

Tropical Forestry

Sampling Methods, Remote Sensing and GIS Multiresource Forest Inventory

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1.1 Focus

Forest inventory is a process for obtaining information on the quality and quantity of forest resources and forms the foundation of forest planning and forest policy. While early concepts of sustainable forest management and forest inventory focused on timber production (Hartig 1795; Cotta 1804), modern forest inventory concepts support a holistic view of forest ecosystems addressing not only timber production but also the multiple functions of forests as well as the need to understand the functioning mechanisms of forest ecosystems (von Gadow et al. 2002; Corona et al. 2003).

Forest resources assessment facilitates a multifaceted analysis and study of forests not only as an important source of subsistence, employment, revenue earnings, and raw materials to a number of industries but also for their vital role in ecological balance, environmental stability, biodiversity conservation, food security, and sustainable development of countries and the entire biosphere. Forests have to be managed judiciously not only for environmental protection and other services but also for various products and industrial raw material. In some parts of the world biological resources are being depleted faster than they can regenerate. Following the 1992 United Nations Conference on Environment and Development (UNCED) conference in Rio de Janeiro considerable progress has been made in the area of sustainable forest management. Among others, the International Tropical Timber Organization (ITTO) and the Forest Stewardship Council (FSC) developed criteria and indicators for sustainable forest management and certification. The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) describes measures to mitigate greenhouse gasses and addresses in Article 3.3 in particular the impact of deforestation and afforestation on global climate change. The Convention on Biological Diversity (CBD) that was ratified in 1994 deals with the protection and maintenance of biodiversity.

Forest resources assessments have their focus on the provision of information, which has several implications:

1. The information provided has to satisfy user needs. An inventory is generally not carried out for the needs of a single stakeholder; multiple issues of forests have to be covered. The objectives must be defined by those who require the data to be collected. All groups of users of inventory results should be involved in this phase of planning. Very often, the number of those interested in the inventory results increases after an inventory has already begun or after the findings have been published, so the data collected usually fail to satisfy all demands for information. Before defining the objectives it is advisable to make an inquiry not only among forest authorities but also among private forest owners, the wood-processing industry, land-use planning and environmental protection agencies, consumers of secondary forest products, wildlife organizations, and other potentially interested parties, thus enabling them to articulate their particular needs for information. In addition, this approach increases the possibility of finding partners who will make a financial contribution.
2. The information obtained by an inventory is typically presented in maps and statistical estimates. The basic concept of any statistical presentation is to summarize the population of interest and extract the facts important for potential users. This is generally done by presenting statistical parameters such as mean values, totals, or ratios and percentages. In addition, information on the variability or diversity of a population is an important ecological issue.
3. The information has to be objective. All parts of the population should be covered by the inventory; no part should be intentionally excluded. Data must be assessed in a nonsubjective way. Objective information requires the objective assessment of data. When information is gathered by some form of sampling, only application of a statistical design with known selection probabilities for any population element can ensure the integrity of the information-gathering process (inventory).
4. The information has to be reliable. The results of any sampling survey are always estimates rather than true values and are thus subject to a certain degree of uncertainty, as only part of the population is assessed. The uncertainty can be reduced through an optimal combination of sampling design and sample size in order to increase the precision of the estimates and to reduce sampling errors. The measurements themselves may be subject to error caused by, for example, inappropriate measurement devices, poor training, or subjective interpretation of measurement rules and definitions. Investments in improved instruments and the provision of intensive

training of field crews usually generate a handsome payback in the form of an increase in the quality and accuracy of data. It is necessary to specify the degree of precision and accuracy (see Chap. 3.4) to which the results should attain. This must be decided by the prospective users, though it is often difficult for administrators to think in terms of sampling error.

5. The information must be assessed in a cost-efficient way. Once forest managers and decision-makers have provided a rough definition of the objectives, several alternative inventory designs should be investigated. Alternatives can be based on different sampling design, sampling intensities, or data sources. Comparison of these alternatives allows assessment of the cost—benefit relationship and the final definition and weighing of the objectives.
6. The results of an inventory should be intuitively clear for potential users. Users are normally not very familiar with sampling statistics and thus the results should not require a Ph.D. in statistics for any immediate and basic interpretation. Users will have confidence only in information that they can understand. The inventory design should be documented and give advice for the impartial interpretation of data. As sample-based results are always subject to sampling errors, it is necessary to accompany any statistical estimate with estimates of sampling error or confidence interval.
7. Forest inventories should “only” present information in statistical and mapped format. It is beyond the mandate of a forest inventory to interpret results. However, forest inventory specialists should give advice for the interpretation of data. This restraint is also intended as a safeguard for the integrity of the inventory process.
8. In inventories on successive occasions, terms and definitions should not be changed unless it can be argued that the benefits outweigh the problems introduced by a change. When terms and definitions are changed between assessments one cannot distinguish between true change and change due to change in definitions.
9. Planning of a forest inventory is a complex task that involves expertise from many fields; thus, experts from silviculture, forest management planning, economics, policy, ecology, or timber products need to be consulted at an early stage.

1.2 Objectives

The main elements of an inventory depend very much upon the inventory objective; thus the objectives of an inventory have to be laid down in a very early phase of inventory planning. The exact definition is a joint action by the inventory designer and the potential user group. It is a very laborious

undertaking and consequently too little effort is often committed; yet without it, one may lose sight of the real objectives with the risk of accepting inappropriate methods and procedures. The formulation of the objectives constitutes not only the basis for the design of the sampling methods but also an instrument for checking success once the survey is complete.

Four specific guidelines should be considered when determining inventory objectives (FAO 1998):

1. Objectives need to be determined jointly by the people who will use the results, including forest managers, planners, and decision-makers, as well as by inventory specialists. Inventory objectives should not be determined by inventory specialists alone.
2. Not all inventory objectives have the same level of importance. Some have higher priority than others and it is the objectives having highest priority that should determine the inventory design and the presentation of results.
3. Inventory objectives should reflect the physical effort that will be required to conduct an inventory, the organization, estimated costs and time, the existing knowledge of resources, the availability of specific aspects of inventory technologies, and institutional capability. All have a direct bearing upon the implementation of an inventory. An overriding consideration is that an inventory must be practicable and achievable. The value of an incomplete inventory that lacks important information and thus limits the possibility to establish causal relationships could be zero or close to zero.
4. All objectives should be *SMART*
 - Specific
 - Well defined.
 - They are clear to anyone who has a basic knowledge of the project.
 - Measurable: They provide quantifiable measures of achievement and variance from set objectives.
 - Agreed upon: There is agreement between the users and the project team on what the objectives should be.
 - Realistic: Looking at the resources, knowledge, and time available, can the objective be accomplished?
 - Time-framed
 - How much time is needed to accomplish the objective?
 - Having too much time can affect the project performance.

The information requirements from forest owners, policy planners, the scientific community, and society in general concerning forest resources have been growing steadily since the 1950s when the main focus was on information about timber supply (Table 1.1). The multiple functions of forests, biomass,

Table 1.1. Increase in information needs about forest lands in the USA (after Lund and Smith 1997)

					Nonforest lands, habitats, old growth and primary forests
				Ecosystems, biodiversity, NWGS	Ecosystems, biodiversity, NWGS
			Global	Global	Global
			warming	warming	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+

NWGS nonwood goods and services

global warming, biodiversity, and nonwood goods and services have since gained prominence (Lund and Smith 1997).

The thematic scope of forest inventories can vary considerably. It is advisable to review global initiatives and obligations in order to get a broad view on potential information topics to be covered by a forest inventory. UNCED criteria and indicators for sustainable forest management have been formulated through several international, national, and nongovernmental processes. These include the Pan-European (or Helsinki) process (for European forests), the Montreal Process (for temperate and boreal forests), the Tarapoto Proposal of Criteria and Indicators for Sustainability of the Amazon Forest, the United Nations Environment Program (UNEP)/Food and Agriculture Organization (FAO) Expert Meeting on Criteria and Indicators for Sustainable Forest Management in Dry-Zone Africa, or the Lepaterique Process of Central America. The ITTO, the Tarapoto Process (TARA), the Center for International Forestry Research (CIFOR), the African Timber Organization (ATO), and the Central American Commission for Environment and Development (CCAD) developed systems of criteria and indicators for sustainable forest management which cover administrative, economic, legal, social, technical, and scientific issues which affect natural forests and plantations. The criteria define the essential factors of forest management against which forest sustainability may be assessed. Each criterion relates to a key management factor which may be described by one or more qualitative, quantitative, or descriptive indicators. Through measurement and monitoring of selected indicators, the effects of forest management action, or inaction, can be assessed and evaluated and action adjusted to ensure that forest management objectives are more likely to be achieved. Table 1.2 summarizes the criteria