follow. This program has developed a core assessment methodology with a core suite of attributes/data to be collected. It might, therefore, be the basis for future continent-wide forest monitoring systems.

The situation of forest information and forest information systems is highly diverse among countries. Data collection and analysis procedures vary, as does the timeliness of the available information. In the course of the past 30–40 years, most countries had some national forest inventories, many of which were funded and technically supported by FAO and bilateral technical cooperation projects. A secretarial note of FAO’s 15th COFO session (FAO COFO 2001) states that of the 17 Latin American countries evaluated, three did not have any forest inventory (as of 2001), and only four had repeated inventories that allowed statistically based monitoring of changes. Many national forest assessment studies in Latin America were not “full-blown” forest inventories (i.e. where a broad set of forestry and ecological variables had been collected), but were mapping studies with an explicit focus on status and change in forest area, forest type area and spatial distribution of forests.

Mexico is probably the country with the longest and most continuous history of national forest monitoring activities. There, the forest service is currently conducting a new cycle of its national forest inventory in close cooperation with the Forest Inventory and Analysis Unit (FIA) of the USDA Forest Service (Subsecretaría de Gestión 2002). It will be the fourth such inventory cycle. The first national forest inventory in Mexico was carried out between 1961 and 1986. An overview of these forest-monitoring
activities is given, for example, in Velazquez et al. (2000). In Brazil, the Space Research Institute INPE (Instituto Nacional de Pesquisas Espaciais) carries out a satellite image based forest cover survey of Amazonia on an annual basis, and presents figures for forest cover and forest cover change for that region (INPE 2004).

Chile is a good example of the national level inventories in Latin America. In Chile, the national land survey (Catastro), is a governmental program devoted to monitoring land use and its changes, ranging from natural forest to exotic plantations and agricultural land. The Catastro is based on a physiognomic approach to vegetation (Long 1974), in which the natural vegetation formation is characterized by a set of variables (in discrete classes) related to vegetation structure and botanical composition. The mapping is based on terrestrial point-related information extrapolated to the rest of the stratum, using direct photo interpretation on available aerial photographs. The Catastro covers the whole country, classifying any single stand to a resolution of 6.25 ha. The results are nation-wide 1:50,000 maps on forest types, based on a combination of small-scale aerial photography and satellite photos.

The Forest Research Institute (INFOR) is currently performing continuous forest inventory (CFI) in a pilot study over a total area of 3.0 million ha. INFOR proposed the CFI approach for solving the multiplicity of questions regarding the status and conditions of Chilean forest ecosystem resources and their sustainability. Thus, a sample-based approach was applied as a multilevel and multi-resource forest inventory. It is implemented in a systematic sampling design covering the whole country in a five-kilometer (east-west) by seven-kilometer (north-south) grid.

**East Asia**

The Acid Deposition Monitoring Network in East Asia (EANET) implements a multinational forest-monitoring program in cooperation with ICP Forests. After a preparatory phase (1998–2000), EANET started its regular-phase activities in 2001. Acid (wet/dry) deposition monitoring and monitoring of its impact on ecosystems (soil, vegetation and inland aquatic environment) are carried out by the twelve participating countries, namely Cambodia, China, Indonesia, Japan, Lao PDR, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Vietnam. Forest monitoring is carried out as part of the soil and vegetation monitoring. EANET’s ultimate objective is to assess the impact of acid deposition on terrestrial ecosystem in a comprehensive and systematic manner, by establishing and maintaining a good quality database. In order to achieve this objective, a step-by-step approach was adopted, and the following initial objectives were instituted: establishment of baseline data, and early detection of the possible impacts of acid deposition on plants and forest ecosystem.

Forest monitoring comprises a description of sample trees (species, diameter at breast height, and height), a survey of understorey vegetation, a survey of tree decline, and analyses of soil chemical properties, such as pH and exchangeable cations. The surveys are carried out at three to five year intervals. Ten countries have started their forest monitoring activities. In order to attain the ultimate objective, comprehensive evaluation of the terrestrial ecosystem, one of the planned methodologies is catchments analysis, including simulation modeling.

**Australia**

In Australia, forest management is a state responsibility, while international treaties or agreements and export authorization are federal responsibilities. The National Forest Inventory (NFI) was established in 1988 to provide a single authoritative source of data at the national level. The Federal Government provides funding for NFI staff and core activities, including the collection of data and the dissemination of value-added information. The States and Territories undertake on-the-ground collection of forest data. However, the scales at which information is collected, and the methodology used, often differ among agencies and according to the purpose of collection and land tenure. The NFI attempts to assemble and standardize the data so that they can be combined to develop an overview of the nation’s forests and to make direct comparisons within and between States and Territories. Despite the attempts to standardize data across the nation, it has been difficult to use the NFI to accurately monitor change in the forest estate. A new framework, the Continental Forest Monitoring Framework (CFMF), is being developed. The CFMF is planned to incorporate remotely sensed data (including Landsat TM and other satellite imagery) and systematically located ground-based measurements, to allow comprehensive monitoring of trends for a range of forest values across all land tenures. The CFMF is being piloted in a region that exceeds 10,000 km² and includes a range of forest types, land uses and tenures, to ensure that the sample size (resulting from a 20 km × 20 km Continental grid) and parameters measured are adequate and appropriate.

An alternative monitoring approach is provided by the National Carbon Accounting System (NCAS), which is responsible for providing information on biomass stock continentally, and on the change in that stock, at a sub-hectare spatial resolution. The NCAS accounts for stock change through a highly integrated digital map-based information system that combines remotely sensed land cover change, land use and management, and climate and soils data (including mapped information from thousands of
Forest inventories and assessment provide information to support policy and management decisions at stand, national, multinational and global levels.

satellite images) with greenhouse accounting and ecosystem modeling. By mapping landscape change, the NCAS provides a dynamic 30-year (1970–2000) perspective on the nature and extent of human-induced change in land systems across the Australian continent. Early development work for NCAS determined that the fine resolution required made a sampling approach impractical and a model-based approach was adopted. The digital map-based information is used in a physiological growth model to predict an asymptotic maximum biomass, while management information and disturbance history are utilized to predict the stage of progress towards this maximum point. Published data on biomass for specific locations are compared against model predictions to determine the reliability of the estimates.

8.4 Conclusions and Recommendations

Forest inventories and assessment are needed for the provision of quantitative and qualitative information to support political and management decisions at various scales, ranging from the stand to the national, multinational and global levels. The evolution of forestry from timber maximization to ecological management caused several paradigm changes in forest assessment with respect to information needs, assessment scales, and assessment methods. The availability of information, particularly of qualitative information meeting the changing needs resulting from paradigm shifts, differs greatly among different regions of the world. Quantitative information on forests (e.g. on forest area, wood volume, and increment) is abundant for the developed countries and is increasingly becoming available for some developing countries. In the best case quantitative information is based on NFIs and can be aggregated on the global scale by FRA/TBFRA. As well, qualitative information (e.g. on forest health, biodiversity, and sustainable forest management) is being assessed by multinational systems such as FRA/TBFRA, but especially by the joint forest condition assessment of ICP Forests of UNECE and under the EU-Regulation “Forest Focus” in Europe, and by EANET in East Asia and several similar large-scale monitoring systems in North America. However, basic quantitative and especially qualitative information is lacking or based on estimations for some countries with large territories and for many developing countries. In the developing countries, information is lacking due to economic, social and environmental history. Politicians and forest scientists should identify the new information needs, establish new concepts for forest assessments, and adjust existing systems in order to comply with the new challenges resulting from changed paradigms.
Information needs exist for the current international processes of environmental politics, such as the Kyoto Protocol, CBD and MCPFE. These processes must be provided with scientific information on global climate change, carbon sequestration, forest growth, forest health, biodiversity, and sustainable forest management. Such information can only be provided through the implementation of new and the extension of existing multinational forest monitoring systems. However, at the same time unnecessary duplication should be avoided and resources should be coordinated. This is difficult because very few donors finance self-sustaining global inventories and national inventories are financed nationally. Forest monitoring systems have to be integrated into political structures, assuring that the scientific information provided by them can lead to political action. A good example for such a structure is the CLRTAP. CLRTAP set out 25 years ago to reduce air pollution in Europe. Based on monitoring programmes such as ICP Forests, legally binding protocols were adopted by the Signatory States that led, for instance, to a reduction of sulphur depositions in Europe by approximately 70%.

In the establishment phase of any forest monitoring system, several requirements crucial to its future success have to be fulfilled. Politicians and scientists have to mutually formulate clear and realistic monitoring objectives. In order to meet these objectives, politicians should assure long-term and continuous availability of financial, human and technical resources from the beginning. Yet, the monitoring design must permit arrival at statistically reliable results within a reasonable timeframe.

Multinational assessments can be realized by means of compilations of data from existing national assessments as well as by means of uniform transnational monitoring systems. Mostly, the first option is more feasible than the latter. The precondition for both approaches, however, is a strict harmonization of definitions, standards and methods among the participating countries. For instance, the definition of forest varies according to the types and functions of forests within and among countries. Such conceptual differences yield incompatible assessment results. Resolving such differences often proves difficult as countries have long established procedures that meet their needs and as they are hesitant to compromise to meet international standards or recommendations. It is for these reasons that international standards and methods are more easily accepted when countries are developing their inventories in the course of capacity building.

The best example of the compilation of data from existing national assessments is FRA/TBFRA. It relies on the best available national information that is harmonized by national experts, as well as capacity building where national systems are weak. It requires only marginal extra costs at the international level, and it does not entail duplication at the national level. As regards harmonization, FRA/TBFRA still has concerns with respect to spatial inconsistencies and changes in information needs, which make comparisons among assessments difficult (Holmgren and Persson 2002). In total, however, FRA/TBFRA demonstrates that compilation of global results can work up to some level, though accuracy and reliability vary.

An example of the development of a uniform international system is provided by the monitoring of forest conditions in Europe by ICP Forests and the EU. This approach was costly and time consuming, but eventually led to a very high degree of harmonization. Harmonization was realized not only with respect to definitions, standards and procedures of field assessments but also with respect to data submission, management, evaluation and the reporting of results.

Both approaches of multinational assessments are suitable for using synergies and avoiding redundancies among national and international surveys. Braatz (2002) and Prins (2002) describe ways to overcome redundancies in national reporting and point out synergies between forest resources assessment and indicators of sustainable management. A good example is provided by the synergies between TBFRA 2000 and the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (MCPFE 2000). Data on quantitative indicators for the third Ministerial Conference in 1998 were not collected by MCPFE, but in the context of TBFRA 2000, ICP Forests and other international arrangements. The close cooperation between ICP Forests and the EU is another example of synergies. The EU-Regulation “Forest Focus” covers the wide field of sustainable forest management. ICP Forests is also partly engaged in this field, but focuses on the effects of air pollution on forests. Despite their different scopes, EU and ICP Forests are sharing the same monitoring system and are cooperating in data bank management. There are also, however, examples of redundancies in multinational assessments. In Europe, for instance, the lack of consistency in multinational assessment efforts has even led to a situation in which a forest component has been included into CORINE Land Cover and LUCAS. This is an unnecessary overlapping, and we may ask why the required information was not gathered by e.g. national queries.

There has been discussion about the possibility of developing one single international assessment process, which would fulfill most future international information needs. Such a goal would be extremely difficult to reach, particularly at the measurement level. More attainable is harmonization at the reporting level. IPCC is a good example of such reporting. This kind of approach can to a large extent fulfill global data needs, but it has to be combined with capacity building where there are no functioning inventories. Lund and Iremonger (2000) describe the development possibilities either from the bottom up based on a combination of national information sources, or from the top down through methods such
as multinational sampling, described above. They highlight the importance of sharing existing information at the international level, and developing joint global assessment objectives.

Global data and reporting needs do not necessarily have to rely on full coverage of ground-based national inventories, as such coverage is not achievable in the foreseeable future. What is needed is a much more attainable goal: the determination or identification of a common global lowest denominator for data. Some kind of expert evaluation or remote sensing approach may be needed for filling the most severe data gaps in this denominator. With time, and improvements in technology and country capacity building, this baseline may shift to reflect additional interpretive capability. As a good start, it may be that global vegetation mapping efforts and sampling based on remote sensing can be used in a harmonized way to produce globally consistent data sets and interpretive products. Remote sensing is already a well-established method, but it may gain additional importance for both quantitative and qualitative assessments with the ongoing development of sensors having higher resolution or operating at previously unstudied frequencies. They permit the provision of data for less accessible areas (such as tropical forests), and even for countries not providing data by themselves. This advantage, and the relatively low costs, make remote sensing a good choice for forest assessments in developing countries or countries with very large territories. Though the limited set of assessable parameters constitutes a restriction (Kleinn 2002), remote sensing can complement or even replace terrestrial assessments, depending on the information required. In Canada, for instance, remote sensing is applied successfully at all scales. A concern may exist for global scale monitoring, as resolutions achieved with current technology may not be acceptable for information needs. Also remote sensing may not provide information for all needs. Original hopes that remote sensing could eventually replace large areas of terrestrial assessments (FAO 1968) have turned out to be overly optimistic. In several cases, the abandonment of terrestrial assessments has been found to lead to a lack of information (Holmgren and Persson 2002). Combining terrestrial assessments with remote sensing remains the best choice.

Multinational forest assessments need efficient institutional management for planning, for making and implementing strategic decisions, and for evaluating. Comparability of results among the participating countries cannot be reached by harmonization alone. Program management also has to implement strict procedures of quality assurance. The necessary efforts for quality assurance are all too often underestimated in the planning stage, resulting in a disproportion of costs and benefits. Data errors are inherent in monitoring design, field assessment, data evaluation and the reporting of results. The reliability of results depends strongly on the measures taken to keep errors within tolerable limits during each phase of the monitoring program. Also, an effective data and information management system has to be established. Moreover, program management has to make sure that the program is regularly evaluated by independent parties with respect to its efficiency and compliance with objectives.

Currently global forest assessments are stand alone activities, not considered with other social and economic needs. However, forest assessments and sustainable forest management need to be considered together with assessments of other resource needs like need for cropland, grassland, urbanization, etc. (Lund and Iremonger 2000). This has recently become very apparent in carbon accounting, where forests, croplands, grasslands, wetlands, settlements, and other land classes must all be considered jointly for effective national and international carbon accounting (Penman et al. 2003). Globalization and technological development have been strong driving forces in shifting society’s attitudes to and perceptions of the environment, and in developing the role of forest assessments. The first two are linked. Technological development can solve problems as well as generate new paradigms, such as the application of genetically modified tree breeding material, the consequences of which may have to be monitored in future assessments. Factors for future assessments, raised by changing values and globalization, include:

- Sustainability
- Ecology
- Economy
- Social and cultural values of forestry
- Ecosystem function
- Better understanding of ecosystem processes and the effects of anthropogenic influences including forestry
- Intrinsic value of all the ecosystems
- Importance of forests and forestry to ground water supply
- Value of non-timber values and services compared to timber production
- Increasing conflicts in land use.

Consequently, one of the most dominant paradigms in the future could be the provision of increasingly global level information for scenario modeling, considering the effects of global change, desertification, water production, and their interaction with the biosphere.
References