The Design of the Second German National Forest Inventory

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Abstract.—In Germany, a sample-based national forest inventory (NFI) took place for the first time from 1986 to 1990 (in West Germany only); the second one took place from 2001 to 2002. The inventory design is based on a systematic distribution of tracts on regular grids of regionally differing width. The primary sampling unit is a quadrangular tract with sides of 150 m. The tract corners located in forests are the centers of permanently marked subplots in which different sampling procedures are used for the selection of sample trees and the survey of other characteristics. The core sampling technique is horizontal point sampling by means of the angle-count method with a basal-area factor of 4 m^2ha^{-1}. The German NFI is a periodic survey conducted in the whole territory at time intervals that are not predefined but have to be determined anew for each repetition. The results obtained by the second survey document an increase of the growing stock and a high level of periodic annual volume increment in West Germany. Generally, the information provided by the NFI is of great importance for forest policy, especially in connection with international commitments to report on forest resources; as the information is also important for the wood processing industry. Due to the societal, ecological, and economic significance of forests and forestry, the third NFI has now been scheduled to take place from 2011 to 2012.

Introduction

In Germany, the concept of a statistically designed national forest inventory (NFI) emerged in the 1970s. It took some time to convince the upper management of the German Forest Service that a sample-based survey is an efficient tool to collect representative and valid data on forest condition. Finally, the NFI, referred to as the Federal Forest Inventory (Bundeswaldinventur), was included into the Federal Forest Act in 1984. The main objective is to provide an overview on large-scale forest condition and forest productivity by using consistent procedures in a permanent design that will enable remeasurement of the same plots to obtain data on increment and drain. According the Federal Forest Act, the NFI is not a mandatory survey to be repeated at predefined time intervals; instead, its implementation requires an executive order law that has to be decided upon anew each time by the Federal Government and the Federal States (the Länder). This procedure is due to the distribution of competencies concerning forestry between the Federal Government and the Federal States. The Federal Government has only limited executive authority in forestry affairs because the Forest Service is in the sphere of competence of the Federal States. Thus, compared with other countries, (e.g., Finland, Norway, Sweden, or the United States), this monitoring system was introduced quite late in West Germany, with the first Federal Forest Inventory carried out from 1986 to 1990. After the reunification in 1990, the second inventory was conducted from 2001 to 2002. Today, the usefulness of a sample-based inventory is generally accepted and the results obtained are widely demanded.

Design

The German NFI is based on a systematic rectangular grid with clusters (tracts) as primary sampling units (fig. 1). The General Administrative Regulation prescribes a grid width of 4 x 4 km as a so-called basic grid covering the complete surface of Germany with a defined starting point. The sample grid is intensified in some Federal States or parts of them to a 2.83-x-2.83-km or 2-x-2-km quadrangular grid. With the second NFI, 45,098 tracts cover forest and nonforest land throughout

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Germany. Of these tracts, 18,822 are located with at least one corner in a forest (table 1). The total number of subplots (tract corners) on forest land is 54,026, of which 51,768 are on accessible wooded ground, including openings (wooded ground temporarily without a forest cover).

The tract is a quadrangle with sides of 150 m. The sides of the tract are oriented north-south and east-west, respectively. Samples are taken on the tract lines as line-intersect samples for the forest road inventory (only in the new States in East Germany) and on the tract corners if they hit a forest. Tracts with at least one corner in a forest are forest tracts and are to be surveyed. The sample selection on a tract corner is made according to different methods (fig. 2): trees with a minimum diameter at breast height (d.b.h.) (diameter at 1.3 m above ground) of 7 cm over bark are selected by the angle-count method (horizontal point sampling) with a basal-area factor of 4 [m^2ha^{-1}] if they are alive or recently dead (fine branchwood maintained in full) and if they belong to the same stand type as that in which the subplot center is located. These trees are subject to various measurements and assessments. According to the permanent design, their locations are recorded by polar coordinates. The attributes recorded are sample tree code (e.g., new, remeasured, removed), species, azimuth, horizontal distance from center, canopy class, d.b.h., tree class (according to Kraft), tree age, tree height (only subsample), upper diameter (only subsample), height code, trunk code, trunk damage, and lopping. An additional angle count with a basal-area factor of 1 or 2 [m^2ha^{-1}] is carried out as a basis for describing the forest structure by tree species and layer. Smaller trees are sampled in circular plots: trees higher than 0.5 m and d.b.h. of less than 7 cm over bark are surveyed in a plot with a radius of 1.75 m centered on the tract corner; trees 20 to 50 cm in height are recorded in a circular plot with a radius of 1 m located 5 m away from the tract corner, generally to the north. Attributes of the small trees surveyed in the circular plots are species, tree size class, damage by game or other animals, individual protection, fencing protection, and canopy class. Deadwood (lying or standing—either whole or broken, stumps, or leftovers from hauling) is surveyed in a plot with a radius of 5 m (centered in the corner). In a circle with a 10-m radius, trees up to 4 m in height, shrub layers, and ground vegetation are surveyed. In a circle of 25 m around plot corners, site characteristics and forest edges are

Figure 1.—*Regular sample-grid of the German national forest inventory with tracts. This example is from the State of Baden-Württemberg with a 2-x-2-km grid.*

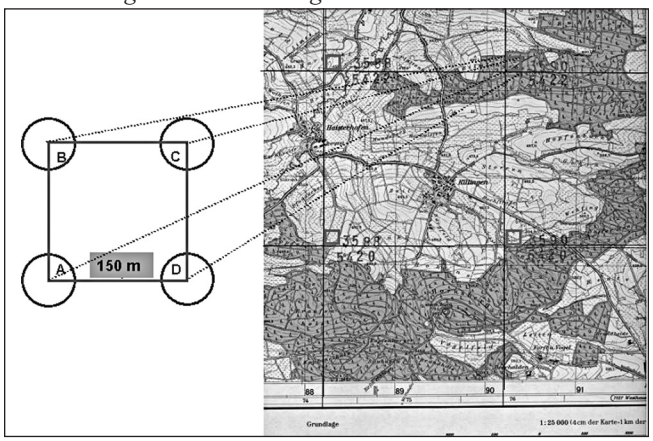


Figure 2.—*Structure of a tract and a subplot on a tract corner.*

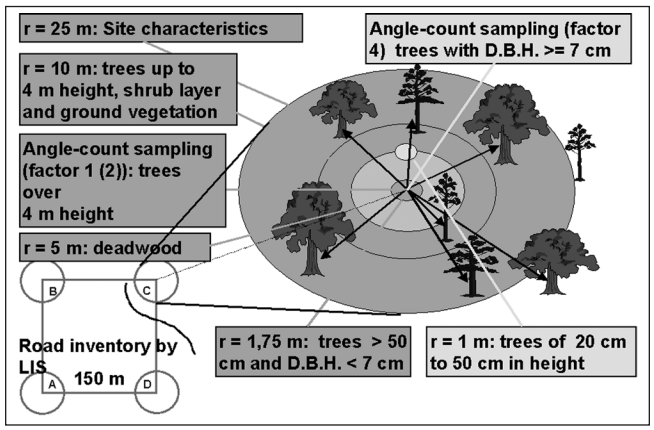


Table 1.—*Number of tracts in regions with different grid widths.*

Grid width	Tracts outside forests	Tracts in forests	Total number of tracts
2 x 2 km	13.737	10.055	23.792
2.83 x 2.83 km	6.174	3.350	9.524
4 x 4 km	6.365	5.417	11.782
Total	26.276	18.822	45.090

recorded. Forest edges are relevant for two reasons: (1) as a characteristic with regard to forest fragmentation and (2) for theoretical statistical reasons. Due to the fact that sample plots are located only in forests, the selection probability of sample trees near a forest border is biased (edge effect bias). Based on the geometry of forest edges captured by polar coordinates related to the plot center, the individual selection probability of sample trees whose limit circle overlaps the forest border can be corrected. To this end, the area of the part of the limit circle lying in the forest is calculated. The ratio of the reduced area to the full limit circle corresponds to the reduction of selection probability.

Altogether, about 150 characteristics for each inventory tract are recorded. As opposed to Germany's first NFI (which occurred from 1986 to 1990 in West Germany), the spectrum of data collected in the second NFI has been expanded to include ecological parameters such as deadwood, closeness to nature, ground vegetation, and forest borders.

The German NFI is conducted as a periodic inventory at time intervals that are not predefined; instead, the repetition of the survey has to be determined anew, if required.

Methodological Note Concerning Growth Estimation

Using horizontal point sampling on permanent plots has the effect that sample composition changes between consecutive surveys due to altered selection probabilities of the sample trees representing different components of forest volume growth. Hence, different estimators of volume growth were developed. A set of literature exists that deals with this issue (for example, Roesch *et al.* 1989, Van Deusen *et al.* 1986). The estimator of volume growth used for the analysis of the German NFI is analogous to one estimator described by Roesch *et al.* (1989) and requires the assessment of the initial volume of the so-called nongrowth trees that were not measured during the preceding inventory because those trees had not yet qualified for the sample. The initial (time 1) volume is assessed by means of growth functions for diameter and height with time 2 tree age and diameter and height, respectively, as predictors.

Organization, Competencies, and Tasks

The German NFI is conducted as a joint mission of the Federal Government and the Federal States that requires close collaboration during preparation and implementation. The Federal Ministry of Agriculture is responsible for the central coordination, scheduling, data management, data processing, and reporting; the States are responsible for the data collection and have to provide the required means (field crews, other personnel, instruments, data logistics, etc.). In each State, a temporary staff unit is in charge of the implementation of the survey. One important task of the State inventory unit is quality assurance of the collected data. Quality assurance is done by a so-called inventory inspection that has to cover a minimum of 5 percent of the plots.

In Germany, only one Federal institution is permanently in charge of inventory and monitoring tasks: the Institute for Forest Ecology and Forest Assessment of the Federal Research Centre for Forestry and Forest Products. At the Federal State level, the Baden-Württemberg Forest Research Institute is the only institution with a research unit permanently dealing with forest inventory issues and tasks (the author's department). In connection with the German NFI, this unit has devised basic methods such as volume functions and taper models (Kublin 2003) as well as the forest development and timber supply model applied for timber supply forecasts based on the NFI data.

Results of the Second National Forest Inventory

Some basic figures on Germany's forests in comparison with the most populous U.S. State, California, and the United States are compiled in table 2. Forest percentage is about the same in the three areas, but growing stock per area is much higher in Germany.

Comparison With Other European Countries

The comparison of forest characteristics between different countries in Europe (with the exemption of Russia) shows that forests are an important natural factor and the basis of multipurpose forestry in a heavily settled country like Germany. Figure 3 displays the total growing stock (volume over bark) of larger

Table 2.—*General information on Germany's forests in comparison with those of the State of California and the United States.*

		Germany	California	United States
Total land area	*1,000 ha*	34,895	41,000	915,896
Forest area	*1,000 ha*	11,076	13,451	303,089
Percent of total land area		*32*	33	33
Total growing stock	*1,000.000 m^3*	3,381	1,907	35,118
Growing stock per hectare	*m^3 ha^{-1}*	315	142	116

Sources: FAO 2005, USDA Forest Service 2006

Figure 3.—*Total growing stock in selected European countries (from FAO 2005).*

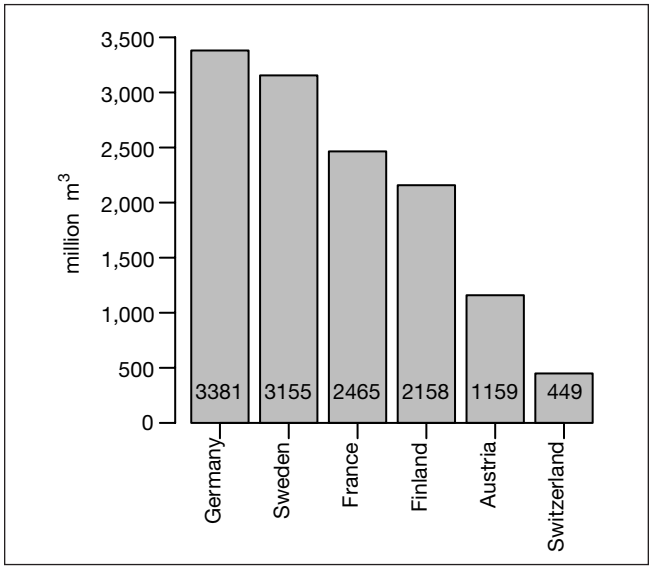
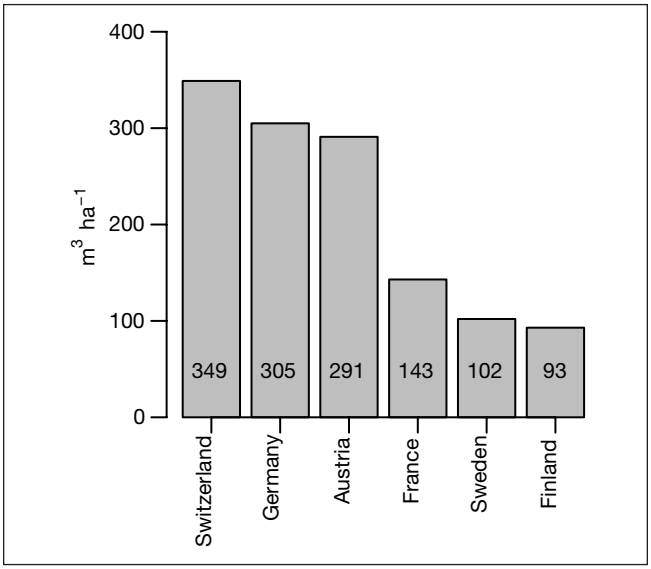


Figure 4.—*Growing stock per hectare in selected European countries (from FAO 2005).*



European countries as well as smaller ones in Central Europe. Although forest area in Germany is not as large as it is in other countries of Northern Europe or in France, Germany's forests are those with the highest growing stock in Europe (excluding Russia). This observation becomes evident when examining the average growing stock per hectare (fig. 4). The highest volume per hectare is attained in Central Europe (Germany, Switzerland, and Austria).

Growth and Drain

With the second NFI, for the first time, growth and drain were assessed on a large, regional scale, but only in the West German Federal States because remeasurement has been done in this area only. The overall number of revisited permanent subplots is 30,538, with a mean period length of 14 (vegetation) years. Growth is expressed as periodic annual increment (PAI) and drain is periodic annual cut and mortality. The average PAI in West Germany is 12.7 $m^3ha^{-1}year^{-1}$ (corresponding to 181.5 ft^3 $ac^{-1}year^{-1}$) The figures obtained substantiate the observation that currently periodic annual growth in West German forests is at a high level, which is in agreement with observations in other European regions (Spiecker *et al.* 1996). Figure 5 shows the comparison of growth and drain from the forests of the major Federal States of Baden-Württemberg, Bavaria, and Lower Saxony for the period from 1987 to 2002 (see also table 3). Generally, drain is below growth expressed as PAI, which leads to an increase of the growing stock in this period, but differences between the regions are evident. In the State of Baden-Württemberg, drain reaches the highest level, almost exhausting increment, whereas in Bavaria and Lower Saxony, only about 67 and 53 percent, respectively, of the increment has been removed.

Assessment of Future Timber Supply

The NFI data is an important base for the assessment of future timber supply in the following 4 decades (from 2003 to 2042). The forecasts of potential timber yield for the period 2003 to 2017 support that an increase of wood harvest is possible. The mean annual cut in West Germany attained about 6.7 $m^3ha^{-1}year^{-1}$ (merchantable volume under bark) in the period 1987 to 2002; in the following period (2003 to 2017), this amount could be raised up to 8.3 $m^3ha^{-1}year^{-1}$ without violating sustainability. The wood processing industry has already responded to these perspectives and has reinvested in additional sawmill capacities.

Figure 5.—*Periodic annual growth and drain in West German Federal States (in cubic meters of volume over bark per hectare and year).*

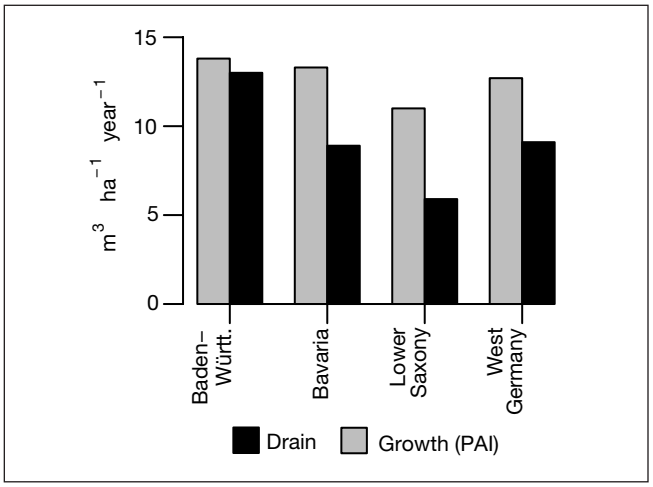


Table 3.—*Growth (periodic annual volume increment) and drain in selected West German Federal States.*

		Baden-Württemberg	Bavaria	Lower Saxony	West Germany
Growth	$m^3\ ha^{-1}\ year^{-1}$	13.8	13.3	11.0	12.7
Drain	$m^3\ ha^{-1}\ year^{-1}$	13.0	8.9	5.9	9.1

Conclusion

In Germany, the NFI is not a permanent institution, unlike, for example, the Forest Inventory and Analysis program in the United States or the NFI agencies in other countries. Instead, the NFI is a temporary mission implemented in close collaboration with Federal and State authorities. Due to this fact, the NFI will remain a periodic survey with a longer time interval. Today, politicians, the Forest Service, the timber industry, and other stakeholders have recognized the usefulness of large-scale, sample-based inventories. The appreciation of the information and data made available by the NFI has increased a great deal. The need for objective data on forest condition and its development is generally accepted. Forest policy has a great demand for objective figures on forests, especially in the scope of international conventions and resulting commitments to report. For example, for the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Kyoto Protocol) signatory States, the part of the national inventory report concerning the carbon budget of forests can be improved significantly if current data from NFIs are available. Another important impact of the second NFI in Germany triggered by the results of the timber supply assessment for the next decades is an increased demand for timber as well as for energy wood. In addition, the timber industry demands reliable data on wood supply for decisions on investments. Therefore, the third NFI is already under way and is scheduled to take place from 2011 to 2012. One reason for the timing is the fact that 2012 is the final year of the first Kyoto Protocol commitment period with the necessity for the signatory States to report on carbon-stock changes in the forests based on reliable data.

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Additional Reading

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