Austrian National Forest Inventory: Caught in the Past and Heading Toward the Future

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Abstract.—The Austrian National Forest Inventory (AFI) started in 1961 on a temporary plot design with a systematic grid and a period of 10 years. For the first 30 years it was conducted as a continuous forest inventory. Since 1981 a permanent plot system has been used and the assessment period was reduced. Only slight changes in the plot design have occurred since the beginning of the inventory. During the past 45 years AFI changed from a survey of forest area, growing stock, and increment to a complex monitoring system covering many aspects of the forest ecosystem. Up to now the assessments have been restricted to the forest area but in the future AFI could be extended to become a landscape monitoring system. An ongoing project uses satellite imagery from Landsat with a *k*-Nearest-Neighbour technique over all of Austria aiming at maps and estimates with higher accuracy for small regions.

Introduction

The Austrian National Forest Inventory (AFI) is carried out by the Federal Research and Training Center for Forests, Natural Hazards, and Landscape (BFW), which until 2005 was a subordinated institution of the Ministry for Agriculture, Forests, Environment, and Water Management. In the meantime its legal status was changed and BFW has become a body of public right, which is similar to a limited liability company. AFI is a binding mandate and embodied in the Austrian forest law, including the right to assess data periodically in every forest in Austria. No legally binding time schedule for the assessment periods exists. Therefore, each assessment cycle is the outcome of negotiations with the ministry. Austria has about 8.4 million ha of total land and about 3.9 million ha of forest land.

AFI provides comprehensive and basic data for forest management on country, provincial, and subprovincial levels. It is used as a tool for forest policy decisionmaking and forest administration, as a database for scientific forest studies, and a source of information for the wood industry. During the last decade, more and more international reporting systems require AFI information. The smallest spatial units for which results are provided are identical with the smallest forest administrative units, from 10,000 ha to 250,000 ha in size. The statistical features of the results for the small units are rather weak.

Statistical Design

In the 1950s when the AFI system was established, Scandinavian forest inventories already existed for more than 30 years (fig. 1). Therefore, some of the approaches of the third Swedish forest inventory were adopted by the AFI. The sources of the first local forest inventories in Europe date from much earlier, however.

Back to the Roots

The oldest document found by the authors dates back to 1459 (Trubrig 1896), which describes the mandate to a forest survey done by horse-riding foresters aiming at a very rough estimation of harvestable growing stock. In the course of centuries the survey methods were improved. The aim of these so called “Waldbeschaue” (e.g., Anon. 1674, Braun 1974) was the estimation of growing stock and the potential for harvest including the efforts to be taken (Braun 1974). The reasons

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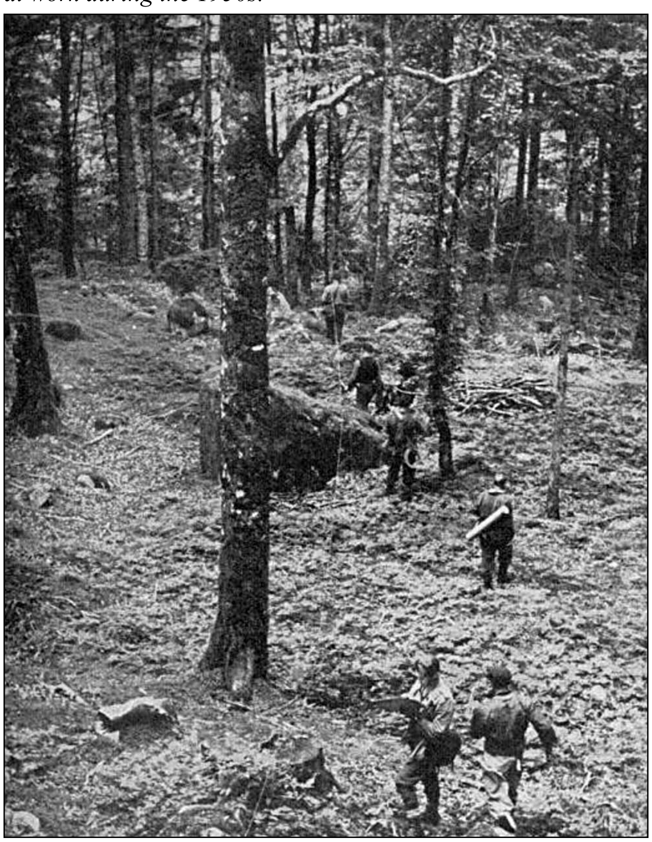
were the increasing wood demands for mining and salt industry. The assessment teams also were instructed to look for what they called forest damages, meaning illegal logging at that time. In the middle of the 18th century the concept of sustainable use of forest resources was developed (Baader 1933). The latest developments are now documented in the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and the Montreal Process. So the aims for developing forest inventories did not change so much during the past 500 years.

The Scandinavian forest inventories started their work in the 1920s with a strip sampling concept (e.g., Heske 1926, Simak 1951). Due to the prevailing topographic conditions and higher variability of growth conditions in Austria, the responsible authorities were obliged to conduct special surveys to find the most adequate layout for the inventory in Austria. These included tract grid density, sample plot sizes, stand and site characteristics, the selection of a nationwide basal area factor

Figure 1.—*Field crew of the Swedish National Forest Inventory at work during the 1950s.*



for Bitterlich's angle count method, as well as sample tree characteristics to be used as input parameter for new volume and form factor functions.

The idea of a systematic grid of sample plots goes back to Zetzsche (Schmidt 1891) and was already applied in practice at the end of the 19th century. The idea to use a systematic grid of clusters (so-called tracts) also in a large-scale inventory stems from Hagberg (1955) and was field tested in the mid-1950s. It was adopted by several national forest inventories.

Actual Design

The AFI uses the following approach (Gabler and Schadauer 2006):

- Nationwide uniform survey criteria and manuals.
- Systematic grid of tracts on the whole federal territory.
- Several sample plots per tract (satellite sample).
- Determined sample plot (300-m^2 circular area) to identify area data.
- Bitterlich's angle count method.
- Line survey (landscape diversity and forest roads).
- Flexibility and creativity for the methodical treatment of ecological issues and special surveys.
- Volume determination of single trees through measurement to identify growing stock, increment, and harvesting.
- Evaluation of results through ratio estimation.
- Indication of a standard error for the individual average value (estimation value).
- Up-to-date measurement equipment.
- Computer-aided data capture and evaluation.

Only a small part of the total area of Austria (0.008 percent) is used for sampling by AFI. The results of the assessment are evaluated (scaled up to the selected geographical level such as the federal territory or the provinces). The average assessment values are indicated with their standard errors.

The survey and assessment unit is the tract consisting of four circular plots 300 m^2, each which are arranged at the corners of a square with 200 m of side length (fig. 2). The side lengths of this square are located in north-south and east-west directions.

The tracts are systematically distributed over the whole federal territory and the number of tracts is about 5,600. This implies about 11,000 sample plot on forest land.

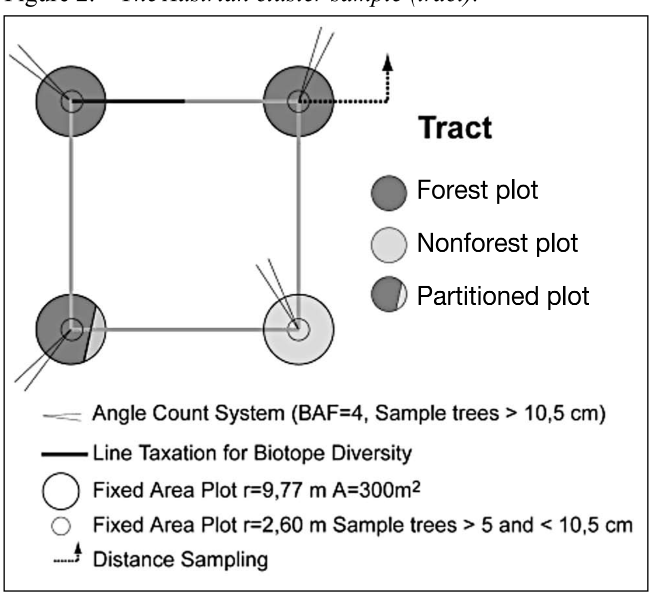
Each sample plot of a tract is subdivided into two concentric circular plots. The small rigid sample circle with a radius of 2.60 m is used for the assessment of trees with a diameter at breast height (d.b.h.) between 50 and 104 mm. Sample trees with a d.b.h. larger than 104 mm are selected according to the Bittlerlich angle count method and the basal area factor 4. The relascope is installed at the centre of the circular sample plot of 300 m^2.

The whole sample circle with an area of 300 m^2 is used to identify the forested area and its structures. These sample plots can be further subdivided. If there is a district, estate, or ownership borderline crossing the sample plot, the plot is subdivided into parts of tenths. If the sample plot is divided by a forest edge, it is subdivided into tenths between forest and nonforest. This division is applied also if other reasons exist for subdivision to be applied only on forested areas. They can both be site related and stand related.

The land cover type *forest* is defined as follows:

- Areas stocked with wooden plants and shrubs.

Figure 2.—*The Austrian cluster sample (tract).*



- Forested areas temporarily unstocked due to harvesting.
- Permanently unstocked areas provided they are in direct relationship with a forest (e.g., forest logging area, timber yards).

The cover type must fulfil the following criteria:

- Minimum canopy density: 3 parts of tenths.
- Minimum surface: 500 m^2.
- Minimum width: 10 m.

The criteria of minimum surface area must meet an additional test. A sample plot of a tract is only 300 m^2. As the minimum area is 500 m^2 the survey team must look over the borders of the fixed circular plot and consider also the stand characteristics beyond the 300 m^2 circular plot for the evaluation.

Volume estimates are obtained by applying tree measurements (d.b.h., height, upper diameter) from about 80,000 sample trees to tree volume equations. Volume data are gross volume of the stem over bark including stump and top. Dead standing trees (snags) are not excluded from volume estimates. Tree height and upper diameters are measured on a subsample of the 80,000 sample trees. To get the corresponding tree heights and upper diameters for all sample trees, data models are used (Gschwantner and Schadauer 2004).

Short Overview of the Austrian Forest Land

The Austrian forest land is mainly owned by farmers with a forest area smaller than 200 ha (54 percent of total forest area); only 16 percent of the forest area belongs to the Republic of Austria. The forest area reaches from 100 to 1,800 m above sea level and has a medium slope of about 40 percent. Eighty percent of the forest area is covered by coniferous species, mainly Norway spruce (*Picea abies*); the dominant broadleaf species is beech (*Fagus sylvatica*). The Alps dominate the ecological conditions and split the area into relatively small-scaled units of homogeneous conditions leading to a forest picture with high spatial variability. Approximately 80 percent of the forest area is used primarily for timber production (fig. 3). One-fifth has a mainly protective function including 4 percent of the total forest land which is not accessible due to extreme topographic conditions. The forest cover in the Alps has a very important

Figure 3.—*Management types of forest use.*

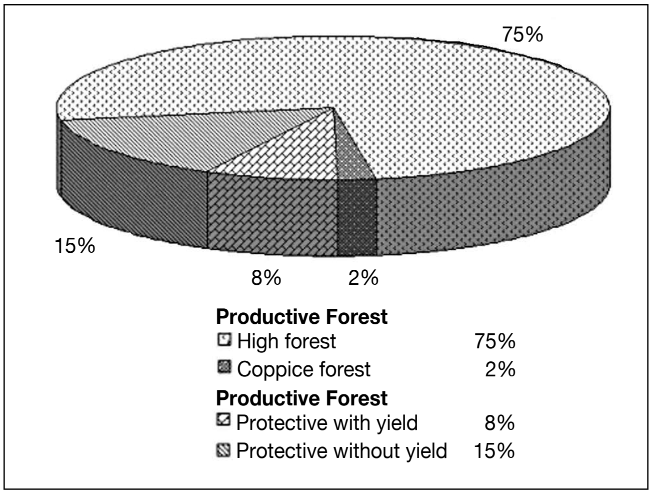
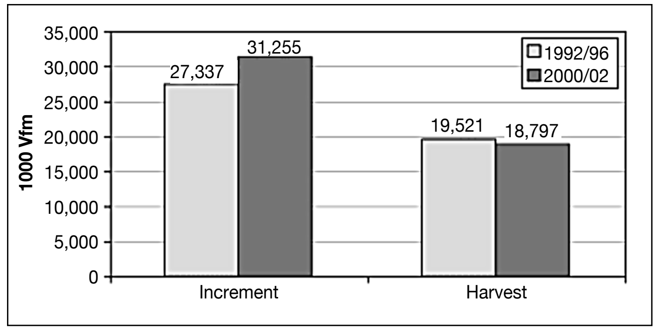


Figure 4.—*Information to Indicator 3.1 "Increment and Fellings" based on the evaluation of the inventory periods 1992–96 and 2000–02.*



function for the maintenance of fresh water resources and soil quality. Main risks relevant for the Austrian Alpine region are avalanches and torrents.

Challenging Tasks for AFI

Sustainable Forest Management

Since the first set of Pan-European Indicators for Sustainable Forest Management was developed in the early 1990s, experience has shown that criteria and indicators are a very important tool for European forest policy. Indicators include forest area, growing stock, increment and fellings, forest under management plans, tree species composition, dead wood, etc. (MCPFE 2003).

Data for these indicators are assessed and supplied by the AFI. The increment and fellings indicator highlights the sustainability of timber production over time as well as the current availability and the potential for future availability of timber. For long-term sustainability, the average annual fellings must not exceed the average net annual increment. For example, figure 4 shows that the sustainability concerning that indicator is satisfactory for Austria.

The result for each criterion and indicator is given by the Republic of Austria (2005).

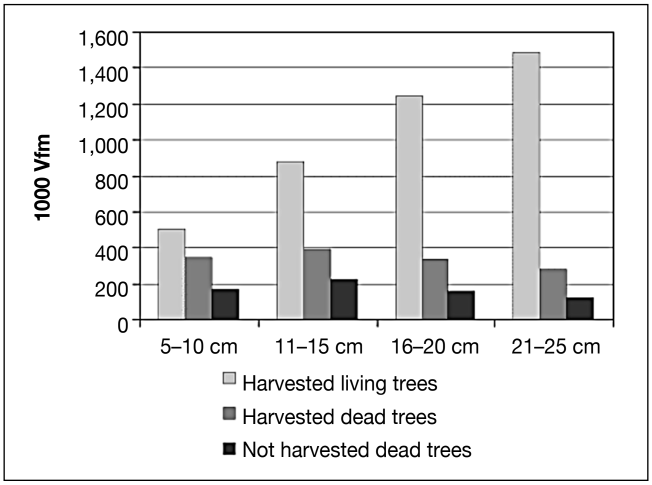
Biomass for Energy Production

Biomass used to produce electricity and thermal energy is increasingly needed. The estimated additional sum for the next two years is about 4 million cubic meters per year; the total annual amount of harvest according to the 2000–02 AFI is 19 million cubic meters. Special assessments and evaluation of the AFI show that there is a huge amount of so called "thinning backlog" available in the forest (17 million cubic meters), which could partly be used for energy production. But according to the actual prices the harvesting of small dimensions is not profitable. An evaluation of mortality and felling per year according to d.b.h. classes can be found in figure 5, falling into three categories: harvested living trees, harvested dead standing trees, and not harvested dead trees. The figure indicates clearly that the total amount of harvested living trees for the lowest d.b.h. classes is less than the volume of dead trees.

Climate and Growth

The AFI has collected permanent sample plot data from 1981 to 2002. Five years after establishment the plots were remeasured in the years 1986–90 for the first time. The consecutive remeasurements took place during 1992–96 and 2000–02. From these measurements 17 increment periods (1981–86, 1982–87, …, 1995–2001, 1995–2002, 1996–2002) can be derived. With this sample plot data a logarithmic basal area increment model was developed according to Monserud and Sterba (1996), who describe the basal area increment as a function of tree size, competition, and site variables:

Figure 5.—*Fellings and mortality for small d.b.h. classes according to a special evaluation of AFI 2000–02.*



AFI = Austrian National Forest Inventory; d.b.h. = diameter at breast height.

$$\text{In}(BAI) = a + b * SIZE + c * COMP + d * SITE \quad (1)$$

where:

BAI = the basal area increment.

a = the intercept.

b = the vector of coefficients for tree size variables.

c = the vector of coefficients for competition variables.

d = the vector of coefficients of site variables.

To estimate the growth trend in basal area increment, Gschwantner (2006) included dummy variables coding for the 17 increment periods *INT* in the basal area increment model according to Monserud and Sterba (1996):

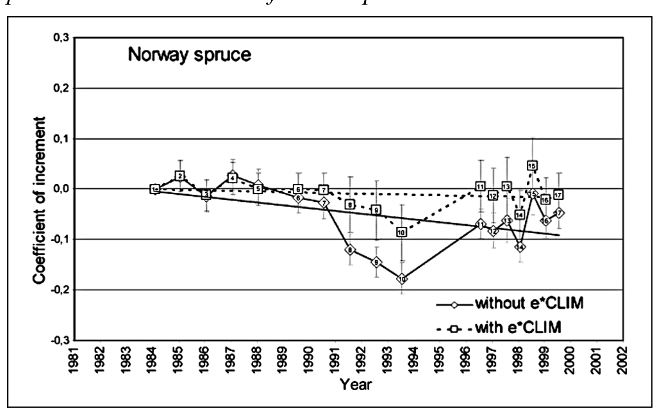
$$\text{In}(BAI) = a + b * SIZE + c * COMP + d * SITE + f * INT \quad (2)$$

The coefficients *f* describe the variation of basal area increment between the 17 increment periods *INT*. Linear regression was applied to estimate the trend in basal area increment from the coefficients *f*. In a further step, Gschwantner (2006) evaluated the role of climate as a cause of the variation in basal area increment between the 17 increment periods. A point version of DAYMET adapted by Petritsch (2002) for Austrian conditions provided climate variables (temperature and precipitation) for each sample plot. These temperature and precipitation values were converted following Kublin *et al.* (1988) into climate parameters relevant to increment. The importance of climate in basal area increment changes was then assessed by additional inclusion of climate parameters *CLIM* into the model:

$$\text{In}(BAI) = a + b * SIZE + c * COMP + d * SITE + e * CLIM + f * INT \quad (3)$$

As we did from basal area increment model (2), we also obtain coefficients *f* from model (3). Again, linear regression was employed to estimate the trend in basal area increment when climate parameters are considered in the model. If the observed growth trends were caused by climate variations, the additional inclusion of climate parameters should have a diminishing effect on the coefficients *f* of the 17 increment periods *INT* and should reduce the slope of the growth trend. This means that the included climate parameters explain the observed growth trend in basal area increment. Figure 6 illustrates this diminishing effect of the inclusion of climate parameters in the basal area increment model for Norway spruce. Thus, we assume that climate parameters are considerable relevant in explaining the observed trend in basal area increment of Norway spruce. Temperatures during the cold season were identified to be of special importance for increment changes.

Figure 6.—*The change of coefficients of the 17 increment periods due to inclusion of climate parameters.*



Application of Remote Sensing Techniques

AFI does not use any remote-sensing techniques for prestratification purposes. Within an ongoing project the satellite image data are combined with field data aiming at mapping of forest attributes and estimates for these attributes with higher accuracy for small regions compared to the existing estimations. In a prestudy, the main emphasis was placed on the incorporation of topographic correction into the *k*-Nearest-Neighbor-based assessment of forest attributes (Koukal 2004). A relatively new radiometric correction method (sun canopy sensor model) is used in combination with atmospheric correction methods. This approach turned out to be suitable also for operational applications. At the moment only results for the eastern part of Austria (more flat) are available. They reveal satisfying agreement with the ground-based results of the attributes: forest area, forest cover type, volume of the main tree species (species groups), and the percentage of the main tree species.

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