CHAPTER 18

EUROPE

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18.1 SWEDEN

18.1.1 Swedish National Forest Inventory

The main purpose of the NFI, which has been taking place since 1923, is to describe the state of forest resources in Sweden, e.g. growth and cuttings, and to trace changes in these. The NFI is a part of the Official Statistics of Sweden (Swedish National Inventory of Forests 2004), however, and thus has numerous fields of application, being, among other things, a powerful resource for environmental monitoring. As a basis for the statistical design of the survey, a geostatistical analysis has been used to determine the variation within areas, the importance of the size of the sample plot, the time required and the economic practicability of the available resources. The analysis has resulted in a division of the country into 5 regions, the designing of survey tracts, a weighting between permanent and temporary survey tracts and a standard size of sample plot (Matern 1960, Matern, 1981, Ranneby, 1981a, Ranneby, 1981b, Hägglund 1985, von Segebaden 1992). Variograms have been used to describe variations in land use, forest volume and topography (Matern 1960, Ranneby, 1981b), and these spatial functions have been used to define an effective layout for the survey tracts.

The Swedish NFI is based on the systematic sampling of tracts, so that the current design, including both permanent tracts (established in 1983) and temporary ones, covers the whole country every year. The tracts consist of circular plots (Fig 18.2) within which samples of the trees, ground vegetation, etc, are selected and used for estimating the total volume of all trees, the total area of land covered by a certain vegetation type, and so on.

A. Kangas and M. Maltamo (eds.), Forest Inventory – Methodology and Applications, 295–308.

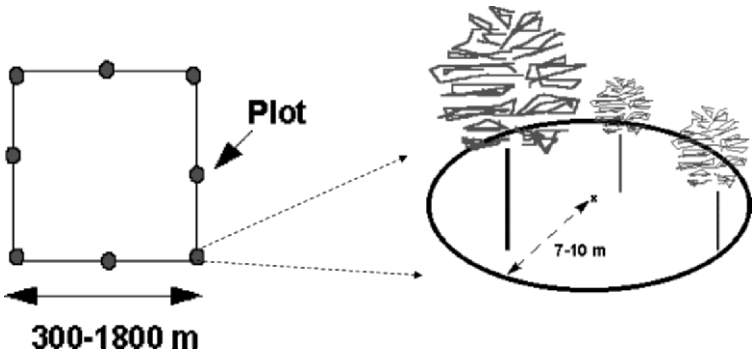

Figure 18.1. The cluster and plot layout used in the Swedish National Forest Inventory (SNFI Web page).

The tracts are square or rectangular in shape and vary in size between different parts of Sweden. They are systematically distributed over the whole country, but lie closer together in the south than in the north (Fig. 18.3). Temporary tracts are surveyed only once, whereas permanent tracts are re-surveyed regularly (Swedish National Inventory of Forests 2004).

Plot size (m)	Trees calipered (cm)
1	<4
3.5	4-9.9
7-10	>10
20	Large trees

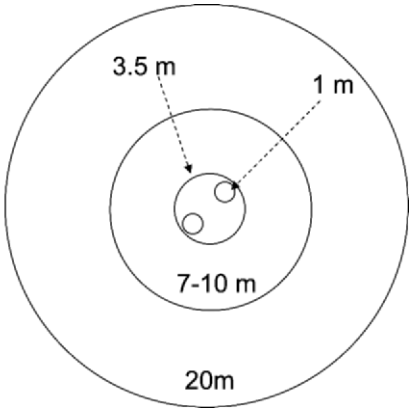

Figure 18.2. Plot layout used in the Swedish National Forest Inventory.

Particular sets of attributes are assessed in different parts of a plot (Figure 18.2):

• Tree and shrub layer. All trees higher than breast height (1.3 m above ground) are calipered (diameter measured), the ages of the sample trees are counted from

annual rings in a core obtained from the stem at breast height, and the cores are sent to a laboratory for further measurements.

• Ground vegetation. The type of ground vegetation is roughly assessed according to 16 field layer and 6 ground layer categories which form the basis of the site index classification. A total of 267 species and groups of species are assessed and coverage is recorded for 71 of these on small subplots.

• Site conditions. Soil moisture and surface water flow on the plot are assessed, and also its inclination and typographic position. A site index is determined to estimate its site quality class. In addition, the effects of forestry and other human activities are assessed.

• Position in the landscape. The position of the plot is determined, with regard partly to administrative boundaries and partly to its location in relation to landscape elements such as roads, fields and lakes. North and east coordinates are also recorded, together with altitude. Since 1996 the positions of all plots have been defined using GPS.

One to three subsamples from each of the circular sampling areas are collected from the O-horizon with a soil corer. Equal numbers of subsamples are collected from each soil horizon, after which all the subsamples for a particular horizon are pooled. The vegetation layers are thoroughly surveyed, giving extensive information on the vegetation in each area. After collection, the soil samples are stored at room temperature in cotton bags for a maximum of one week before transportation to the laboratory, where they are dried to constant weight in a chamber.

The Swedish NFI presents its results in a variety of ways, ranging from the supplying of individual figures over the telephone to extensive analyses that includes year-round work. Some standard tables including mean values for the last 5 years are presented in an annual publication called *Skogsdata*. The results from 1983 up to the present are the easiest to handle and the fastest to present, but many results from as far back as 1923 can be shown and compared. As the Swedish NFI is carried out on the basis of systematic sampling, the precision of its figures can be estimated (see Chuan-Zong and Ranneby 1992) using specific approximations. The density of the tracts/plots can be adjusted by using information for a 5-year period in order to give high precision for estimates at a county level, whereas more extensive estimations for smaller units such as municipalities or catchment areas require modified methods of field sampling (a denser sampling network) and/or remote sensing techniques (Swedish National Inventory of Forests 2004). Annual results are presented on the Internet (http://www-nfi.slu.se/).

The Forest Soil Inventory is a detailed inventory of the soils on the permanent plots based on sampling of the humus layer and mineral soil to a depth to one metre and assessment of a number of attributes, including soil type, mineral texture, type of humus, degree of humification and thickness of the humus layer. Samples are also taken from the various soil horizons for later analysis of pH, nitrogen and carbon levels, degree of base saturation, heavy metal content, etc.

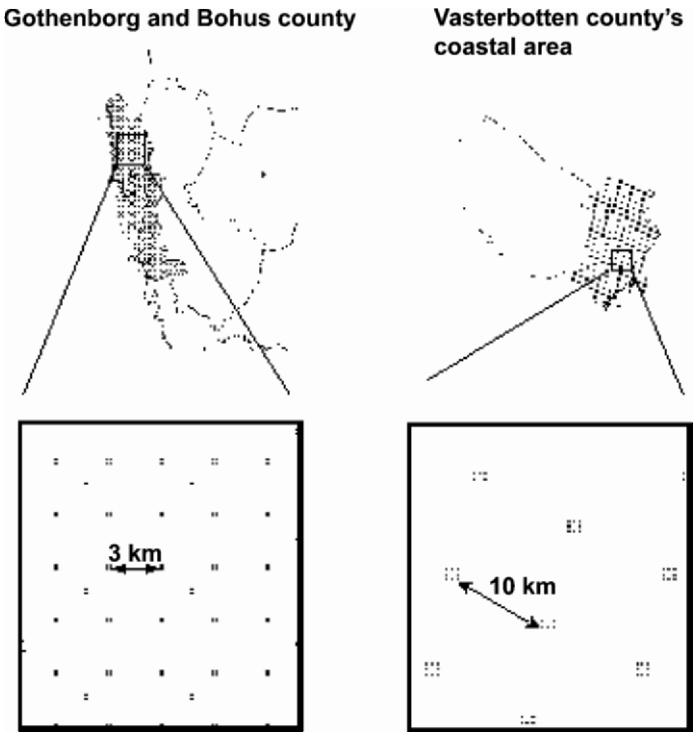

Figure 18.3 The distance between clusters varies in different parts of Sweden.

18.1.2 Inventory for forest management planning

One especially striking feature of Sweden as compared with other timber-producing countries around the world is that private companies are the largest single category of forest owners, accounting for 44% of the country's forests, while approximately 32% are family-owned. The average size of a private forest holding is about 50 hectares. These holdings are the dominant category in the southern part of the country, accounting for 80% of the forest land. The state owns 17% of the productive forest land and other public owners account for 7%.

Sampling procedures have been used in forest inventories and intensively implemented for stand surveys for a long time in Scandinavia by comparison with other European countries. Ocular assessment of stands is employed in Sweden, but as this method is liable to subjective bias, the resulting estimates are supplemented with inventories based on PPS sampling or systematically distributed circular plots and calibrated accordingly. Wood procurement mapping is applied only on a limited

scale, the most important reason being the large forest properties owned by the paper companies and the lower level of market competition (relative to Finland).

18.2 GERMANY

Around 30% of Germany is covered with forests, of which a good third consist of deciduous trees. Over half of the approx. 11.1 million ha of forests in Germany are owned by the federal states or municipalities and 44% are privately owned (Bundeswaldinventur 2002). Forestry in general is organized at the level of the federal states, and most forest management projects are implemented by the states' forest administrations. Although the federal states are the large forest owners, the federation as such owns only about 4% of the total forest area. All the forest areas in the country are considered "close to natural" and are managed, i.e. there is not a single untouched or virgin forest left, as a result of a long period of historical development. Forest damage, mainly from air pollution and storms, is an important issue (Akça 1994).

The maintaining of the various ecological and socio-economic forest functions requires differentiated forest inventory methods to support the management, sustainment and conservation goals. Forest inventories can be categorized according to the size of the inventory area and the significance of the inventory for forest enterprise policy and economic management of the forests (Table 18.1).

Table 18.1 An overview of inventory methods employed at various management levels.

Inventory Level	Inventory Method	Goals and target variables
National	National Forest Inventory	Forest Area and Volume Increment Survey
	National Forest Damage Inventory	Inventory of Forest Damage
	National Soil Condition Survey	Evaluation of Soil Condition
Regional	Forest Framework Planning	Inventory of forest attributes relevant to regional land use planning
	Forest Functions Mapping	Recording of forest functions
	Forest Biotope Mapping	Biotopes within forests
Forest Enterprise	Site Type Mapping	Recording of natural site conditions
	Forest Management	Providing an internal aid to information, control and planning

One essential source of recorded data for forest inventories is fieldwork. Forest maps are mostly derived from the German basic map (scale 1:5 000) or topographical maps (scale 1:25 000). The use of remote sensing methods is limited

to aerial photographs or orthophoto consulted for update purposes, the mapping of forestry data, the definition of forest stands in the context of forest management planning and as an orientation aid in inventories at the level of forest enterprises and regional planning. Satellite images are rarely used as yet in forestry practice. Cartographic presentation of the recorded results and/or the defined management measures is normal practice in every forest inventory procedure (Akça 1994).

At the federal level, the results of the National Forest Inventory, National Forest Damage Inventory and the National Soil Condition Survey particularly serve forest policy purposes. The results of the regional management procedure are for the most part presented in the form of maps, while rge results of forest framework planning are presented on two forms of map: a map of forest functions, which shows the forest functions aspired to (currently planned and legally binding forest functions), and a measures map, which defines the foreseen changes and the measures required to attain the goals. Various thematic maps are made for the individual forest enterprises within the framework of forest management and site type mapping. These illustrate the current conditions, planned improvement measures or the desired future situation and are drawn up for given forest units or areas under common cultivation, and therefore specifically take ownership into account (Akça 1994).

18.2.1 National Forest Inventory: Natural forests

Inventories are made over the entire territory of Germany in order to record the size and distribution of the forested areas and timber reserves (National Forest Inventory), the degree of forest damage (National Forest Damage Inventory) and the prevailing soil conditions (National Soil Condition Survey). The first national forest inventory took place in 1986 -1990, and the main fieldwork for the second was carried out in 2001-2002 and the results published in 2004 (Polley 2001, Bundeswaldinventur 2002).

The collection of data for the second national forest inventory was based on permanent field sample plots chosen from among approximately 44 000 square cluster plots of size 150 x 150 m with a systematic layout on either a 4 km × 4 km or 2 km × 2 km grid, depending on the state concerned (Figure 18.4). About 400 000 sample trees were measured in the second inventory and about 150 variables were recorded for the sample plots (Survey instructions for Federal Forest Inventory II, 2000).

Each corner of a cluster plot located in a forest forms the centre of an angle-count sampling sub-plot with a basal area factor of 4. This sub-plot type is used to define the sample trees, which are described in more detail to form the basis for a wide variety of evaluations. The following trees are included:

- those falling into the angle-count sample (basal area factor 4) that are
- either alive or have died recently (fine branchwood maintained in full) and
- belong to the same stand as that in which the centre point of the sample lies and
- have a diameter at breast height of at least 7 cm.

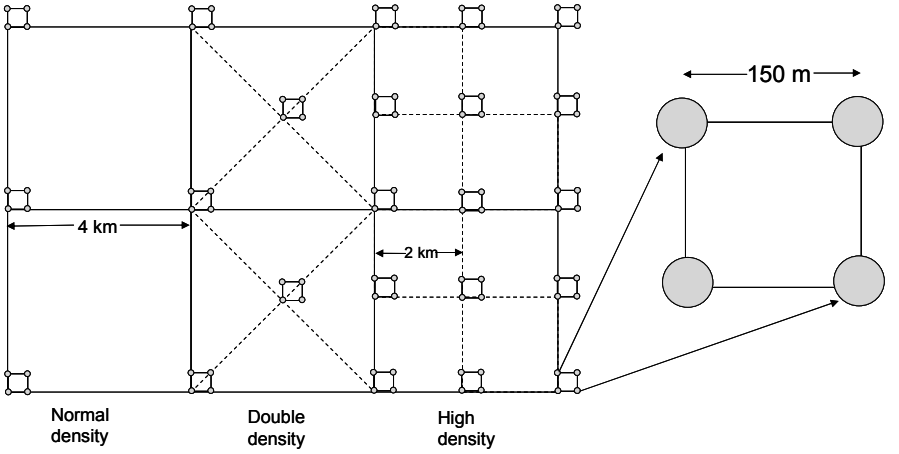

Figure 18.4 Cluster layout for the second NFI in Germany. Each cluster contains 4 plots.

In addition, angle-count sampling with basal area factor of 1 or 2 is carried out, in which the trees are counted as a basis for describing the forest structure by species and storey., Stand boundaries are not taken into consideration, but the angle-count sampling is subjected to regular reflexion at the forest edges.

In addition, use is made of specific sample sub-plots or circles within the cluster plots (Figure 18.5):

1. Each plot corner located in forest is taken as the centre of a sample circle with a radius of 1.75 m in which all trees over 50 cm high and under 7 cm in diameter at breast height are surveyed.

2. A circle of radius 1.00 m is located 5 m away from the corner of the plot, generally to the north, for the recording of all trees of height 20 cm to 50 cm.

3. The occurrence of deadwood is determined in a circle of radius 5 m around the plot corner.

4. Trees up to 4 m in height, the shrub layer and the ground vegetation are surveyed in a circle of radius 10 m around each plot corner.

5. Site characteristics and forest edges are recorded in a circle of radius 25 m around each plot corner located in forest.

If a sample circle of radius 1.75 m or 5 m is crossed by a stand boundary, the course of this boundary is surveyed and only the part cut off by it in which the cluster plot corner is located is considered for inventory purposes.

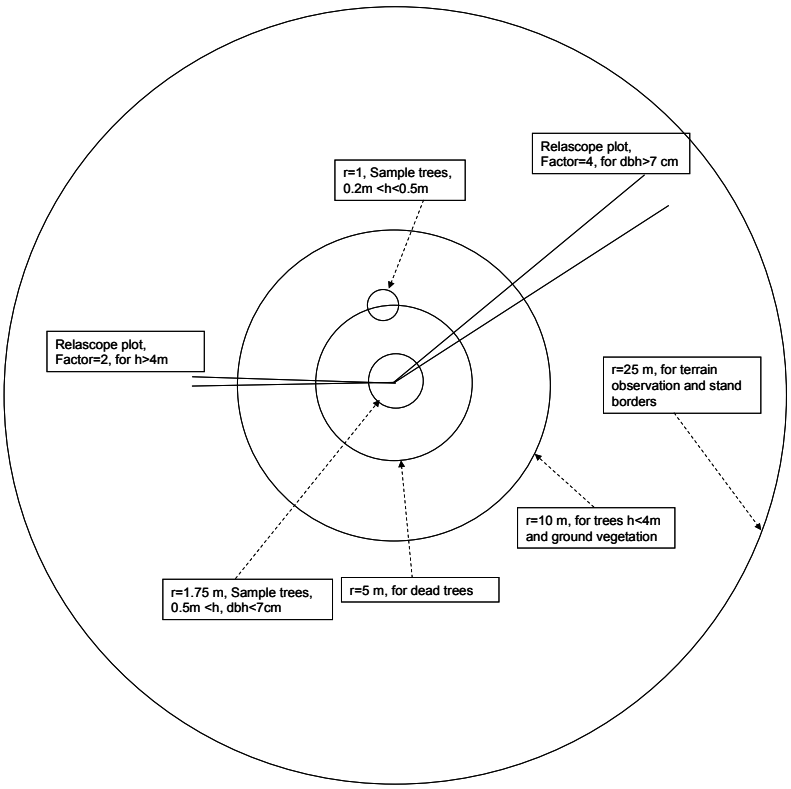

Figure 18.5 Plot layout for the NFI in Germany.

Forest edges are surveyed within a radius of 25 m of all plot corners located in forest. In addition, stand boundaries which are not forest edges must be included in the survey,

1. if they intersect the boundary circle of a sample tree defined by angle-count sampling with basal area factor of 4. These are all stand boundaries within a radius of 25 times the breast-height diameter around the trees defined in angle-count sampling. Stand boundaries which are further than 25 m from the plot corner are not surveyed, however.
2. if they divide a sample circle of radius 1.75 m or 5 m, provided that some sample elements (trees of height at least 50 cm and diameter at breast height up to 6.9 cm, or deadwood) are available in the circle (Polley 2001).

The stand boundaries surveyed during the Federal Forest Inventory need to be checked. The surveying of these and of forest edges is simplest if the horizontal

distance and azimuth are determined for two points on the boundary line. If the stand boundary does not run in a straight line, a further point must be surveyed at the knickpoint. The survey points on the stand boundary should be at least 10 m apart (Polley 2001).

18.2.2 Regional inventories

Regional administration and planning is organized by the Bundersländer (i.e. forest administration is located in the national Ministry of Finance). Various forms of map material produced by contractors are used for environmental decision-making.

Forest framework planning, forest functions mapping and forest biotope mapping are employed as forest policy management aids at the regional level. **Forest framework planning** sets the goals for proper forest sustainment, forest development and forest management and defines the measures to be taken, **forest functions mapping** describes the various functions of the individual forest areas, including a forest's special recreation value or particular importance for climatic conditions, and **forest biotope mapping** records and localates biotopes within the forests. All three management aids and their respective inventory methods serve the essential purpose of sustaining and improving the various functions of the forests beyond the enterprise level and regardless of ownership for the benefit of the population and the balance of nature. Their results should be taken into account by all internal and external decision-makers dealing with forest questions (Akça 1994).

18.2.3 Forest management planning: compartment level inventory

Forest management plans are produced for landowners, and there are a large number of consultants bidding for contracts to prepare such plans for the largest landowners. The most important objective in a forest inventory is to obtain information for the internal operational management of forest enterprises. Two supplementary inventories are employed at this level (Akça 1994).

Site type mapping describes existing site conditions and potential natural forest stands within the properties of the forest enterprises and forms the basis of silvicultural planning in a forest enterprise. Apart from defining natural forest stands, it offers proposals and possibilities for assisting in the choice of tree species and forest stands. The results of this inventory and mapping method are of long-term importance due to the relative continuity of site conditions (Akça 1994).

Forest management inventories contribute to obtaining information for the management of individual forest enterprises. Forest management may be viewed as a combination of the instrumental aids of inventory, control and planning. In this manner, by recording and analysing internal and external natural economic and organizational site conditions, proposals can be made for the silvicultural management of forest enterprises which conform to the goals laid down for this (Akça 1994).

It is of particular importance that regional and internal inventory methods

should complement one another. Internal management planning should be in accord with the goals set at a regional level. National inventories provide fundamental information for formulating regional and internal guidelines based on the political and legislative decisions derived from them (Akça 1994).

The recording of conditions within forest management basically comprises three sectors:

1. Surveying of forested areas and forest development
2. Surveying of forest stands (timber reserves, timber increment, management conditions)
3. Surveying of the landscape (cultivational, environmental and ecological) importance of forested areas (conservational and recreational functions).

The purpose of surveying forest stands is to record the locations and sizes of the areas owned by given forest enterprises. Forest stand (compartment or sub-compartment) definition mapping is above all an aid to planning and control, providing a real distribution system. Moreover, a forest stand map should serve as an aid to orientation, forest surveying, the transport, logging and processing of timber, to creation of order in an area and forest protection. Within the forest enterprise itself, the areas are subdivided once again, according to their use being seen either as wood production areas (forested areas) or non-wood production areas (e.g. forest roads or timber depots). The forest stands (compartments and sub-compartments) form the base for recording timber volumes and improvement conditions, thereby permitting investigations into current production potential and future development possibilities. The third sector of an internal "natural inventory" is the recording of forested areas of landscape importance (cultivational, environmental and ecological). Counted among these are the conservational and recreational functions of the forests, which are of relevance to the silvicultural and economic management of the areas.

The data are either digitized on location by means of mobile data input systems or else digitized centrally. In this wayu the forest management data can be stored and evaluated centrally for each state. Analogue mapping is performed at the Forest Management and Planning Institutes and is very seldom carried out digitally. The integration of digitally stored and administrative data with their respective spatial relations in the form of geographical information systems is in the development phase in various federal states (Akça 1994).

18.3 OTHER EUROPEAN AREAS

Planning procedures are continuously being adapted to current needs and conditions, so that there are many different procedures in use within Europe today. The fact that federal systems usually leave forest planning to the authorities of each state or canton and the existence of different regulations for public and private forests have led to a situation in which there are no uniform regulations for forest planning within Central Europe and consequently no uniform sampling procedures. Data on stands and enterprises are mainly collated through a combination of total tallies, ocular assessments for taxation purposes and sample surveys. In some East European countries the situation is different, as recent reforms of the property laws and planned economy have provided a basis for uniform regulations. Remarks on current

domain and stand inventory practices in certain selected countries are provided below (Köhl 1992).

In **Norway**, the sixth NFI began in 1986 and results were presented for the year 1990. The results of seventh inventory were available for year 1996. The sampling design applied in NFI is systematic sampling and single-stage cluster sampling. Field data collection for the sixth inventory employed clusters of plots forlaid out in a grid pattern over the whole country with 3 km spacing. The basic shape of each cluster was a half square (L-shape), and the plots were located 300 m apart within each cluster. The southernmost plot was established as a permanent plot, while the others were temporary ones. Although the 3 km grid was fixed, the number of plots and the distance between them within a cluster sometimes differed between counties. If the percentage of forest land or the total area of the county was small, the number of plots was increased. This led to clusters of up to 12 sample plots (Tomter, 1992). Permanent sample plots are circular, fixed area plots of 250 m^2. Temporary sample plots are concentric fixed area plots of 100 m^2 and 250 m^2 for trees larger than 5 cm and 20 cm, respectively. (EC 1997)

Forest management plans in Norway are prepared by private institutions, principally forest-owner organisations, as a service for their own members and other interested parties. The planning process is as follows:

1. Aerial photographs are taken of the area for which a plan is to be prepared.
2. The aerial photographs are compared with a map of the area and the forest stands are identified and classified.
3. Records are prepared with the aid of the map while out in the forest. All the stands are systematically examined, and various measurable factors are recorded, such as average tree height and diameter, number of trees, yield class and age, and data associated with multiple land-use considerations (edge zones beside water, marshland, rivers and roads, and also large deciduous trees and hollow trees, the amount of dead wood, vegetation types etc.).
4. The data are processed and the findings are presented in the completed forest management plan.

In **Austria**, sampling design applied in the Austrian Forest Inventory (AFI) is a systematic cluster sampling. The field work of first inventory was carried out 1961-70. Since 1981 four permanent sample plots, located in the corner of the square, have formed the tract with a side-length of 200m. Distance between tracts is 3.89 km. Data are collected from circular concentric plots with areas of fixed area 300 m for stand data, bitterlich plots for trees with diameter larger than 10.5 cm and fixed circular plots of 21 m^2 for trees between 5-10.5 cm. (EC 1997) Forest holdings are either surveyed by means of ocular assessment of individual stands or sampling procedures. Standing timber reserves are estimated on the basis of yield tables for stands between 20 and 60 years of age and by point sampling for those between 60 and 80 years. Stands over 80 years old are assessed on fixed-area plots or by means of total tallies. The sampling units are systematically distributed, one or two plots per hectare, or sometimes one per two hectares, being surveyed, depending on the stand conditions. Stand features, site characteristics and data for individual trees are recorded, and this information can then be extrapolated to larger units such as whole forest holdings, stand units or large stands. The current practice thus employs a

mixture of ocular assessments and sample surveys (Köhl 1992).

In **France,** the first cycle of National Forest Survey (IFN) started in 1960 and lasted nearly 20 years. The second inventory ended 1994. The IFN service is part of Department of Agriculture and field data is mainly collected by local departments. The sampling is a 3 step double sampling for stratification:

1) Aerial photographs are interpretated to stratify categories defined by land cover type, localisation and ownership. Systematic photo-plots (25 m radius circle) are distributed on photographs and plots are assigned to strata.
2) Photo interpretation is checked in the field and modifications to interpretation is carried out.
3) Field plots are chosen randomly among plots in the various strata. Field plots are temporary plots and consist of three concentric circle plots. Trees are measured on plot with different radius (6m, 9m and 15 m). Regeneration is assessed on nine plots of 2.26 m radius.

The sampling fraction may vary from one department to another. Data are stored in a national forest survey database. (EC 1997).

The national forest inventory in the **United Kingdom** employs the yield and production sections of the Forest Management Tables for all stands except final felling crops. A diversity of methods are used for collating data on privately-owned forests, volume being estimated on the basis of yield tables, while standing volume is extrapolated from visual assessment, the measurement of felled trees or, in exceptional cases, point sampling. (Köhl 1992).

National forest inventories are undertaken by the Forestry Commission. The first assessment was done 1924 and has been repeated on average every 15 years. The sampling frame covers all of Great Britain. Randomly selected square 1 km temporary field plots are assessed using aerial photography then two 250 m by 250 m are sampled at random from within the 1 km square. The yield models are empirical and based upon periodic measurements from 1500 permanent and 1000 temporary sample plots. (EC 1997).

Switzerland has been described as the land of control and selection forestry. Continuous forest inventory techniques have been combined with control to furnish an inventory system that has been implemented in many Swiss cantons. Control sampling is based on permanent plots, while standing reserves are calculated from tariffs. Increment is determined through the comparison of data on standing reserves in successive inventories. Control sampling can justifiably be regarded as a procedure combining the classic methods of forest planning with the possibilities offered by sample surveys. Because of its practicalities and its many interesting possibilities for solving particular problems, the procedure has been widely adopted even outside Switzerland. A review of current methods shows that stand surveys for forest management planning are usually based not on sampling but on ocular assessments. Sample surveys are as a rule reserved for district-level inventories. One of the main arguments against the use of sample procedures for stand inventories is that most forest stands in Europe are relatively small and the sampling intensity must be very high to produce acceptably precise results.

Since the observation of what came to be known as “a new type of forest damage” (forest decline) in the forests of Central Europe in the early 1980’s, forest

health monitoring has been introduced at the national and local levels. The variables of interest in such inventories are ocular assessments of crown transparency and discoloration (Köhl 1992).

The goal of the National Forest Inventory (NFI) is to record the current state and recent development of the Swiss forests in a representative and reproducible manner using various data sources. To this end, the second inventory (1993–1995) employed a combination of methods. A double sampling design made use of aerial photos on a 0.5×0.5 km grid in the first phase to estimate strata sizes, to identify forest plots and stocks outside the forest and to provide reference points for the field survey and field sample plots on a 1.4×1.4 km grid in the second phase to record a number of variables connected with individual trees and stands, young growth and damage by game, together with features of the surrounding areas. The plot layout was a concentric circle of 200 and 500 m^2 with thresholds at diameters of 12 and 36 cm. Diameter at 7 metres and height were recorded for a sub-sample of the first-stage trees, following a scheme with inclusion probabilities proportional to the expected error of the volume estimates. The work and costs involved in the different steps of the terrestrial survey were recorded and evaluated, and ongoing training of the survey teams and control surveys were employed to ensure high-quality data. Further information was obtained by interviewing representatives of the local forest services, from external data sources, from models describing the site conditions and from specially designed studies of forest transportation systems and the effects of game browsing on tree growth. The data were stored in a relational database and evaluated using statistical software developed specifically for this purpose. Static models were used to evaluate the following complex forest characteristics: the volume of standing and cut timber, tree growth, the work and cost involved in timber felling and extraction, the sustainability of forest regeneration, the protection provided by forests against avalanches and rockfalls, the recreational value of the forests, and the biotope values of the stands and forest edges. Furthermore, a dynamic model was developed which yielded prognoses for the future development of each individual tree in particular management scenarios (Köhl 1992).

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