Chapter 13
Germany

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13.1 Development of the German National Forest Inventory

13.1.1 Forest Surveys Before NFI

Since the beginning of the nineteenth century, forest statistics were recorded as part of agricultural statistical surveys. Their information content, however, was low, as the forest statistics were limited to forestry-holding based statistics, which chiefly included the number and area of holdings with forested properties.

In 1878, the first forest survey was conducted covering the entire German Empire as a combination of official statistics. On 7 July 1892, the Federal Council of the German Empire resolved to conduct a forest survey every 10 years. In the course of time, the forest survey became increasingly detailed. This considerably improved the informative character of the surveys. Nevertheless, these changes had negative effects on the comparability of the different forest statistics. The 1937 forest survey provided the most extensive information on the condition and the yield of the Länder of the German Empire.

In the first years following World War II, reliable data about the forests, particularly about timber stock, were very valuable. In 1946, the Allied Control Commission ordered a stand inventory in all four occupied zones to determine the timber stock. This inventory was inadequate, however, because of the lack of uniformity and incompleteness of the results.

Two years later, in 1948, a second forest survey was conducted in the American and British zones, which was extended to include the regions of the French

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occupied zone in 1950. This survey had methodological deficiencies as well, yet it was the first attempt to record the timber stock by tree species and age classes.

World War II and the post-war era in the German Democratic Republic (GDR) led to great shifts in forest ownership structures. The data from the forest survey of 1937 were outdated. Therefore, the German Economic Commission resolved to conduct a first extensive forest survey (begun on 1 April 1949) in the Soviet zone, in order to obtain information about the conditions of the forests for individual structural units and for the entire GDR and also to create a foundation for new forest management. All forest areas larger than 0.5 ha were recorded according to area size, type of ownership, tree species, yield class, soil type, timber quality grading and unstocked forest land. Based on work from 1956 to 1957, the GDR conducted random sample, large-scale forest inventories on the timber stock from 1961 until the early 1970s.

Between April 1961 and March 1962, the data for the first forest survey with reference date of 1 October 1960 were collected in the Federal Republic of Germany. The survey was based on holdings, i.e. all areas and parameters belonging to one economic unit (holding) were identified in the town in which the holding was headquartered. The results were evaluated and prepared by the statistical offices of the states (Länder) of Federal Rebublic. The Federal Statistical Office in Wiesbaden published them in four reports in 1964 and 1966.

Beginning in 1970, the GDR set up the Datenspeicher Waldfonds (DSWF), a nationwide forest management database. The forest cover data referred to partial areas (stands). The DSWF was centrally administered for all state managed areas in the GDR. It contained extensive data on the condition and the planned management of the forests. The status data were to be collected, on average, every 10 years. In the years between the data were updated with the aid of an increment model and based on notifications of changes by the forestry holdings. The DSWF was updated until 1 January 1993.

13.1.2 First German National Forest Inventory from 1986 to 1990

In the mid-1970s a debate commenced in the Federal Republic of Germany on how to best further develop the forest survey of the 1960s which resulted in the creation of a legal basis for the National Forest Inventory (NFI) in 1984. Questionnaires and estimates were finally replaced with a nationwide sample-based data survey according to mathematical and statistical methods. Hence, by the year 1990 – almost 30 years after the last survey – a comprehensive and reliable data base should be created for forest policy and trade policy decisions. It was a matter, in particular, of securing and strengthening the raw material function of the forest as well as preserving its protective and recreational functions. After many years of preparation the data of the first NFI (NFI1) were collected in the Federal Republic of

Germany (territory prior to 3 October 1990 including West Berlin) from 1986 to 1988. This large-scale inventory (reference date 1 October 1987) conducted on a random sampling basis according to mathematical-statistical methods was the first to provide information on extensive units, such as regional economic areas. It gave an overview of the extensive forest conditions and forest production potentials in the old federal states.

All of the sample ploots established for NFI1 were permanently, although not visibly, marked and the coordinates of all sample trees from 10 cm *dbh* were measured for distinct identification. This created the foundation for successive surveys of identical random sample objects and hence for the high reliability of future assessments of changes, increment and removals.

Even before the NFI1 had been evaluated, German reunification in 1990 led to the need for new information. However, the NFI1 could not be replicated in the new federal states, since too much time had already passed. Therefore, the initial inventory in the new federal states was linked with a subsequent survey in the old federal states. As an intermediate solution, the forest conditions in the new federal states were evaluated based on forest planning data (D*atenspeicher* W*aldfonds, DSWF)* as per 1 January 1993 analogously to the NFI1. Nevertheless, only limited comparability could be achieved since the evaluation was based on an entirely different kind of data situation. While NFI1 took relatively few random samples with great precision, the DSWF contained less precise data on approximately one million stands. In addition, the DSWF did not contain information on the assortment structure, damage caused by game, trunk damage and forest access. The precision of NFI1 could be appraised using its sampling errors, whereby in evaluation of the DSWF, collection errors and, in particular, entry and updating errors played major roles.

13.1.3 Second German National Forest Inventory (NFI2)

The federal government and federal states governments resolved to carry out a new German forest inventory in order to ascertain the extensive forest conditions and forest production potentials for the entire Federal Republic after German reunification. Due to the historical developments, in former West Germany it was a repeat survey and in former East Germany an initial inventory. The data of NFI2 were collected starting October 2000 until the end of 2002, then checked and evaluated until 2004.

In Germany, the federal states are responsible for forestry (under Art. 30 of the German Basic Law (*Grundgesetz*, abbreviated GG)). Only a few federal states conducted state forest inventories to plan forest policy tasks and timber market policy measures. There are too few state inventories and their survey methods are too inconsistent to reach a satisfactory, sufficiently corroborated national result. Because of the common forest policy intentions of the federal and federal states governments and the necessity to base these on a corroborated data basis,

the federal and federal states governments resolved to carry out one German large-scale inventory.

To account for ecological and forestry developments and to meet the increased need for information, NFI2 covers new parameters that had not been taken into account in NFI1.

- Forest edges: As zones of transition from forest to open spaces, forest edges are important habitats for a wide variety of plant and animal species. The ratio between the length of forest edges and the forest area also serves as a measure of the size of forest areas and the diversity of the landscape.
- Deadwood is a special habitat and therefore an important component of the forest ecosystem. It contributes to the diversity of forest species. Surveying is limited to deadwood with a diameter over 20 cm at the thicker end or, for standing deadwood and stumps, a *dbh* of at least 50 or 60 cm diameter at felling height.
- The shrub layer and the ground vegetation allow conclusions about the silvicultural, hydrological and wildlife biological situation of a forest. During NFI2 the density of the ground cover was estimated in four stages for 14 different morphological plant groups (e.g. lichens, mosses, grasses, shrubs) as well as eight significant forest plant species (e.g. bracken fern, stinging nettles, blackberries).
- The comparison of the present composition of tree species at the sample plot with the composition of tree species of the natural forest community provides information on the naturalness of the tree species composition. The model of the present potential natural vegetation (PPNV) has been used as natural forest community for the NFI. It has been ascertained for each cluster by the experts of the federal states and has been described with regard to its main, secondary and pioneer tree species with regional and altitudinal zone differentiation. The PPNV is a proven comparative basis since it offers the safest evaluation basis through the acceptance of the site and flora changes that have occurred and the exclusion of possible future changes. Because it assumes the present site conditions, flora and tree species competitive relationships, in addition to indigenous tree species, permanently naturalised tree species also belong to the natural forest community. A wild plant species is considered an indigenous plant when it maintains itself as a population over a number of generations in the wild and without human assistance. The inventory crews examined the classification of the natural forest community on site and if necessary corrected it, in particular when azonale forest communities were found.

13.1.4 Other Forest-Related National Inventories

In addition to the NFI there are two other systematic sample-based inventories in German forests – the forest health inventory and the forest soil inventory. Their

sampling grid was moved a few hundred metres away from the NFI. Since 1984 the forest health inventory has recorded crown condition and other data every year. The first forest soil inventory took place from 1987 to 1993 and the second from 2006 to 2008 (results are expected in 2013). Their basic grid is 8 × 8 km, but the sampling intensity for the forest health inventory varies form year to year and between the federal states. The 16 × 16 km sub-sample is part of the European level I system.

13.2 The Use and Users of the Results

Sustainable forest management and promotion of this management require knowledge of the state, structure, dynamics and productive capacity of the forests on individual holdings and at regional and national levels. This not only forms the basis for work and financial planning, but also influences many other areas, such as economic, traffic, environmental and structural policies. The NFI provides this important information on the extensive forest conditions and forest production potentials of the German forests. Furthermore, this information enables Germany to comply with its growing obligations in respect of international climate protection, to act for forest issues in the European Union and to provide international trade with up-to-date and comprehensive knowledge of its national resources.

The NFI must therefore meet the needs of various target groups: the political sphere, public administration, State forestry administrations or their legal successors as large forest owners, wood-based industries, forestry and timber associations and professional representations, research and training institutions, and the public.

The results assist in shaping policy: they provide justification and support for lines of argument regarding the development of funding principles (e.g. management of funds for renewable energies), funding projects (e.g. establishment of processing capacities) and research projects (development of products depending on the availability of raw materials, processing technologies).

The NFI is the public administration's source of information for national and international statistics on variables such as land use, land cover etc. The information is reported to, e.g., statistics for the Federal Statistical Office, the Food and Agriculture Organization of the United Nations (FAO) and EUROSTAT. These statistics are in turn used by the above target groups for their tasks. The statistics are of particular importance in connection with the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol: With regard to the subject of forests, the essential information comes from the NFI (forest area, volume of growing stocks and biomass and changes to these). Due to the Kyoto Protocol, an interim inventory was carried out on the NFI grid in 2008. Mention is also to be made of the nation-wide forest soil survey as another source regarding subterranean carbon stocks.

The NFI data are also used for assessing the requirements of biodiversity convention.

In research and training, the results are used as a foundation for information on forests and their development in general as well as for the purpose of clarifying specific questions on forests or surveying methodology. Fact sheets are frequently requested by schools.

Questions from the public as to methods and results are proof of the public's interest in forests and in the NFI.

The results have been published via various media: A brochure was published containing a succinct presentation of the essential results, methods and background information in a series of texts, tables and graphics. It is intended for the political sphere and for the public. The first edition of 10,000 copies was distributed in one year and was consequently reprinted (Schmitz 2004). Another brochure is intended for specialists and provides a deeper insight into the results via a section containing extensive and detailed tables. The methods are also explained in detail (Schmitz 2005a, 2006a, b).

The same pattern was used to draw up two brochures on the results of the future modelling of timber harvesting potential (Schmitz 2005b, c). They contain the results of a model on potential roundwood availability. The model takes into account the current usual rotation periods, target diameters and thinning procedures. Another volume of tables contains the parameters of the remaining stocks which have been estimated using the model (Schmitz 2005d). Explanations of NFI methods and background information, as well as a volume of tables with NFI results were printed in English for use in the international arena.

All results are available on the Internet in German and English (www.bundeswaldinventur.de). This enables the non-specialist to quickly become accustomed to the system, while also providing the specialist with the possibility of conducting a targeted search. It is, however, not possible to ascertain the uses to which the results are put. A DVD has been produced with the same content as that on the Internet site (Schmitz 2007a, b).

Large-scale consumers of wood have, subject to reimbursing the expenses, had their own timber stock models calculated by the Federal Research Centre for Forestry and Forest Products, which is responsible for technical execution of the NFI. This enables specific needs of the industry to be met.

Some federal states have issued their own publications, either in paper form or via the Internet, containing information for their territory, in some cases providing greater regional detail than the Federal Republic publications.

13.3 Current Estimates

The estimates of forest area and volume of growing stock for Germany with the associated definitions are given in Table 13.1.

Table 13.1 The estimates of forest area and growing stock volume

Quantity	Results for national definition	The national forest definition differs from the reference definition in that it...		Results for reference definition	
	Value	Includes...	Excludes...	Value (% of national value)	comment
Forest area (1,000 ha)	11,075.8	Areas from 0.1 to 0.5 ha Width from 10 to 20 m	Canopy cover <50%	Approx. 99.5%	Results from two federal states show no difference; canopy cover not considered Application of the reference definition is planned for the next NFI (2011–2012)
Volume of growing stock (million cubic metre)	3,380.6	Stump Newly dead trees	Trees <7 cm *dbh* Tree top (<7 cm diameter)	98.4%	All data available

13.4 Sampling Design

The NFI uses a systematic single-level cluster sample with regionally different sampling intensities. The reference grid of the random sample is designed to fulfil the precision requirements on the national level. In order to increase informative value, some federal states regionally have applied a denser sampling grid, so that in the end the sampling intensity over 21% of the area has been doubled and over another 26% quadrupled (Fig. 13.1 and Fig. 13.2).

The sampling grid (Fig. 13.1) is described by the NFI Administrative Regulation. The samples (clusters) lie on the intersection points of a national 4 × 4 km quadrangle grid. The north-south and east-west alignment of the quadrangle grid is aligned to the Gaus-Krüger coordinates system based on the Bessel ellipsoid. The sample grid is shifted relative to the grid of the crown condition assessment, because the latter is openly marked and therefore silvicultural influences on the grid of the crown condition assessment cannot be ruled out. The sampling grid of NFI1 has been expanded to the new federal states for NFI2.

Only plots in the forest are sampled (Table 13.2). The sample plots are given permanent concealed marks. In the old federal states, the sample plots measured for NFI1 are revisited and the forests thus reinventoriesd. The south-western corner of each cluster is allocated to this grid. It consists of a square with side lengths of 150 m. As a rule, each cluster has four plots (Fig. 13.3), fewer on border clusters. In every plot within the forest, data for different objects are surveyed in different survey units (e.g. sample plot circles).

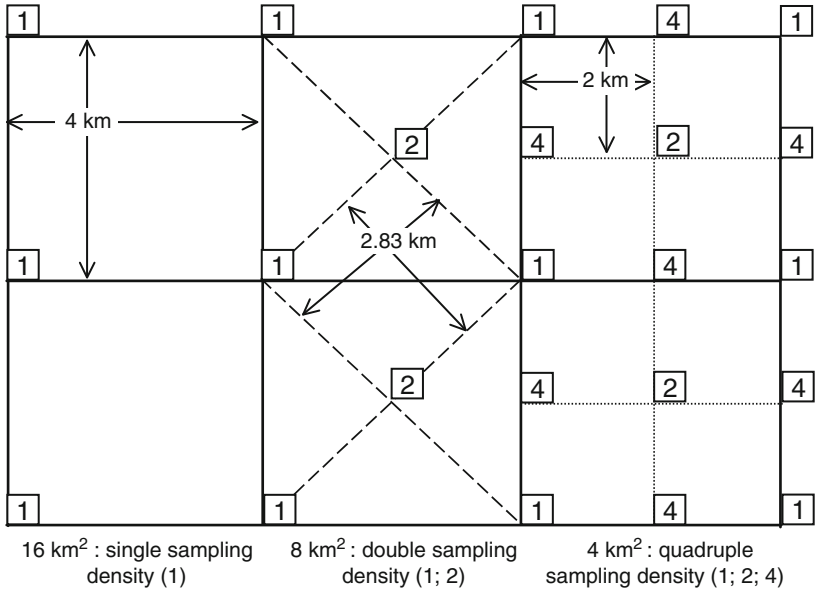

Fig. 13.1 Sampling scheme for different sampling densities

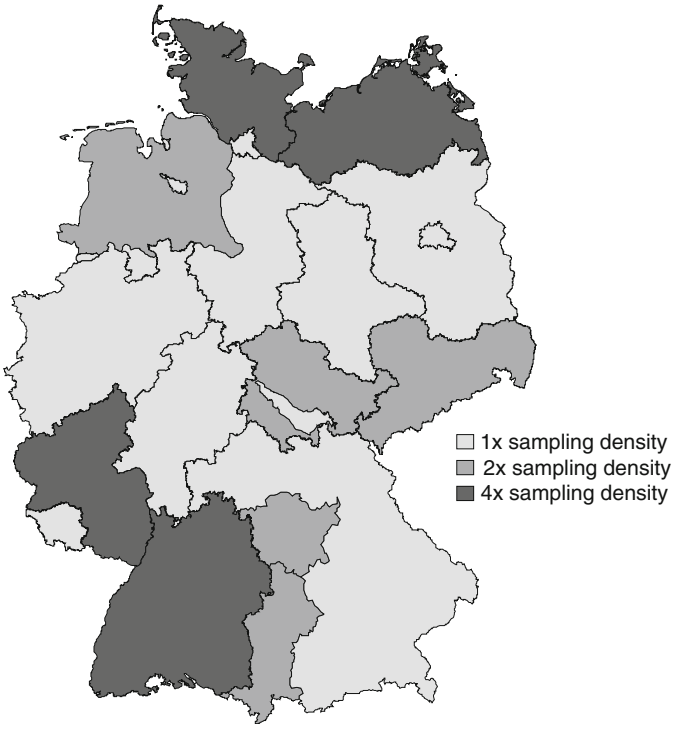

Fig. 13.2 Sampling density regions

Table 13.2 Sample size of the second German NFI

Federal states	Forest clusters	Forest plots	Newly measured sample trees of $dbh \geq 7$ cm	Remeasured sample trees of $dbh \geq 7$ cm	Total sample trees of $dbh \geq 7$ cm
Baden-Württemberg	4,598	13,619	39,534	57,184	96,718
Bavaria	2,711	7,747	24,640	37,840	62,480
Berlin	11	38	194	87	281
Brandenburg	809	2,676	17,908	0	17,908
Bremen	3	8	46	0	46
Hamburg	3	9	8	26	34
Hesse	694	2,202	5,852	8,626	14,478
Mecklenburg-Western Pomerania	1,911	5,351	36,035	0	36,035
Lower Saxony	1,495	3,794	12,223	11,225	23,448
North Rhine-Westphalia	841	2,228	6,267	8,885	15,152
Rheinland-Palatinate	2,811	8,391	48,989	7,720	56,709
Saarland	94	249	775	780	1,555
Saxony	900	2,565	16,400	0	16,400
Saxony-Anhalt	432	1,324	7,896	0	7,896
Schleswig-Holstein	734	1,632	4,507	5,854	10,361
Thuringia	749	2,266	16,130	0	16,130
Germany (all states)	18,796	54,009	237,404	138,227	375,631

13.5 Management

13.5.1 Organization

The composition and evaluation of NFI2 and the coordination tasks were undertaken by the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL). The Ministry assigned the national inventory administration to the Institute of Forest Ecology and Forest Assessment of the Federal Research Centre for Forestry and Forest Products (now Johann Heinrich von Thünen-Institut, Federal Research Institute for Rural Areas, Forestry and Fisheries) in Eberswalde. The national inventory administration worked directly with the federal state inventory administrations, chiefly to clarify specialised questions on the implementation and inventory controls and to check and evaluate the data.

The national inventory administration provided the federal state inventory administrations with all data from NFI1 needed for the repeat survey as well as with specially designed survey software. This contains programs for data management in the federal state inventory administrations, for data collection and validation by the inventory crews and for describing the tree species composition of the natural forest communities.

The data survey is the resposibility of the federal states. Each of the federal states established a federal state inventory administration, which was responsible at the federal states level for conducting NFI2. Their work encompassed duty planning

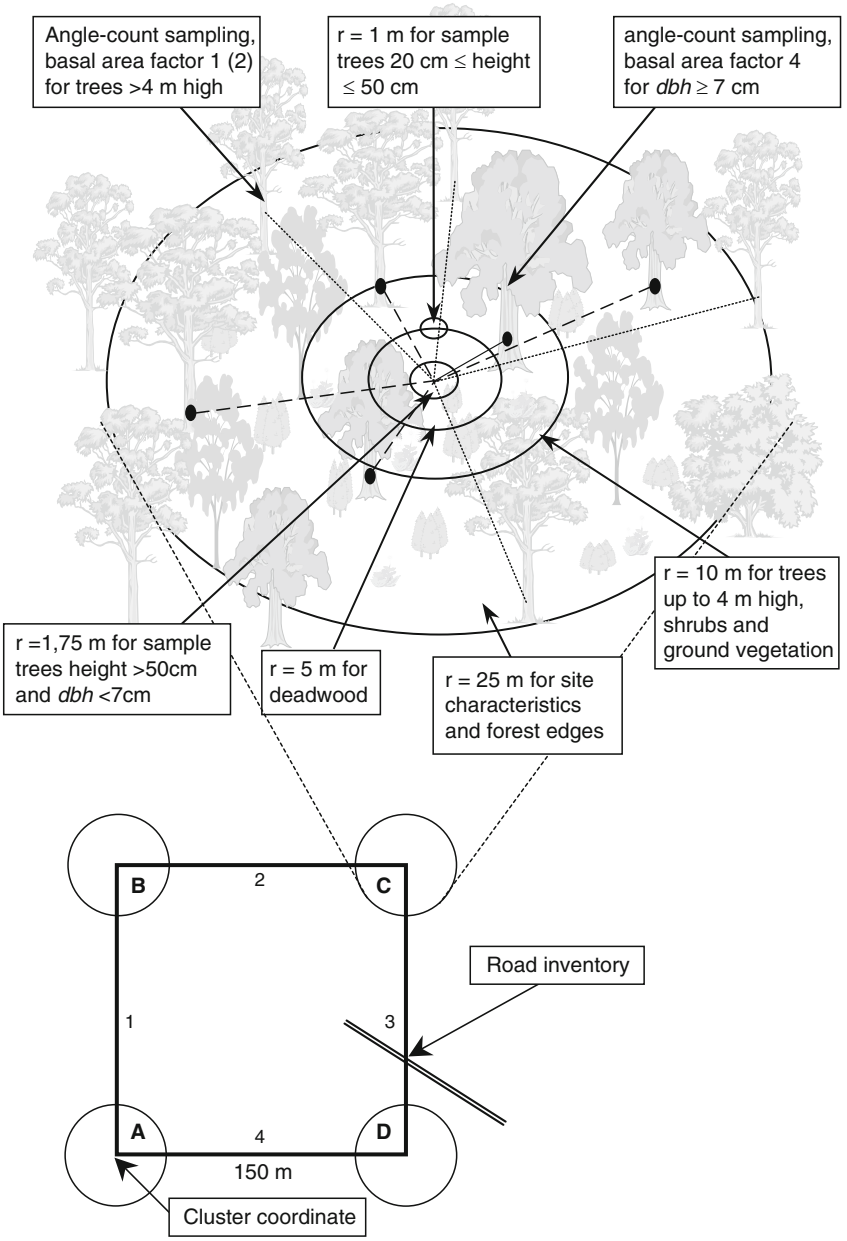

Fig. 13.3 Sample plots and clusters

and coordination of the inventory crews, the preliminary details of the cluster, controlling the survey work and data as well as sending the data to the national inventory administration.

The Federal Government and the federal states cooperated closely to develop the inventory procedure. A regular dialogue between the national and the federal state inventory administrations ensured that detail questions were uniformly clarified. Specific problems were solved by ad hoc working groups.

13.5.2 Inventory Crews

The federal state inventory administrations employed approximately 50 inventory crews to survey the clusters. Each team was composed of two forestry experts (at least one forest engineer or comparable qualification). The data was surveyed by private forest service firms in the following federal states: Brandenburg, Baden-Württemberg, Hesse, Lower Saxony (partially), North Rhine-Westfalia, Schleswig-Holstein, and Saxony-Anhalt. Forest personnel recorded the data in the remaining federal states.

Before fieldwork began, the BMVEL trained approximately 100 participants (staff of the federal state inventory administrations, leader of the inventory crews as well as their staff) in autumn 2000 and spring 2001. In addition, some federal states held their own training courses e.g. on recognising the natural forest community, plant species, etc.

The equipment of the inventory crews included: altimeter and distance metre, tape measure, diameter tape measure, relascope, compass (400 grade), upper diameter callipers for tree diameters to 30, 40, 60 cm as well as 7 m telescopic rod for upper diameter calliper. Mobile, robust field computers with built-in keyboards, active screens and with internal and external Flash RAM cards were employed for the data recording.

As a rule, the inventory crews entered the data on site in the survey database. Plausibility checks in the survey software pointed out data errors and contradictions on site and supported data controls. Program modules of the survey software supported the inventory crews in their search for the plots and sample trees on site.

13.5.3 Quality Assurance

A graduated control system in three steps ensured the quality of NFI2 data:

- Data control by the inventory crews: The survey software contained check routines for field data and for preliminary detail data. Data records were pre-initialised for all of the objects (clusters, plots, sample trees, stand edges) from the NFI1 that were known and clearly identifiable via coordinates. The tree species and *dbh* were displayed for each angle count sample tree from the NFI1. If these objects no longer existed, e.g. because a sample tree had been removed,

this was documented. Additionally, permanent attributes, such as coordinates, were preset in the repeat survey.
The plausibility checks were contained in the survey software and enabled the inventory crews to check and correct the recorded data on site after entry. Examples are renewed measurement of a value, surveying and replacing erroneous values, etc.

- Data control by the federal state inventory administration: The field database containing the recorded data of an inventory crew was transferred to the federal state database where it was checked again. The federal state inventory administration carried out the necessary corrections itself or passed on the erroneous data to the respective inventory crews for them to correct.
  The federal state inventory administration reviewed at least 5% of the clusters with quality control crews. Errors and deviations (particularly systematic ones) were clarified with the respective inventory crew. The federal state inventory administrations recorded the reviews with the ascertained deviations and had taken measures to assure the data quality.
- The national inventory administration checked the data from the federal states for plausibility and completeness using additional testing algorithms that were not contained in the software of the crews or the federal states. The data were transferred to a national database for the evaluation.

13.6 Estimation Techniques

13.6.1 Evaluation Steps

1. Predicting missing values, e.g.
   - Predicting tree height; tree height was measured only for a sub-sample of trees
   - Predicting upper diameter; the upper diameter was measured in West Germany only during the first NFI and in East Germany during the second NFI for a sub-sample of trees
   - Predicting *dbh* for trees which could not be measured at a height of 1.30 m
2. Calculation of derived attributes, e.g.
   - Calculation of individual basal area factors for sample trees near the stand boundary
   - Calculation of tree space, volume and increment for sample trees
   - Calculation of volume for pieces of deadwood
   - Calculation of attributes for plots, e.g. number of trees and volume per hectare
   - Virtual subdivision of the plots according to the area proportion of the tree species or age classes
   - Derivation of the naturalness of tree species mixture

3. Stepwise aggregation of data

– For plots and clusters
– For strata with uniform sample plot density
– For evaluation units

13.6.2 Angle Count Sampling (ACS)

This optical sampling method was first published in 1947 by Walter Bitterlich (1947, 1984). It uses sampling probabilities for trees proportional to their basal area. For the German NFI the sample trees are also measured. This considerably enhances the evaluation possibilities. Using this method, each tree trunk is focused on from the sample point with a prescribed horizontal angle α.

The constant $K = 10^4 \cdot \sin^2\left(\frac{\alpha}{2}\right)$
is called the basal area factor, often denoted by BAF. For the German NFI $K = 4$ m^2/ha, corresponding to a horizontal angle of $\alpha = 2.3°$. A tree is selected when its *dbh* is intersected by both sides of the angle α.

A sample tree z represents a basal area of K m^2/ha and a number of $N_z = \frac{K}{g_z}$ trees per hectare. where $g_z = \frac{\pi}{4} \cdot dbh_z^2$ is the basal area of the tree z.

The distance $R_z = \frac{dbh_z}{2 \cdot \sin\left(\frac{\alpha}{2}\right)}$ around the sample tree is called the marginal distance circle (Fig. 13.4). Every tree whose marginal distance circle includes the plot centre is a angle count sample tree. In other words: all trees not more than 25 times their *dbh* from the plot centre are sample trees. Only trees with *dbh* more than 7 cm and the marginal distance circle located inside plot centre stand are considered. Trees whose marginal distance circle is intersected by a stand boundary have a lower sampling probability. The part of the marginal distance circle area located within the stand is calculated for these trees. The coordinates of the stand boundaries have been accessed for that purpose.

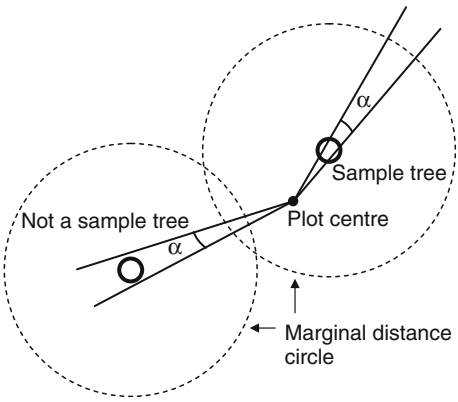

Fig. 13.4 Angle count method – selection of sample trees

The plot and tree-specific basal area factor K_z is

$$K_z = 4 \cdot \frac{Area\ of\ MDC}{Area\ of\ MDC\ inside\ the\ stand} \tag{13.1}$$

where *MDC* is the marginal distance circle.

These plot and tree-specific basal area factors give the basal area per hectare, represented by a tree at the stand boundary.

In the evaluation a value per hectare $\hat{X}_{ha}$ of an attribute x is estimated from the ACS as

$$\hat{X}_{ha} = \sum_{z=1}^{Z} \frac{K_z}{g_z} \cdot x_z = \sum_{z=1}^{Z} N_z \cdot x_z \tag{13.2}$$

where K_z is the tree specific basal area factor, g_z is the tree specific basal area, x_z is the value of the attribute x for tree z, Z is the number of ACS sample trees, and N_z is the number of trees per hectare represented by sample tree z. This formula is the basis for the calculation of all area-related stand attributes from the sample trees of the ACS.

13.6.3 Aggregation

The up-scaling is an aggregation of sample data for several levels and the calculation of sampling error. The systematic distribution of clusters with a random starting point results in a single stage cluster sampling. Because of the different sampling densities, post-stratified estimation is required. The strata h consist of areas with identical sampling intensities.

In principle all projections follow the same procedure:

1. Aggregation for plot and cluster level total value for plot j

$$x_{hij} = \sum\nolimits_{z=1}^{Z_{hij}} x_{hijz} \tag{13.3}$$

total value for cluster i

$$x_{hi} = \sum\nolimits_{j_{hi}}^{M_{hi}} x_{hij} \tag{13.4}$$

with x_{hij} value for plot j in cluster i in stratum h

M_{hi} : number of plots (forest and non-forest) for cluster i in stratum h.

2. Calculation of mean values per hectare total area (forest and non-forest) from the cluster values within stratum h.

Mean value per hectare total area

$$\bar{x}_h = \frac{\sum_{i=1}^{n} x_{hi}}{\sum_{i=1}^{n} M_{hi}} \tag{13.5}$$

variance

$$v(\bar{x}_h) = \frac{1}{\left(\sum_{i=1}^{n} M_{hi}\right)^2} \frac{n}{n-1} \sum_{i=1}^{n} \left(x_{hi} - \bar{x}_h \cdot M_{hi}\right)^2 \tag{13.6}$$

with n number of clusters (forest and non-forest). Most of the mean values per hectare total area are of low information value. Only the forest area per hectare total area has importance as a forest percentage. However, multiplication with the total area gives total final values for the stratum, e.g. forest area or timber volume.

The ratio of two mean values per hectare total area is called a ratio estimator. An often used ratio estimator has the forest percentage as denominator. This gives values per hectare of forest area, e.g. growing stock per hectare.

The up-scaling of mean values per hectare total area simplifies the calculation of sampling errors, because the denominator is not a random component. Note that the mean values per hectare forest area do have two random components.

3. Finally the results for the strata are aggregated to give results for the evaluation units. These are sums or area weighted means – according to the up-scaling projection type.

Many results are obtained in this manner, because up-scaling projections are not only made for the total inventory region but for multiple combinations of classification attributes.

13.6.4 Area Estimation

Forest area is estimated as the product of total area and the percentage of plots that are inside the forest (= mean value of forest area per hectare total area). Total area is preferably taken from official area statistics or from maps and is assumed to be error-free. Forest area is estimated for each stratum separately; the individual estimates are then added together.

Mixed stands are virtually subdivided into pure even-aged stands (equal age class and tree species group) for NFI estimation purposes. Most evaluations for tree-species groups or age classes refer to these virtual pure stands. The subdivision is carried out by calculating tree spaces for the main stand layer. Therefore tree-space functions of the form $F_z = \mathrm{a} + \mathrm{b} * g_z$ are used where g_z is the cross-sectional area = $\pi/4 * dbh_z^2$ and a and b are parameters specific to the tree species. Then the represented area of the plot is subdivided according to the area proportion of the

tree species groups or age classes. Trees not belonging to the main stand layer are not considered because they do not cover additional area, but share their space with the main layer trees. Thus the estimates per hectare for tree species or age classes always refer to the main stand layer which is the layer with the main economic focus.

13.6.5 Volume Estimation

Volume estimation is based on sample trees with $dbh \geq 7$ cm selected by angle count sampling. For this purpose, taper curve (spline functions) that include the *dbh*, the diameter at 7 m height and the tree height are fitted and integrated for each specific tree. Because tree height and the upper diameter have been measured only for a sub-sample of trees, they are predicted with models for the others. Because bark thickness, top diameter, stem length and harvesting slash can be optionally included or excluded, predictions can be given for different growing-stock definitions. Furthermore it is possible to subdivide the tree volume into commercial assortments. This is especially important for the drain statistics estimation. The growing stock and the increment are always given as volume (m^3) of compact wood, i.e., above-ground stem volume with bark having a diameter of at least 7 cm. Stem tip is thus excluded.

13.6.6 Increment Estimation

In the old federal states, in which the NFI was being carried out for the second time, the increment for each sample tree was calculated as the difference in volume between the first and the second NFI. Account was taken of removed and ingrowth trees since the first inventory as well as trees assessed in both inventories. The respective missing data are predicted with models for trees which are documented in only one NFI. This relates in the case of the removed trees to their volume halfway between the successive inventories and in the case of trees newly grown into the sample to their volume at the first inventory. To predict these data, growth models have been developed using data from the sample trees assessed in both inventories. The projection of increment follows the same algorithms as shown in Section 13.6.3. The represented number of trees per hectare N_i for the trees measured in both inventories and for the trees newly grown into the sample is taken from the second NFI and for the removed trees from the first NFI.

Increment per hectare refers to the mean area of the evaluation region from both inventories. This avoids a bias and misinterpretation if the corresponding area – e.g. of the tree species – has changed. The mean annual increment refers to the time between the two assessments at the sample plot and is not calculated in calendar years but in vegetation periods. This is not identical to the time between the appointed dates of the inventories and is different for the evaluation units.

13.6.7 Drain Statistics Estimation

The volume of cut and dead trees is estimated from the removed trees. Their volume is predicted using models for the point in time half-way between the successive inventories. The number of trees represented per hectare N_i is taken from the first NFI. The volume is normally given in m^3 excluding bark, top and harvesting slash. The top diameter depends on *dbh* and tree species, e.g. 12–15 cm for a tree with a *dbh* of 30 cm.

Because the first NFI only assessed trees with $dbh \geq 10$ cm the drain estimates do not include trees which were smaller than 10 cm at this time. This gap between 7 (NFI2) and 10 cm (NFI1) is of low economic importance.

The volume of cut trees per hectare refers to the area of the evaluation unit at the time of the first NFI. As for increment, the mean annual results for cut volume refer to the time period between the two assessments at the sample plot, which is not identical to the time between the appointed dates of the inventories.

13.6.8 Estimation of Changes Between NFI1 and NFI2

Because the inventory methods have been modified between the first and second NFI, estimates of change are not simple differences. To obtain unbiased estimates for the changes between the first and the second NFI, data from the first NFI have been evaluated with the methods used for the second NFI. Furthermore only the intersection of the two samples was considered.

13.6.9 Software

Prior to actual up-scaling, the database from the survey has been completed by:

1. Predicting missing values, e.g.
   - Tree height (to decrease measurement effort it was only measured on a sub-sample of trees)
   - The diameter at 7 m height (to decrease effort, it was only measured in the old federal states during NFI1 and in the new federal states only at the south-western plot and only on a sub-sample of trees)
2. Calculating derived variables from the measured values, e.g.
   - The tree-specific basal area factors for sample trees at stand edges
   - The tree space, the stock and the increment for sample trees
3. Deriving parameter values on the plots, e.g.

- Virtual breakdown of the main stand according to the tree space percentage of the tree species
- Naturalness of the tree species composition

The steps are carried out once and the results are stored in a database to serve as the basis for the up-scaling.

Flexible evaluation software has been developed consisting of a modular system of three combinable parts. These parts carry out the tasks

(a) Providing data for a up-scaling
(b) Up-scaling data and storing the results in results databases
(c) Presenting the results from results databases (each with multiple results from one or more topics)

The evaluation stages are abstracted and modularised. The up-scaling projection program works with anonymous target parameters (x, y) and classification parametres (k1 to k7) and stores the results for areas anonymously. It remains anonymous until data presentation outputs the results as a table or graph with the specified target and classification parameters.

The task of providing data (a) encompasses both deriving parameters on the lowest level, such as the volume or the tree space of trees, as well as data selection and data transfer of pre-aggregated values for plots to up-scaling projection. This task depends on the concrete samples inventory and in most cases also on its data model. Therefore, special software modules have been developed for the NFI. In addition to the databases with the actual inventory data, a key database is set up, in which the nominal or ordinal scaled parameters (nominal: e.g. type of ownership, tree species; ordinal: e.g. age class, *dbh* class, elevation) and their classifications are defined. The results can be called up via control or meta data. Because of abstraction, the tasks of projection (b) and results presentation (c) are independent of any specific questions.

The results presentation module is available for public use on the Internet (www.bundeswaldinventur.de) or locally on DVD. The up-scaling module is reserved for selected users, since it requires specialised technical inventory and evaluation knowledge.

13.7 Options for Harmonized Reporting

13.7.1 Forest Area

Evaluations to compare forest area using national and COST Action E43 forest definition (see also Tables 13.1 and 13.3) were carried out for two test areas (federal states). The first test area (*Schleswig-Holstein*) is characterised by highly fragmented forests and the second test area (*Brandenburg*) has mostly compact forest areas.

Table 13.3 Differences in forest area definitions

Variable	German NFI definition	COST Action E43 reference definition
Minimum area	≥0.1 ha	≥0.5 ha
Minimum width	≥10 m	≥20 m
Minimum crown cover	≥50% currently	≥10% potential
Minimum tree height in situ	Not defined	≥5 m

Two different approaches have shown for the *Schleswig-Holstein* test area that the forest area estimate according to the COST Action E43 reference definition is 0.5% and 0.8%, respectively, less than the national estimate because of the lower minimum area and minimum width. No differences in estimates of forest area were detected for the *Brandenburg* test area. The influence of crown cover has not been evaluated. However, estimates of forest area, where the crown cover is potentially greater than 10% (reference definition) and less than 50% (national definition), are not expected to be significantly greater.

These results show that there is little difference in forest area estimates when using the national and the COST Action E43 reference definitions. Better results can be obtained when the COST Action E43 reference definition is employed in the next NFI (2011–2012).

13.7.2 Growing Stock

The German NFI contains all necessary data for calculating growing stock according to the COST Action E43 reference definition. A first evaluation has shown that the growing stock volume is 1.6% lower than the timber volume according to the national definition. This concerns mainly spruce, fir and larch, whose growing stock is about 3% lower compared with the national results. However the growing stock volume is higher for the aggregated group of "other broadleaved trees" because of a higher percentage of smaller trees.

Table 13.4. shows the difference in the volume definitions. On the one hand the COST Action E43 reference definition for the growing stock includes an additional volume of 1.0% (conifers 0.5%, broadleaved trees 1.8%) from trees smaller than 7 cm *dbh*. But on the other hand, the exclusion of volume from the stump is higher than the inclusion of volume from the stem top for trees with more than 20 cm *dbh*.

13.8 Options for Estimates Based on Reference Definitions

The status of harmonization of the German NFI is presented in Table 13.5.

Table 13.4 Differences in growing stock definitions

Variable	German NFI definition	COST Action E43 reference definition
dbh	≥7 cm	0 cm
Top diameter	7 cm	0 cm
Stump	Included	Excluded
Branches	Excluded	Excluded
Bark	Included	Included
Newly dead trees	Included	Excluded

Table 13.5 The availability of estimates based on national definitions (ND) and reference definitons (RD)

Quantity	ND	RD	Responsible	Remark
Forest area	Yes	No	NFI	Nearly no difference of Forest area between ND and RD
Growing stock volume	Yes	Yes	NFI	For RD special evaluations necessary
Above-ground biomass	Yes	No	NFI, models	ND only contains trees
Below-ground biomass	No	No		
Dead wood volume (=$DW_{10\ cm}$)	Yes	No	NFI	
Dead wood volume by decay stage classes	Yes	No	NFI	
Afforestation, deforestation, reforestation (Kyoto 3.3)	Yes	No	NFI	
Forest type	Yes	No	NFI	

13.9 Current and Future Prospects

The next NFI is planned for the years 2011 and 2012. This is the first repeat survey in reunited Germany and therefore the first NFI with estimations for increment and removals for the whole country. There are signs that indicate a strong increase in removals in recent years. We therefore await the results with great excitement. In 2008, was carried out an intermediate survey on a sub-sample of the NFI plots in order to get a quick idea of the situation and with a view to the opening balance for the first commitment period in of the Kyoto Protocol.

The future interaction between NFI and other forest monitoring activities is currently under discussion. Especially, it is examined how NFI data could extend the analyses of the forest soil survey which are carried out between 2006 and 2009 on another sampling grid than the NFI.

Methodological suggestions are currently being developed with regard to how the NFI could be used for reporting under the FFH Directive (Fauna, Flora and Habitats) of the EU. The NFI could take on the monitoring of large-scale forest habitat types. Furthermore the assessment of forest types and the reduction of minimum diameter for the asessment of deadwood to 10 cm is under discussion.

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