Chapter 7
Austria

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7.1 The Austrian National Forest Inventory

7.1.1 History and Objectives

The beginning of large-scale forest surveys in Austria is marked by the "Österreichische Waldstandsaufnahme" (Austrian Forest Survey) conducted during the years 1952–1956. This survey aimed to assess the state of Austrian forests after World War II and to evaluate the potential for sustainable forest utilisation and management (Gabler and Schadauer 2008; Gschwantner et al. 2010). The need for forest statistics at both national and local level required a special survey design with the basic features of a stand-wise assessment and a combination of aerial photograph interpretation and terrestrial assessment of delineated forest stands (Braun 1960). From the experiences in this forest survey and after several pilot studies (Braun 1974) the first sample-based National Forest Inventory (NFI) was conducted during the years 1961–1970. The field assessments were based on a temporary systematic sampling grid. Also the second NFI from 1971–1980 was designed as a temporary inventory. The primary emphasis of the first two sample-based NFIs was on the assessment of the current status of the forest estate. Thereafter, the

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importance of monitoring changes in the forest resulted in the establishment of a permanent sampling grid during the third NFI from 1981–1985. All subsequent NFIs were based on this permanent sampling grid. The first re-measurement of the permanent plots was done in the fourth NFI in 1986–1990 which also included assessments on an additional temporary grid. In the fifth NFI from 1992–1996 the continuous assessment changed to a discontinuous scheme and several new and mainly ecological variables were integrated in the inventory (Schieler and Schadauer 1991). The assessment of these new variables were continued and extended in the sixth NFI from 2000–2002 which was accompanied by a reduction of the field assessment period to 3 years. The most recent seventh NFI in 2007–2009 introduced further assessments including the topics of sustainability, biomass availability, biodiversity, protective function of forests and providing data to fulfil the reporting obligations of the Kyoto Protocol. Also a step towards landscape monitoring was made to facilitate reporting of activities in the land use, land-use change and forestry (LULUCF) sector. The harmonisation efforts at the European level (Tomppo et al. 2010) led to the implementation of field assessments according to commonly agreed definitions in COST Action E43 (2010). In parallel with the national definitions, the forest and Other Wooded Land definitions of the Food and Agriculture Organization of the United Nations (FAO 2004) were also applied in the field assessments and trees below the national dbh-threshold of 5.0 cm were recorded as stem counts in two diameter classes. From 2011 to 2013 a special survey to satisfy carbon reporting requirements under Article 3.3 of the Kyoto Protocol was implemented and included a remote sensing as well as a field assessment component.

7.1.2 Sampling Methods and Periodicity

The Austrian NFI is the largest forest monitoring program in Austria and covers all federal territory. Only forest areas were assessed prior to the seventh NFI (2007–2009). However, in the most recent seventh NFI a step towards landscape monitoring was made by the assessment of the management type and land use category of each inventory plot and also outside the forest. The field measurement period lasted for 3 years. The sampling grid is systematically divided into three parts so that each year one third of the grid covering the whole of Austria is inventoried. The time span between the measurements of the two latest inventories is seven years.

The Austrian NFI uses a sampling grid which has a size of 3.889 × 3.889 km. Clusters of four sample plots are located on the intersections of the grid. The clusters are square-shaped and have a side length of 200 m. The sample plots are located at the corners of the clusters. The shape and size of the grid and clusters are uniform all over Austria. In total, there are approximately 22,300 sample plots, of which about 11,000 are located on forest land.

The sample plots consist of a large circular plot of 300 m^2, a small circular plot of 21.2 m^2 and an angle count plot. At least one tenth of the large sample plot has to be covered by forest to qualify the sample plot as forest plot and to assess the stand- and site-specific variables and to measure tree-specific variables on the sample trees. The large circular plot forms the basis of forest area estimation and stratification according to ownership categories, management types, age classes, growth classes, tree species, species mixture, and natural forest type. Stand- and site-specific variables are assessed at and assigned to the 300 m^2 plot. Forest plots that are covered by stands of different age classes, stand structure, tree species, management type, or that reveal different soil types, vegetation types, exposition, slopes, etc. are subdivided into sub-plots that are described separately. The small circular plot is used for data collection for trees with a diameter at breast height (dbh) between 5.0 and 10.4 cm inclusively. Trees with a dbh of more than 10.4 cm are sampled using Bitterlich's angle count sampling (Bitterlich 1948, 1952, 1984) and by applying a basal area factor of 4 m^2/ha.

7.1.3 Data Collection

Aside from basic data such as the allocation of sample plots to administrative regions, growth districts according to Kilian et al. (1994), ownership categories and management types, the Austrian NFI assesses three main categories of variables: stand, site and sample tree. Detailed and further information about the data collected by the Austrian NFI and the assessments and measurements of variables are available from the field assessment instructions (Hauk and Schadauer 2009).

Stand-specific variables describe the forest stand in which the sample plot or the sub-plot is located. They include the assessment of:

- Growth classes
- Age classes in 20-year intervals
- Share of tree species in age classes
- Age sub-class in 5-year intervals if ascertainable
- Dominant height of even-aged conifer stands
- Forest structure: Crown coverage, Stand structure, Development stage, Coverage of shrubs in stands
- Stand stability: Damage, Required tending activities, Factors that influence game
- Actual woodland community
- Natural woodland community
- Regeneration
- Stand layers and their coverage
- Occurrence and abundance of woody plant species with attribution to stand layers
- Deadwood.

The site-specific variables describe the site conditions that influence the growth and development of single trees or stands. They include the following variables:

- Elevation above sea level
- Slope direction (exposition)
- Slope gradient
- Relief
- Local climate situation
- Vegetation type
- Soil moisture
- Soil layer thickness
- Soil group
- Soil movement
- Humus layer thickness
- Humus type
- Soil texture.

Sample tree variables refer to those that are measured or assessed on the sample trees. In some NFI periods variables like tree height, height to the living crown base, and upper diameter are measured only on a sub-sample of sample trees and the values of non-measured sample trees are predicted using data models (Schieler 1997; Gschwantner and Schadauer 2004). The tree-specific variables measured or assessed on sample trees are:

- Species
- Diameter at breast height
- Tree height
- Height to the living crown base
- Upper diameter at 3/10 of tree height
- Length of broken stem part for newly broken trees
- Crown radius and type of crown base
- Stem quality
- Reserved tree and trees with advanced growth
- Dead standing tree
- Forked tree
- Growth class
- Age class
- Tree class
- Stem damage
- Proposed felling in required tending activities
- Distorted tree.

7.1.4 Data Processing, Reporting, and Use of Results

Field assessments and measurements constitute the input variables for the estimation algorithms applied by the Austrian NFI. Basically area-related estimates and volume- or biomass-related estimates can be distinguished.

The estimation of area has two components, on the one hand the data collected at the 300 m^2 sample plots, and on the other hand the area of the Austrian territory. The area represented by one 1/10-share of a sample plot is calculated by dividing the land area by the total number of 1/10-shares of sample plots and parts of sample plots located in the respective land area. The area of the Austrian territory, the Federal States and Forest Inspection Service districts is obtained from the official statistics of Statistik Austria (2009) and is assumed to be error-free. The area estimate of a given stratum is equal to the sum of 1/10-shares located in this stratum multiplied by the represented area of one 1/10-share.

The estimation of the volume and biomass of standing stock, growing stock, increment, and harvest is of particular interest for productive forest land. The estimation procedure includes several steps. After field data collection, the data undergo quality control procedures. Volume and biomass is then calculated for each sample tree. Different models are applied depending on the species and size of the sample tree. Since the sample trees are sampled by angle count sampling and a small circular sample plot, the per hectare values represented by the individual trees are obtained according to the respective sampling method. For each plot or sub-plot the represented volume per hectare is calculated as the sum of per hectare values represented by individual trees. These per hectare estimates are aggregated to a mean volume or biomass per hectare for productive forest and multiplied by the area of productive forest to obtain the total volume or biomass of standing stock and growing stock. Mean volumes and biomass per hectare and total volumes and biomass are also estimated for strata within productive forest like management types, ownership categories, age classes, and growth classes.

Change estimates are obtained from the assessments of two consecutive NFIs. The volume and biomass increment of sample trees is calculated as the difference between the second and the first occasion. Sample trees that have exceeded the dbh-threshold of 5.0 cm between the two NFIs are also included in the increment estimation. Increments per hectare are obtained by referring to the measurement at the first occasion. The drain is assessed by recording the sample trees that have been harvested or that have disappeared naturally since the previous field assessment. The drain of volume and biomass is calculated using the individual tree volume and biomass and the sampling probability of the first assessment.

The Austrian NFI provides estimates at different regional scales, the national level, the nine federal states, and the 75 Forest Inspection Service districts. The estimates include among others forest area, growing stock, increment, harvest, number of stems, stem damages, regeneration, and dead wood (http://bfw.ac.at/rz/wi.home). The results of the Austrian NFI are used as the basis for decision-making in forest and environmental policy, forest management, forest product industries, and for evaluating the consequences of the decisions taken. Reporting obligations of many international processes and organisations are fulfilled using the data and results of the Austrian NFI. Reporting processes include: the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 of the Kyoto Protocol, the indicators and criteria for sustainable forest management for FOREST EUROPE (FOREST EUROPE, UNECE and FAO 2011), and on the conservation status of natural habitat types under the Habitats Directive (Council of the European Communities 1992). NFI data are a valuable data source for numerous research projects and were used to develop the forest growth simulators PrognAus (Monserud and Sterba 1996; Ledermann 2006) and Caldis (Kindermann 2010), in scenario analyses to estimate the current and future potential of Austrian forests for wood and biomass supply HOBI (Neumann and Schadauer 2007; BFW 2009), in several remote sensing projects (Eysn et al. 2012; Dorigo et al. 2010; Hollaus et al. 2007, 2009a, b), for the evaluation of the protective functions of forests (Bauerhansl et al. 2010), to assess the degree of naturalness of Austrian forests (Grabherr et al. 1998), and for the development of a forest biodiversity index (Geburek et al. 2010).

7.2 Land Use and Forest Resources

7.2.1 Classification of Land and Forests

7.2.1.1 General Land Classification

The land classification system used in the Austrian NFI follows a hierarchical system of land management types (Table 7.1). At the highest level the land area is divided into forest and non-forest by applying the national forest definition. To qualify as forest, a piece of land requires a minimum area of 500 m^2, a minimum width of 10 m, and a crown cover of woody plants including shrub species of 30 %. Forest land contains the classes of productive forest, protective forest, and permanently unstocked parts of the forest. Non-forest land is distinguished into agricultural land, natural land, built-up areas and other non-forest land which are subdivided into further classes as described in Table 7.1. The details of the land classification system applied by the Austrian NFI are described in the field assessment instructions (Hauk and Schadauer 2009).

The areas of forest and non-forest land classes according to the Austrian NFI are given in Table 7.1 and the classes are compared to the definitions of the Forest Resources Assessment of FAO (2004). Since the Austrian forest definition includes shrub-land there is an overlap with the Other Wooded Land (OWL) definition of FAO (2004). The Austrian forest definition contains also areas of land that are

Table 7.1 Land use classes according to the national definition with area estimates (Seventh NFI, 2007–2009) and correspondence with FRA classes

Class name		Description	Area (1000 ha)	Corresponding FRA classes (FAO 2004)
Forest	Forest land	Productive forest, protective forest, permanently unstocked parts of the forest	3991	Forest, intersection with OWL, intersection with OL and OLwTC
Non-forest	Agricultural land	Cropland, fallow land, orchards and vineyards, land for wood energy production, windbreaks, Christmas tree plantations, grassland, grazing land	2763	OL, OLwTC, intersection with forest
	Natural land	Water bodies, reed beds, bogs, heath lands, rocks, areas of gravel and debris, landslides, other natural lands	334	OL, OLwTC
	Built-up land	Industry and commerce, mining, traffic and transport, disposal sites, tourist facilities, dwellings and parking sites, gardens and parks	496	OL, OLwTC
	Other land	Inaccessible and unproductive non-forest land	805	OL
Total land area			8388	

considered as Other Land (OL) and Other Land with Tree Cover (OLwTC) by FAO (2004). This is as a result of the smaller minimum area and smaller minimum width, and higher minimum crown cover in the national definition compared to the FAO definition. The non-forest categories correspond to OL and OLwTC depending on the crown cover. Agricultural land according to the national definition contains some elements that belong to forest according to FAO (2004) like for example land for wood energy production and Christmas tree plantations.

7.2.1.2 Forest Classifications by Use

Forest land is further sub-divided according to the forest management system, the productive and protective forest function, and stocking characteristics. The management system refers to the distinction of high forest and coppice forest. Most of the forest area (98 %) belongs to high forest and the remaining 2 % to coppice forest. With regard to wood resources the distinction of productive forest and

Table 7.2 Classes within forest land and their area (Seventh NFI, 2007–2009)

<table>
<tr><th colspan="2">Class name</th><th colspan="3">Description</th><th colspan="2">Area (1000 ha)</th></tr>
<tr><td rowspan="7">Forest land</td><td rowspan="2">Productive forest
–high forest
–coppice forest</td><td rowspan="2">Forests available for wood supply, includes forests with protective function and with yield</td><td colspan="2">Stocked or temporarily unstocked</td><td>3342</td><td rowspan="2">3367</td></tr>
<tr><td colspan="2">Shrub-land</td><td>25</td></tr>
<tr><td rowspan="3">Protective forest
–high forest</td><td rowspan="3">Forests with protective function and without yield</td><td rowspan="2">Accessible</td><td>Stocked or temporarily unstocked</td><td>188</td><td rowspan="3">500</td></tr>
<tr><td>Shrub-land</td><td>110</td></tr>
<tr><td colspan="2">Not accessible</td><td>202</td></tr>
<tr><td>Permanently unstocked parts of the forest</td><td colspan="4">Unstocked due to
–Forest management (e.g. forest roads, timber yards)
–Natural reasons</td><td>124</td></tr>
<tr><td colspan="5">Total forest land area</td><td>3991</td></tr>
</table>

protective forest is particularly relevant. Productive forest contains all forest areas that are available for wood supply and as such include protective forests with yield. The latter have protective and economic function at the same time and contribute to wood supply from regular and commercial harvests. Protective forests without yield have a mainly protective function and no or negligible yield. They are located in areas that are difficult to access or even inaccessible and often they are on sites of very poor productivity. Protective forests classified as not accessible amount to 202,000 ha. The area of productive and protective forests includes also shrub-land. Shrub-land is defined as area that fulfils the national forest definition and that is dominantly covered by shrub species. About 25,000 ha of shrub-land are included in productive forest and potentially would be available for wood production if managed accordingly. Protective forest without yield but in accessible locations has a considerably larger area of shrub-land that amounts to 110,000 ha. All resource-related estimates like standing volume, growing stock, increment, and harvest are calculated for the productive forest land category. Permanently unstocked parts of the forest are unstocked due to forest management features such as forest roads and timber yards or for natural reasons. They are a separate category in the forest classification scheme given in Table 7.2 and belong to productive as well as to protective forest areas.

7.2.1.3 Classification by Ownership Categories

The Austrian NFI distinguishes three main categories of forest ownership: small private forests, forest enterprises, and the Austrian federal forests managed by the

Table 7.3 Forest area according to the national forest definition by ownership categories (Seventh NFI, 2007–2009)

Ownership category		Area (1000 ha)
Small private forest <200 ha		2153
Forest enterprises	200–1000 ha	386
	>1000 ha	729
	Area municipalities (≥200 ha)	130
Österreichische Bundesforste AG		593
Total forest area		3991

Österreichische Bundesforste AG. Small private forest properties own forest with an area of <200 ha. Forest enterprises manage forest properties that have a size of 200 ha or more. This category is divided into three sub-categories which are Private forests with 200–1000 ha, Private forests >1000 ha, and area municipality forests of 200 ha upwards. Over half (54 %) of the Austrian forest estate belongs to category of small private forests. Private forests >1000 ha comprise 18 %, and the Österreichische Bundesforste AG manages 15 % of the Austrian forest area. The remaining forest area belongs to Private forests with 200–1000 ha (10 %) and area municipalities (3 %) (Table 7.3).

7.2.1.4 Forest Management and Cutting Systems

The forests in Austria are managed in even-aged and uneven-aged management systems. A recent study showed that about half of the stocked productive forest land is covered by stands having one age class and the remaining half is covered by stands having more than one age class. The highest share of uneven-aged forest stands is in small private forests <200 ha, whereas the highest share of even-aged stands is in enterprises >1000 ha (Prskawetz and Gschwantner 2011). In the last decennia small-scale management practices, like cutting of single stems and harvesting of small areas, have become more frequent as well as regeneration fellings and have contributed to a modest increase of uneven-aged stands. The management of even-aged forests normally incorporates the following activities during the stand development: (1) stand establishment with natural regeneration or planting, (2) enlargement of growing space and cleaning, (3) thinnings, (4) clear cutting or final cutting of remaining trees after regeneration fellings.

The harvested wood volume can be distinguished by the type of harvesting. According to the most recent NFI 2007–2009 about one third of harvested wood was felled in clear-cuts. However, it has to be noted that the minimum area-threshold for qualifying as clear-cut is 500 m^2 which is rather small and therefore may not be considered as clear-cut from other perspectives. Thinnings account for about 11 % of fellings. Regeneration fellings and final cutting of remaining trees together account for 17 %. Cutting of single stems and of small areas contributes about 15 % of the total harvest. Major storm events contributed to a high amount of wood harvested in salvage logging (12 % of the fellings) and also increased the amount of natural mortality and disappearance (9 %). Other tending activities like enlargement of growing space in young stands and clearing of damaged or dead standing trees together contribute only about 2 % of the harvested wood.

The decision to harvest trees is made by the forest owner but all operations must comply with the regulations specified in the Austrian Forest Act. In pre-mature stands clear-cuts are prohibited and also stand tending activities are not allowed to exceed a certain intensity level. Clear-cuts must not exceed a certain area and a new stand has to be established either by natural regeneration or planting at the latest at the end of the fifth year following the year of the harvest.

7.2.1.5 Legal and Other Restrictions for Wood Use

Forests in Austria have to be managed in accordance with the Austrian Forest Act (Jäger 2003). It shall ensure the sustainable management of forests and specifies limits for the area of clear-cuts, restricts the harvest in pre-mature stands by limiting the intensity of tending activities, and defines a species-specific age-limit to prevent pre-mature stands from being clear-cut. It also contains specifications for forests with protective functions, forests with special natural habitats like national parks, natural forest reserves, and nature protection areas, and for forests in recreational areas. In addition to the specifications of the Austrian Forest Act further legal restrictions can apply for national parks, natural forest reserves, and nature protection areas. The availability of wood resources is also restricted in water protection areas, military training areas, research forests, etc. Certain forest and environmental policy incentives like the promotion of habitat tree preservation also have an influence on the harvesting.

An important point with regard to the availability of wood resources is the accessibility particularly in mountainous regions. Long logging distances and steep slopes increase the hauling costs for wood. Cable crane logging is necessary in forest areas that cannot be accessed by machinery like harvesters, forwarders or tractors because of steep slopes. These logging technologies are more expensive than conventional harvesters or forest tractors and may not be economically feasible in every case. Some sites have poor productivity and render forest harvesting negligible. Ecological considerations to sustain the site productivity can also restrict the amount of removable wood resources in harvesting operations.

7.2.1.6 Further Classification of Forests

In addition to the previously described classifications of the forest area further stratifications are used in national statistics and reporting. Commonly used stratification variables are tree species, age classes and growth classes. The stratifications of the forest area are based on the field assessment of the 1/10-shares of the forest plot covered by the species, the age classes and the growth classes. Also the share

Table 7.4 Productive forest area according to the national definition by species (Seventh NFI, 2007–2009)

Tree species	Area (1000 ha)	Percent (%)
Norway spruce (*Picea abies*)	1709	50.7
Silver fir (*Abies alba*)	81	2.4
Larch (*Larix decidua*)	154	4.6
Scots pine (*Pinus sylvestris*)	152	4.5
Black pine (*Pinus nigra*)	21	0.6
Stone pine (*Pinus cembra*)	15	0.5
Other conifers	6	0.2
Beech (*Fagus sylvatica*)	336	10.0
Oak (*Quercus* spp.)	69	2.0
Other broadleaved hardwood	275	8.2
Other broadleaved softwood	142	4.2
Clearings and gaps in stands	309	9.2
Shrubs in stands	73	2.2
Shrub land	25	0.7
Total productive forest land	3367	100.0

of clearings (i.e. temporarily unstocked areas >500 m^2) and gaps in stands (i.e. openings in the stand having an area of 50–500 m^2) are included in the assessment. The coverage of shrubs in stands is collectively assessed without distinction of shrub species. Different from shrubs in stands is the category shrub-land which is predominantly covered by shrub species.

The predominant tree species in Austrian forests is Norway spruce (*Picea abies* (L.) H.Karst.) with a share of 51 % of the productive forest area. It is followed by European beech (*Fagus sylvatica* L.) with 10 %, larch (*Larix decidua* Mill.) and Scots pine (*Pinus sylvestris* L.) both with 5 %. The remaining species together cover 18 % of the forest area. The productive forest area and the coverage by the tree species is given in Table 7.4.

The age classes are assessed in intervals of 20 years. The highest age class includes all tree ages above 140 years. The area and percentage area covered by the individual age classes is given in Table 7.5. The second age class has the largest coverage among all age classes. For higher age classes beyond the second age class, the forest area covered decreases as the age classes increases.

Growth classes are defined by the tree size. Regeneration I has a height below the breast height of 1.30 m, Regeneration II has a minimum height of 1.30 m and a maximum dbh of 10.4 cm, the Pole stage has a dbh from 10.5 cm to 20.4 cm, Timber I has a dbh from 20.5 to 35.4 cm, Timber II has a dbh from 35.5 to 50.4 cm and Large timber has a dbh > 50.5 cm. The area covered by the growth classes is given in Table 7.6. Timber I has the largest coverage, followed by the growth classes Pole stage, Regeneration II and Timber II. The growth classes Regeneration I and Large timber cover much smaller areas.

Table 7.5 Productive forest area according to the national definition by age classes (Seventh NFI, 2007–2009)

Age class	Area (1000 ha)	Percent (%)
1–20 years	433	12.9
21–40 years	750	22.3
41–60 years	527	15.7
61–80 years	360	10.7
81–100 years	317	9.4
101–120 years	243	7.2
121–140 years	147	4.4
>140 years	182	5.4
Clearings and gaps in stands	309	9.2
Shrubs in stands	73	2.2
Shrub land	25	0.7
Total productive forest land	3367	100.0

Table 7.6 Productive forest area according to the national definition by growth classes (Seventh NFI, 2007–2009)

Growth class	Area (1000 ha)	Percent (%)
Regeneration I	94	2.8
Regeneration II	621	18.4
Pole stage	677	20.1
Timber I	896	26.6
Timber II	566	16.8
Large timber	107	3.2
Clearings and gaps in stands	309	9.2
Shrubs in stands	73	2.2
Shrub land	25	0.7
Total productive forest land	3367	100.0

7.2.2 Wood Resources and Their Use

7.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock, increment and drain are based on the sample tree measurements at the plots on productive forest land. They are calculated as volume of stem wood over bark. Stem wood according to the Austrian NFI includes all stem parts above the stump i.e. the bole with bark and stem top and conforming to the definitions of tree elements by Gschwantner et al. (2009). The minimum dbh is 5.0 cm measured over bark. Trees below this threshold are not included in regular NFI estimates. The Austrian NFI estimates the volume of standing stock which can be divided into the volume of growing stock and volume of standing dead wood. Increment and drain are calculated as mean annual estimates for the period between two consecutive NFIs. The estimation is based on the permanent sample plots and refers to the sampling probability of the first measurement. The volume of drain is

Table 7.7 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with dbh ≥ 5.0 cm over bark, including the bole (wood and bark), and stem top, and excluding the above-ground part of the stump
Increment	Volume increment of surviving trees with dbh ≥ 5.0 cm over bark plus the volume of ingrown trees into the small circular plot between two consecutive NFIs
Drain	Volume of trees with dbh ≥ 5.0 cm over bark at the first measurement that were found to be harvested in the subsequent NFI

further stratified into natural losses and nine types of harvesting. The national definitions for standing stock, increment and drain are compiled in Table 7.7.

Similar to volume estimation the Austrian NFI also calculates biomass estimates for various purposes. Stem volumes are converted to biomass by applying nationally valid wood densities and shrinkage factors. A set of species-specific biomass equations is available for estimating the biomass of branches and needles (Weiss 2006). The biomass of roots can be calculated using the model of Wirth et al. (2004) for coniferous trees and the model of Wutzler et al. (2008) for broadleaved trees.

The productive forest land in Austria has a standing volume of 1135 million m^3 of stem wood over bark of which 2.5 % are standing dead wood. About 30 million m^3 of volume increment are produced each year and almost 26 million m^3 harvested annually. Thus, the drain between 2000/2002 and 2007/2009 is about 85 % of the increment in the same time period. During the 80s and 90s of the last century this ratio was on average 65 %. The intensified utilisation of wood resources can be attributed to changes in forest policy, an increased demand for energy wood, storm damage events and attractive wood prices for forest owners.

The largest part of the standing stock volume is contributed by Norway spruce (*Picea abies* (L.) H.Karst.) (61 %) and is followed by European beech (*Fagus sylvatica* L.) (10 %), larch (*Larix decidua* Mill.) (7 %), Scots pine (*Pinus sylvestris* L.) (7 %), Silver fir (*Abies alba* Mill.) (4 %), oak species (*Quercus* spp.) (2 %), ash (*Fraxinus* spp.) (2 %) and maple (*Acer* spp.) (1 %). The remaining tree species altogether account for 6 % of the standing volume. For the increment and drain this order of tree species is similar, although Norway spruce (*Picea abies* (L.) H.Karst.) contributes a larger share of increment and is also harvested to a larger extent. Silver fir (*Abies alba* Mill.), larch (*Larix decidua* Mill.) and Scots pine (*Pinus sylvestris* L.) produce about the same increment per year, but the latter is harvested more often than the others. Table 7.8 gives the estimates of standing stock, increment and drain by tree species.

Table 7.8 The volume of standing stock, increment, and drain on productive forest land (Seventh NFI, 2007–2009)

Tree species	Standing stock (1000 m^3)	Increment (1000 m^3/year)	Drain (1000 m^3/year)
Norway spruce (*Picea abies*)	694,853	20,112	17,775
Silver fir (*Abies alba*)	49,725	1263	1026
Larch (*Larix decidua*)	75,439	1195	1044
Scots pine (*Pinus sylvestris*)	74,497	1227	1624
Black pine (*Pinus nigra*)	9154	65	146
Stone pine (*Pinus cembra*)	4784	58	31
Weymouth pine (*Pinus strobus*)	175	6	3
Douglas fir (*Pseudotsuga menziesii*)	635	43	6
Other conifers	351	28	2
Beech (*Fagus sylvatica*)	108,699	2746	1753
Oak (*Quercus* spp.)	27,429	665	564
Hornbeam (*Carpinus betulus*)	8992	246	125
Ash (*Fraxinus* spp.)	23,705	833	309
Maple (*Acer* spp.)	15,001	439	193
Elm (*Ulmus* spp.)	1468	56	45
Chestnut (*Castanea sativa*)	1340	60	47
Black locust (*Robinia pseudoacacia*)	2633	94	70
Sorbus spp. and *Prunus* spp.	3462	97	81
Birch (*Betula* spp.)	6770	206	230
Black alder (*Alnus glutinosa*)	8168	260	138
Grey alder (*Alnus incana*)	3603	126	210
Linden (*Tilia* spp.)	3488	107	41
Aspen & White poplar (*Populus tremula & alba*)	4049	150	117
Black poplar (*Populus nigra*)	502	24	58
Hybrid poplar (*Populus* spp. X)	2465	110	137
Willow (*Salix* spp.)	2616	114	98
Other broadleaves	779	41	16
Total	1,134,780	30,371	25,888

Increment and cuttings are average annual values for the period 2000/2002–2007/2009

7.2.2.2 Tree Species and Their Commercial Use

Norway spruce (*Picea abies* (L.) H.Karst.) is the most economically important tree species in Austria and is mainly used for sawn wood production and industrial round wood. According to the "Holzeinschlagsmeldung" provided by the Federal Ministry of Agriculture, Forestry, Environment and Water Management for the year 2011 (BMLUFW 2012) 56 % of the harvested wood in Austrian forests is used as sawn wood, 17 % as industrial round wood, and 27 % for energy purposes. Coniferous wood is used for sawn wood (64 %), energy production (19 %), and industrial wood (17 %). Broadleaved wood is used for energy production (71 %), industrial wood (18 %) and sawn wood (11 %). Certain broadleaved species are used for special purposes if they feature high wood quality or unique properties. In the recent years the use of wood for energy production has increased considerably. The amount of harvested fuel wood was about 2.9 million m^3 in 2001, 4.7 million m^3 in 2006, and 5.1 million m^3 in 2011.

7.3 Assessment of Wood Resources

7.3.1 Forest Available for Wood Supply

7.3.1.1 Assessment of Restrictions

The field assessments of the Austrian NFI include all sample plots in the sampling grid, with the exception of plots in inaccessible terrain which are assessed using aerial photographs. The existence of legal restrictions is not assessed in the field, but rather obtained from a post-stratification approach by intersecting sample plot locations with a GIS database that contains the areas where harvesting is restricted. Any restriction available as geo-referenced GIS-layer can be considered in assessing the forest area available for wood supply.

With regard to other restrictions and in particular to harvesting possibilities the Austrian NFI assesses several relevant variables. The slope is decisive for the use of harvesting and logging technologies. In driveable terrain technologies like harvester, forwarder, and tractor can be employed, whereas in steep areas cable cranes and cable harvesters have to be used. Another crucial factor is the distance to the nearest forest road. In field assessments the distance to the next skidding road and the distance to the next forest road were assessed for sample plot locations. These assessments are complemented by the analysis of aerial photographs and the determination of the shortest distance to the next forest road.

7.3.1.2 Estimation

In the study on the potential of Austrian forests in the period 2000–2020 for wood and biomass supply HOBI (Neumann and Schadauer 2007; BFW 2009) the legal restrictions due to nature protection and conservation were taken into account by excluding areas where harvest is prohibited like in national parks, and by limitation of harvests in protected areas according to the Habitats Directive and according to the Birds Directive. Depending on the respective research aim further areas of restricted forest utilisation can be added if GIS layers are available. NFI plots can be divided in three categories, forests without any restrictions for resource use additional to those in the forest act, forests where cuttings are partly limited, and forests where cuttings are not allowed. Work is currently on-going to estimate the forest area under the different harvest restrictions and will be available in the future.

The utilisation of wood resources also depends on the harvesting costs. In locations with difficult accessibility the harvesting costs may render harvesting uneconomic as the costs are not covered by the revenue obtained from the harvested product. To estimate the available wood resources under given economic conditions the harvesting costs (including machine costs and labour costs) are calculated and compared to the revenue achievable under the current wood price situation.

7.3.2 *Wood Quality*

7.3.2.1 Stem Quality and Assortments

The assortment of wood traded in Austria is defined and covered by the Austrian timber trade guidelines (Kooperationsplattform Forst Holz Papier 2006). The assortment includes diameter classes based on the mid-diameter and assortment according to the length of the log. The diameter classification comprises the nine classes 1a (10–14 cm), 1b (15–19 cm), 2a (20–24 cm), 2b (25–29 cm), 3a (30–34 cm), 3b (35–39 cm), 4 (40–49 cm), 5 (50–59 cm) and 6 (60 cm and more). The requirements for the minimum diameter and minimum length of logs depend on the quality class. The basic quality classes for round wood are veneer logs, sawn timber and industrial round wood like pulpwood. Apart from these categories other assortments may be specified for particular purposes, such as instrument or resonance wood and mine timber. Veneer logs are of very good quality and require a minimum length of 2 m and a minimum diameter of 30 or 40 cm depending on the veneering technology. The quality classes of sawn timber contain the grades A (best quality), B, C, and Cx (lowest quality), and furthermore specify logs with butt rot and logs with low diameters. For the individual quality grades the minimum log lengths are also specified. The specifications of the quality grades are different for coniferous and broadleaved logs. Broadleaved round wood can have particular species-specific requirements. Also the minimum diameter and length requirements for coniferous and broadleaved logs for one and the same quality grade are different in several cases. Logs from broadleaved trees may be used for special purposes and thus can have particular size and quality requirements.

7.3.2.2 Assessment and Measurement

During field data collection in the Austrian NFI the stem quality of all sample trees with a dbh ≥ 20.5 cm is assessed. Since the stem quality assessment according to

Table 7.9 Stem quality classes as assessed by the Austrian NFI

Stem quality class	Description
1	stem upright, full-bodied, free of knots, without faults
2	stem upright, full-bodied, with some knots or little faults
3	stem crooked, knotty timber or stem conical, with bad faults

the Austrian timber trade guidelines (Kooperationsplattform Forst Holz Papier 2006) has limited applicability in the field, three classes of stem quality are distinguished. The same quality classes are used for conifers and broadleaves. Standing trees including dead standing trees are classified. The stem quality assessment concerns the lowermost third of the stem. The three stem quality classes are described in Table 7.9.

In addition, several other variables are assessed on individual sample trees that are relevant with regard to stem quality. These include the tree status dead or alive, information whether a tree is forked or not, stem damages in several classes of damages, the height of the living crown base, the upper stem diameter, and some other stand- and site-specific variables like management type and elevation above sea level.

7.3.2.3 Estimation and Models

In order to obtain volume estimates by stem quality and assortments a new timber assortment model was developed during the latest timber supply study in Austria (Eckmüllner and Schedl 2009; Eckmüllner et al. 2007; Neumann and Schadauer 2007; BFW 2009). The model can be applied to individual stems to convert them into merchantable assortments. The assortment model consists of several sub-models like taper curve models, bark thickness models, and assortment algorithms, and it requires the following variables: management type, elevation above sea level, tree species, dbh, tree height, height to the living crown base, damage from bark stripping, felling and logging, length of rotting, stem quality independent of damage, sweep of the bole. The output of merchantable assortments corresponds with the currently effective Austrian timber trade guidelines (Kooperationsplattform Forst Holz Papier 2006). According to the results of the latest timber supply study the quality classes of round wood available until 2020 are distributed on average to 3 % grade A, 45 % grade B, 23 % grade C, 4 % grade Cx and logs with butt rot, 12 % logs with low diameters and 19 % industrial round wood. However, the actual use of wood is not only driven by qualitative attributes but also by the wood market sentiment. The high demand for energy wood nowadays leads to the utilisation of lower quality classes for energy production.

7.3.3 Assessment of Change

7.3.3.1 Assessment and Measurement

The estimation of increment and drain in the Austrian NFI is based on the field measurements on permanent plots at two consecutive points in time. Sample trees can be distinguished into trees present only at the first occasion, trees present at the first and second occasion, and trees present only at the second occasion. Sample trees present at the first occasion and that are no longer present on the plots at the second occasion are recorded in the field assessments and the type of harvesting is determined. Depending on the size of a sample tree different variables are measured. For trees with a dbh ≥ 10.5 cm the dbh, tree height (h), height to the living crown base (hk), and the upper diameter at 3/10 of the tree height (d03h) are measured. For sample trees with 5.0 cm ≤ dbh ≤ 10.4 cm the dbh and h are measured. Variables such as h, hk, and d03h are measured on a sub-sample of sample trees during certain field assessment periods. Tree heights and hk were measured on all sample trees in the first NFI (1981–1985) and in the seventh NFI (2007–2009). In between, height measurements were recorded for a sub-sample of sample trees. Upper diameters were measured in the first assessment period for all sample trees and on sub-samples afterwards. Data models are applied to predict the missing values. In each inventory also the status "living" or "dead" of each sample tree is assessed.

7.3.3.2 Estimation of Increment

The increment estimated by the Austrian NFI is defined as the volume increment of survivor trees between two field assessment periods plus the volume of ingrown trees that exceed the dbh-threshold of 5.0 cm between the two points in time (Schieler 1997). This corresponds to the gross growth of the initial volume including ingrowth as defined by Beers (1962). The volume of the sample trees is calculated by applying the volume models given in formulas (7.1) and (7.2). The stem volume (V) of trees with 5.0 cm ≤ dbh ≤ 10.4 cm is calculated as:

$$V = f(c_i, \text{dbh}, h) \tag{7.1}$$

and the stem volume (V) of trees with dbh ≥ 10.5 cm is obtained from:

$$V = f(c_i, \text{dbh}, h, \text{d03h}, \text{hk}) \tag{7.2}$$

where dbh is the diameter at breast height, h the tree height, d03h the upper diameter in 3/10 of the tree height and hk the height to the living crown base. The coefficients c_i of the volume models were estimated by Braun (1969), Pollanschütz (1974) and Schieler (1988). The volume estimates contain all stem parts above stump height and include the tree elements bole plus bark and the stem top. Other change components, such as the increment of trees that between cycles die, are felled, fall over naturally, or grow into the sample as nongrowth, are not part of the increment estimate. Also the trees on land areas converted to forest or changing from forest to other land uses are not included in increment estimates. The increment estimates of the Austrian NFI are average annual increments for the time period between two field assessments. To obtain increment per hectare and total increment, the increment data of individual sample trees are converted into annual and per hectare values for each sample plot. For angle count trees the increment per hectare is calculated by referring to the dbh at the time of the first measurement. The plot-level estimates are averaged to obtain the mean increment per year and hectare and furthermore multiplied by the forest area to calculate the total increment. National estimates are gross increment and they are calculated for forest management classes, ownership categories and tree species. Also gross increment in units of biomass can be calculated, but are not part of the standard estimation procedures. These biomass increment estimates can include other tree parts apart from the stem, like branches and needles, and the below-ground parts. The biomass estimates for these tree elements are obtained by applying the models developed in a special study (Weiss 2006) and the generic models of Wirth et al. (2004) and Wutzler et al. (2008).

7.3.3.3 Estimation of Drain

The drain estimated by the Austrian NFI is defined as the volume of trees that were found to be harvested between two field assessment periods. The volume of the sample trees that are found to be harvested is calculated by using the tree measurements at the first occasion. The volume models given in formulas (7.1) and (7.2) are used. The volume estimates contain all stem parts above stump height and include the tree elements bole plus bark and the stem top. The increment of the sample trees between the measurement at the first occasion and the harvest is not taken into account in harvest estimates. The volume of felled trees on land areas converted to other land-uses is included in the drain estimates. The drain estimates of the Austrian NFI are average annual volumes of drain for the time period between two field assessments. Drain per hectare and total drain are obtained by referring to the situation and the number of trees represented by the sample trees at the time of the first assessment. National estimates are calculated for forest management classes, ownership categories, tree species and types of fellings. Drain can also be calculated in units of biomass. These estimates can include other tree parts like branches and needles, and the stump and root biomass of felled trees. The models cited beforehand (Weiss 2006; Wirth et al. 2004; Wutzler et al. 2008) with regard to biomass increments are also applied to obtain harvest biomass estimates.

Besides the periodic drain estimates of the Austrian NFI, annual statistics on the amount of wood harvested in Austrian forests are compiled in the "Holzeinschlagsmeldung", which is published by the Federal Ministry of Agriculture, Forestry, Environment and Water Management (e.g. BMLUFW 2012). These statistics are based on three methods of data collection and include a sampling survey in selected forest properties having forest areas between 2 and 200 ha, a full census in forest properties from 200 ha upwards, and expert judgement. The application of the data collection methods varies for the federal states. The estimates given by the "Holzeinschlagsmeldung" are lower compared to the NFI estimates. The differences are mainly due to the fact that the "Holzeinschlagsmeldung" reports commercial volume under bark whereas the Austrian NFI reports standing gross volume.

7.3.4 Other Wooded Land and Trees Outside Forests

7.3.4.1 Assessment and Measurement

The sampling grid of the Austrian NFI covers all land-use classes and ownership categories of the federal territory of Austria. Shrub-land is defined at the national level and is a separate category during field assessments. It broadly corresponds with the Other Wooded Land definition of FAO (2004). Measurements on trees have been limited to productive forest, i.e. the area that is available for wood production. In forests with protective function and without yield, volume was assessed in the fifth and sixth NFI (1992–1996 and 2000–2002) by expert evaluation and guided by the formula of Denzin (1929). Trees on shrub land have not been measured nor their volumes estimated. In the most recent seventh NFI 2007–2009 angle-counts were conducted on the sample plots located in forests with protective function and without yield and on shrub-land to capture the tree volume on these areas. Also site-specific and some stand-specific variables were collected. The land-use category and management type was also determined for plots located outside the forest. The trees on these plots were not subject to measurements or rough estimation during the field assessments. However, a remote sensing study focusing on the comparison of the national definition and the FAO (2004) definition of forest and other wooded land also distinguished the category of other land with tree cover.

7.3.4.2 Estimation

The area of shrub-land according to the national forest definition is included in the forest area estimate. However, separate area estimates for shrub-land are available as given in Table 7.2. The latest NFI 2007–2009 provides volume and biomass estimates for shrub-land according to the national definition. Specific models have been developed to calculate the estimates for shrub-land areas. In the most recent NFI also the definition for Other Wooded Land of FAO (2004) was applied in the field assessments. Thus, an area estimate according to the FRA definition is available. Other land with tree cover is currently not comprehensively assessed as it is not considered as the primary domain of the NFI. However, area estimates for this land category could be obtained but have not been calculated until now. Such estimates become more feasible due to the increased use of wall to wall remote sensing.

7.4 Conclusion

The availability of wood and biomass resources has become an increasingly important issue in the recent years both nationally and at a European scale. Therefore reliable data and information about the amount of wood and biomass available on a sustainable level are essential to develop strategies that take into account the multiple forest functions including: economic use, nature conservation and protection, and recreation. The Austrian NFI as the largest national forest monitoring program has continuously broadened its thematic scope since its establishment in the 1960's. Through the integration of additional data from various sources like remote sensing, but also other relevant cartographically mapped information, the Austrian NFI has become a multisource forest monitoring program that is able to answer future questions on many thematic areas. With regard to the estimation of available wood and biomass resources, the consideration of new reporting requirements will provide further methodological developments to satisfy the information needs of decision makers.

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