National Forest Inventory in Finland[1]

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Summary

Finland's first National Forest Inventory started in 1921. To date, eight inventories have been completed with the main objective of providing forest resource information for forestry planning at both a local and national level. The results of the inventories have played a central role in developing forestry and forest industries. A systematic sampling method covering the total land and inland water area is employed. In the first four inventories, sampling was based on transects running south-west to north-east through the country. Systematic cluster sampling has been employed in more recent inventories, with field work carried out as a continuous annual process. Today, an additional network of permanent sample plots produces large volumes of new data concerning the status of and changes in the forest ecosystem. Modern methods using satellite imagery have also made it possible to acquire better localized information and more reliable results for smaller areas.

Introduction

Finland is the most forested country in Europe. Of the total land area of 304,000 km^2, 86% is under forest cover. Forest land with a mean annual increment exceeding 1.0 m^3/ha/yr. accounts for approximately 200,650 km^2, i.e. over 4.0 ha per head of Finland's population of 5.1 million. Sixty-three percent of the forest land is privately owned, and 24% state owned. There are over 400,000 forest holdings in private non-industrial ownership in Finland. Total growing stock is approximately 1,900 million m^3, with an annual growth of 80 million m^3. Species include Scots pine (46%), Norway spruce (37%), birch (14%) and other broadleaved species (3%). Annual timber harvest volumes vary between 45 and 55 million m^3. The sawmilling industry began to expand in the 1800s, followed later with the establishment of cellulose and paper industries. In the early 1950s, forest industry products accounted for almost 90% of Finland's total exports. This figure currently lies at 40%.

At the end of the 1800s, virgin forests were to be found only in the northern- and eastern-most parts of the country. Everywhere else had seen signs of irresponsible slash-and-burn cultivation, tar distillation and the procurement of construction timber and firewood. This led to growing concern about the state of Finland's forests, which were generally seen as entering a period of decline. Such

concern led to the initiation of forest inventories. Finland was the first country in the world to conduct a nationwide forest resource inventory. Today, Finland is the only country boasting of a record of national forest resource data dating back over 70 years.

History and objectives of the National Forest Inventory

Finland's national forest inventory is carried out by the Finnish Forest Research Institute. Eight inventories have been completed to date, with field work carried out during the years 1921-24, 1936-38, 1951-53, 1960-63, 1964-70, 1971-76, 1977-84, and 1986-94. During the first four inventories, measurements were taken systematically from sample plots lying on transects running south-west to north-east through the whole country. In later inventories, however, systematic cluster sampling was adopted, with field work becoming a continuous annual process proceeding region by region from south to north. During the 6th and 7th National Forest Inventories, a two phase sampling method employing aerial photograph interpretation was used in areas to the north of the country. A new era commenced in 1989, when, in addition to the field measurements, satellite imagery and digital map data came into use.

In the beginning, the objective of the National Forest Inventory was to gather information on the quantity and quality of Finland's forest resources, and to provide a reliable basis for forest income and property taxation (Kuusela, 1978). More recently, the results of the inventory have been used as an information basis for utilizing and developing forest resources. The huge volume of statistics produced on forest development throughout the country provides a firm basis for forest investment decisions.

Sample design

During the 8th National Forest Inventory, the sampling unit employed was a cluster, and the sampling plot a temporary relascope-restricted plot. Four different sampling intensities were used, with the distance between clusters and the amount of sample plots per cluster varied (Figure 1 illustrates the sampling design used for an area in North Finland, including cluster location and the position of sample plots within clusters). Within each plot, data collected included the species, dbh, tree class and crown storey of each tree. In addition, every seventh tree was adopted as a sample tree and measured for diameter at 6.0 m, height, diameter and height increment, green crown, damage, and timber assortments (Figure 1). Estimates were also made for the compartment within which the sample plot fell, including

- general information (inventory date, plot number and coordinates, elevation, ownership group, restrictions on forestry, etc.),

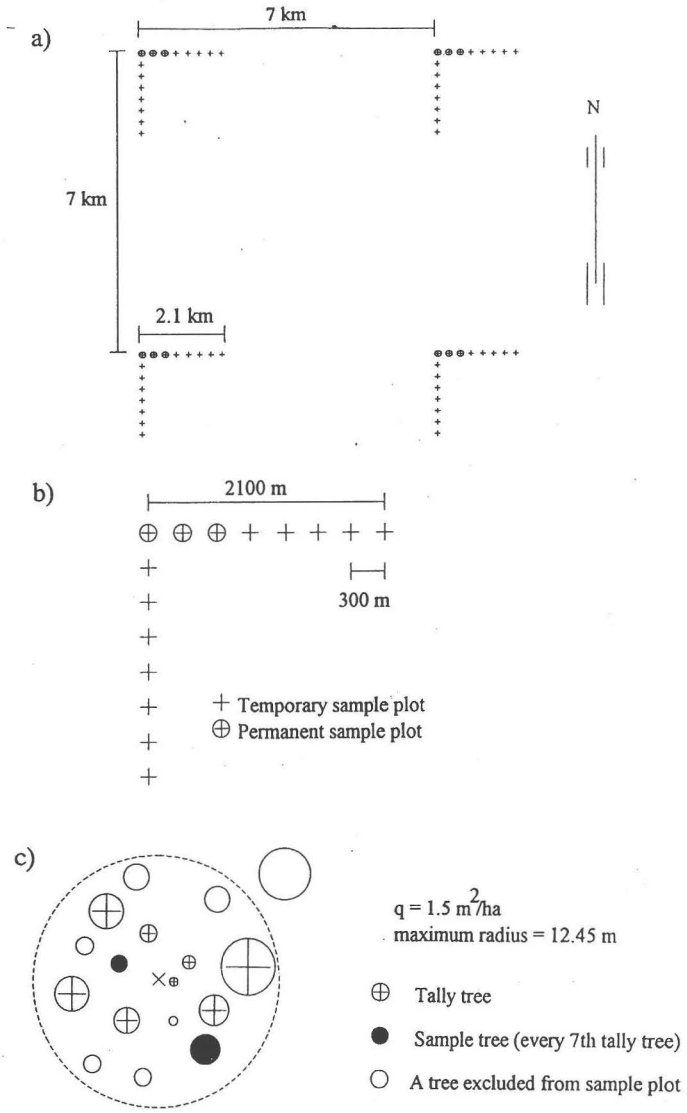

Figure 1. *Sampling design for the Kainuu and Pohjois-Pohjanmaa Forestry Board Districts used during the 8th National Forest Inventory, showing (a). location of clusters, (b). location of sample plots within clusters, and (c). a restricted sample plot.*

- site information (land class, site class, soil, drainage, completed or proposed soil preparation, taxation class, etc.), and
- information on the growing stock (tree species, development class, age, crown storey, establishment, basal area, stem numbers, mean diameter and height, damage, stand quality, silvicultural or felling treatments proposed or completed, etc.).

Data was collected using field computers and transmitted daily *via* mobile phone for further processing (Tomppo and Siitonen, 1991). The 8th National Forest Inventory saw the introduction of a small number of permanent sample plots among the temporary plots. During the inventory, approximately 0.5 million trees were measured, of which 70,000 were sample trees. The total amount of sample plots was approximately 80,000.

Permanent sample plots

A separate network of 3,000 permanent fixed radius sample plots was established throughout the country during the period 1985-86, for the purpose of providing information on changes in single trees and the overall forest ecosystem. For most of the country, four-plot clusters located 16 km x 16 km apart were used, while in the northern-most region, three-plot clusters located 24 km x 32 km apart were employed. Principal measurements relating to compartment and tree data were similar to those taken in the temporary plots, with measurements directed more towards younger trees. The main objective of these plots is to acquire more information about changes in young stands, damage, mortality, and the development of the technical quality of trees. The plots also produce data for growth modelling. In addition, biologists assigned to each work group collects data on site classification and vegetation, including berry and mushroom production, tree lichens for chemical analysis, and mosses for the study of heavy metal deposition. Almost no visible traces are left on the ground after the surveying of the plots, in order to keep their location secret and to avoid interference.

Permanent plots were first remeasured in 1990-91, and again in 1995. In the future, remeasurements will be extended to a 10 year interval. The plots, which have been the subject of intensive research over the last decade, form a basic network for soil analyses and the monitoring of tree health and vitality, and produce significant quantities of new information concerning the status of and changes in the forest ecosystem.

Satellite imagery and digital map data

The Finnish Forest Research Institute started to develop a new inventory system in 1989 during the 8th National Forest Inventory, in order to obtain geographically localized, up-to-date information and more reliable results for small-

er areas. The method utilizes Landsat™ imagery and digital map data in addition to field measurements. Imagery analysis methods have been chosen to allow the computation of estimates of all inventory variables for each pixel. Data for the whole country will be available in 1995. The map themes utilized to date are (i) arable land, (ii). built-up areas, (iii). roads, (iv). peatlands, (v). digital terrain models, and (iv). boundaries of computation units (Tomppo, 1994). Digital map data will be used to enhance the accuracy of land classification and to separate forest and non-forest land from each other (Tomppo and Siitonen, 1991).

Results

The most common way of presenting the results is through the use of tables. These may represent areas and growing stock volume by administration districts and owner groups. Other important characteristics include land classes, sites, drainage status of wetlands, taxation classes, age and development classes by dominant tree species, damage, stand silvicultural condition, and completed and proposed cuttings and silvicultural treatments. From information concerning the growing stock, total volume, mean volume, structure, quality and increment can be presented on a species basis. Such variety reflects the wide range of characteristics and information now being used for planning the multiple use of Finland's forests. The development of the country's forest resource can be presented in a time series commencing in 1923 (Figure 2), with most of the detailed time series beginning in 1952.

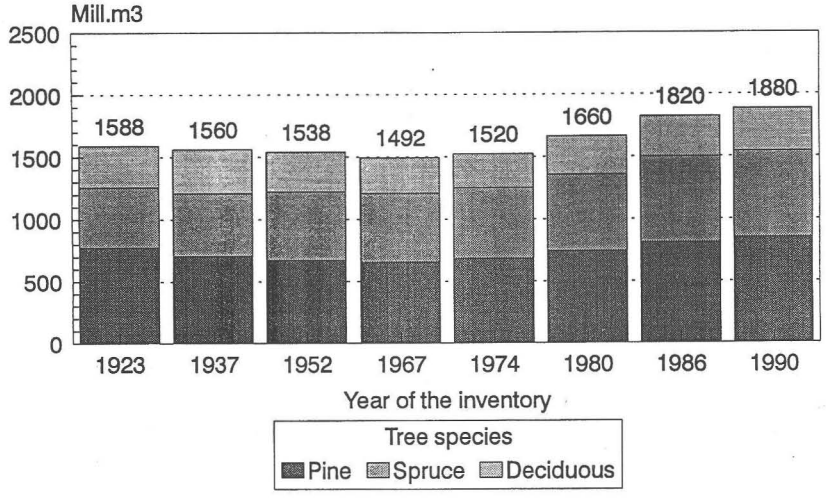

Figure 2. *Total volume of the growing stock by main tree species during the period 1923-90 on forest land and other wooded land.*

The most important administration unit in Finnish forestry is the Forestry Board District. There are 20 districts, each with an area of approximately 0.5 to 1.0 million ha. The standard error of the growing stock volume estimation for these districts is 2.0 to 4.0%. The standard error of the growing stock for the whole country is 0.7%, with the standard error of the estimation of the area of forest land at 0.4% (Kuusela, 1978).

The traditional role of the National Forest Inventory is to produce objective and up-to-date information on forest resources and their development for the purpose of national and regional decision making. The new inventory system with satellite information creates better opportunities to fulfill these requirements. Estimates of different variables for each point of the country give results for smaller areas, while forest data for the whole country can be kept up-to-date (Tomppo and Siitonen, 1991).

Forest calculation system

A computerized forest management planning system (MELA) was designed during the late 1970s to analyse long term timber production possibilities at both regional and national levels, based on the sample plot data collected during the National Forest Inventory. The MELA system is a framework for gathering and managing all relevant information for forest management from individual trees and forest stands, and represents the basis for decisions concerning the whole forestry unit (Siitonen, 1993). In effect, the system calculates alternative strategies for the development of forests and enables the long term planning of timber production.

Forest resource information can be updated from field measurements, cutting statistics and increment variation measurements. The first country-wide update was completed with the MELA system in spring 1990, giving up-to-date estimates of the growing stock and increment. MELA has also been used in the formulation of the Forest 2000 Programme, a long term strategy for forestry and forest industries (Anon., 1986).

Conclusion

National forest inventories have been one of the primary functions of the Finnish Forest Research Institute. The inventory method is now changing from the repeated temporary field inventories to an up-to-date multi-source forest resource monitoring and forest management planning system. In addition to the traditional publications, inventory results will be supplied as thematic maps and in digital form for further processing. The field sample of the inventory will serve as a general forest sampling framework for forest research, with the utilization of the inventory results now creating new levels of cooperation between practical

forestry and forest research (Tomppo, 1993). Meanwhile, the results of the inventories have played a central role in developing forestry and forest industries. The future of the inventory will also bring the increased use of modern technology. For example, research is ongoing into the use of microwave instruments in forest inventory work.

The multi-source inventory method described is now operative and will soon be in use throughout Finland. Such a method has also been tested, or will soon be in use, in Sweden, Germany, New Zealand and China (Tomppo, 1994).

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