Forest Inventory

Basic knowledge

The Forest Inventory Module is intended for people involved in the collection of data on forest resources. It provides insights into the types and purposes of forest inventories and sets out the main steps in conducting them, from measurement methods to data collection.

The module provides basic and more detailed information on forest inventory, as well as links to forest inventory tools and case studies of effective forest inventories.

Forest inventory is the systematic collection of data on the forestry resources within a given area. It allows assessment of the current status and lays the ground for analysis and planning, constituting the basis for sustainable forest management.

In general, all inventory operations should follow at least the following steps:

Definition of the inventory objectives and information desired.

Development of sampling design and methods.

Data collection (field surveys, remote sensing data analysis and other sources).

Data analysis and publication of the results.

Due to cost and time constraints inventories are generally carried out using **sampling** techniques. The general principle of sampling is to select a subset from a population and draw inferences from the sample to the entire population. The selection of the most appropriate sampling design is subject to several considerations (more details can be found in the Tools section of this module). Two basic considerations involve whether the objective is to set up a monitoring system (repeated measurements over time) and whether auxiliary information (i.e. aerial or satellite imageries) is available or not.

The main factors determining the overall methodology are the **purpose** and the **scale** of the inventory.

The **purpose** (objective/goal) and the targeted audience of a forest inventory must be clearly defined, and the focus of the data collection outlined accordingly with the information needs of the users. While in the past forest inventories were primarily aimed at assessing timber availability, in recent years the forest is recognized as a complex ecosystem with several elements (including humans) interacting. A forest inventory is now commonly conceived as a **multipurpose forest inventory** with the contribution of expertise from different fields such as sampling theory, surveying, information technology, remote sensing, social science, mensuration and modelling to assess the multiple functions of forests and trees.

In terms of **scale**, a wide range of needs, and therefore approaches, are possible. Global forest inventories are aimed at determining the extent and status of forest resources at the global level (i.e. FAO's Forest Resources Assessment being carried out since 1946 which also serves as mechanism for facilitating the harmonization of terminologies and definitions).

Smaller areas inventories are usually driven by specific goals, often for forest planning and operations. They include regional inventories (portions of the country area); reconnaissance inventories (rough insights of forest resources in a limited area); diagnostic sampling to orient silviculture and forest management; exploitation surveys (focused at assessing harvestable timber availability and planning of harvest and logging operations); post-harvest inventories (to assess regrowth and damage caused by logging operations); forest health monitoring (often linked to salvage cuts operations).

Forest inventory contributes to SDGs:

In more depth

Measurements methods

At the base of every forest inventory lies a set of activities carried out in the forest that are defined as forest mensuration. Forest mensuration deals with the determination of dimensions, form, weight, growth, volume and age of trees, individually or collectively, and the dimension of their products.

To some extent the availability of financial resources and human capacity determines the methodologies to be used. In a best-case scenario, multi-purpose field-based forest inventories collect primary data on tree species, diameter and height, land use, and more, combining permanent sample plots with a remote sensing survey to assess forest cover and other parameters.

Field survey

In a field survey, forest inventory teams collect data on the ground. For a relatively small forest area, such as a logging coupe, it is possible (and often required) to conduct 100 percent inventories (also called full-cover or wall-to-wall inventories) in which all trees in the stand (usually above a specified minimum diameter) are measured. For larger-area inventories, such as at the landscape, provincial or national level, a 100 percent inventory is likely to be impractical and prohibitively expensive. A sampling strategy is therefore required whereby measurements are made in permanent and/or temporary sampling units, and those measurements are used subsequently to estimate values for the entire forest area. The sample area is the total area of all sampling units in which measurements are made.

The sampling procedure can be random, but a systematic sampling is usually more efficient, as this tends to provide better representation of the distribution of land uses and forest types. Sampling can also be pre-stratified in order to intensify the sample in strata that are more heterogeneous or of higher priority, thus increasing the precision of estimates where it is most required. The sampling units may be stands, plots, strips or points, and plots may be circular, rectangular or square (or some other shape) and of fixed or variable size. Plot size is determined according to the expected number of measurements of the parameters of interest. For example, plots for measuring small trees can sometimes be smaller than plots for measuring larger trees, as small trees often are more frequent than larger trees (and therefore a similar number of stems can be measured in a smaller area). The number of plots is determined by the need for statistical precision, especially for key parameters, and by cost and time constraints. More time and effort is usually required to measure a widely dispersed set of plots than plots arranged in clusters (i.e. ‘cluster sampling’).

Remote Sensing survey

A remote sensing survey (e.g. using data from air-born or satellite-born sensors) can be used for either full-cover or sampling approaches. In a sample-based approach, observations are made in sampling units (sample area), while in a full-cover approach the entire area of interest (e.g. a landscape, province or nation) is surveyed. Remote sensing observations can be used in particular to determine the extent of different land-cover (or land-use) classes. This can greatly assist in extrapolating volume and biomass densities generated by field-based measurements over large areas and over time in repeated assessments to estimate changes in total volume and biomass stocks, and to stratify the analysis of field data.

Radar and laser-derived space-borne or air-borne remote sensing can be used to capture data for estimating both volume and biomass stocks. The accuracy of these methods depends a lot on the ability to calibrate and validate the measurements with field data, and the technologies are still experimental and relatively expensive, but show promise, particularly for areas that are difficult to access in the field.

Data collection

Measurements and observations in the field are made on individual trees (and shrubs) as well as on the whole forest ecosystem.

Common tree measurements and observations are: diameter, height, stem form, health condition and taxonomical species. A variety of instruments and tools is available for measuring tree parameters, depending on budget and expertise.

Diameter – Typically, the tree stem diameter is measured over bark at a height of 1.3 m above the ground commonly referred to as breast height (hence the expression diameter at breast height – dbh). For special cases (e.g. trees with irregular form or trees growing on a slope) refer to NFMA field manual. Equipment: Diameter tape, scale stick, caliper

Height – Tree height is the vertical height of a tree from the ground to the top of the tree. Commercial bole height is the length of the bole from the stump to the height of the bole at the point of the first stem fork or smallest merchantable diameter (i.e. the minimum bole diameter able to be used as timber). The measurement of tree height can be particularly difficult in forests where tree tops are not visible because of the dense canopy (e.g. in closed tropical forests). Given that it is far more costly to measure tree height than dbh, tree height is often measured for only a subsample of trees. On the basis of such a subsample the relationship between dbh and tree height can be modelled and applied to predict the height of all trees in the sample. However this will give less accurate results than actual height estimates.

Both total height and commercial bole height can be estimated using a variety of tools, and the more accurate height measurement tools (clinometers) measure angles and enables the user to determine the height of a tree when standing at a given distance. Refer to *NFMA field manual for further information and diagrams on tree height measurements. Equipment: clinometer, hypsometer, relascope, rangefinder, scale stick, measurement pole.*

Health and vitality of forest ecosystems can be determined through selected ecological indicators. Those indicators are mainly observations on the presence or absence of affecting biotic or abiotic agents and environmental problems (or their symptoms) as well as overall assessment of the condition of forest and trees. They are recorded in the plots either at tree level (overall tree condition and crown condition, causative agents) or at forest stand level (environmental problems observed and the degree of severity and trends). The information on forest health and vitality is derived from both field observations as well as from interviews with local population and key informants.

Biological diversity good identification of tree species is a fundamental prerequisite of any forest inventory. In many cases it is much more serious to be wrong in the identification of the species of a tree then to make a mistake about any of its other characteristics. In species-rich tropical forests species identification is often a challenging task, due to the restriction of specialised botanical expertise to a few taxonomists. A recommendation is to take samples of parts of the trees, preferably including fertile material like flowers, seeds and fruits, to be identified by experts in a laboratory. Detailed photographs of similar material could serve the same purpose. To limit the efforts some inventories focus only on those species considered “important”, be so for their commercial value, their role in ensuring biodiversity or other reasons.

A comprehensive assessment of biological diversity would then include results on dbh and height by species, their spatial distribution, forest structure and observations of indicator species (both flora and fauna).

Environmental and socioeconomic services are essential functions provided by forests and trees. For large area inventories these services are important to assess and monitor in order to provide decision-makers with needed information to improve the livelihoods of local people and to protect soil and water. The information on these services is collected through field observations and through interviews with local people and other key informants.

Estimating growing stock and biomass

Volume or biomass estimates for individual trees in the sample area are aggregated to derive the total inventoried tree volume in the sample area. The growing-stock density (m^3 per hectare) and biomass density (tonnes per hectare) can be calculated by dividing the total inventoried tree volume or biomass by the sample area. Some volume functions with measurements at the stand level (e.g. basal area) generate estimates of volume density directly.

Tree allometry is the use of equations, models and functions to describe the quantitative relationship between various tree parameters. In combination with tree inventory data, allometric equations can be used to estimate tree volume, tree biomass and, ultimately, the growing stock, biomass and carbon stocks of forests at various scales. Allometric models can be species specific or for a group of species and they can be generically derived for different forest types. A useful source for identifying appropriate allometric models is the GlobAllomeTree: an international web platform for tree allometric equations to support volume, biomass and carbon stock assessment.

Further learning

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Videos

Ministerio del Ambiente, Peru. *Inventario Nacional Forestal.* Online video clip. YouTube, 6 November 2013. Last accessed 02.02.15.

Credits

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