Chapter 17
Denmark

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17.1 The Danish National Forest Inventory

17.1.1 History and Objectives

From 1881 to 2000, a National Forest Census was carried out roughly every 10 years based on questionnaires sent to forest owners (Larsen and Johannsen 2002). Since the data was based on questionnaires and not field observations, the actual forest definition may have varied. The basic definition was that the tree covered area should be minimum 0.5 ha to be a forest. There were no specific guidelines as to crown cover or the height of the trees. Open woodlands and open areas within the forest were generally not included. All values for growing stock, biomass or carbon pools in the National Forest Census were estimated from the reported data on forest area and its distribution to main species, age class and site productivity classes. The last census was carried out in 2000.

The National Forest Census provided brief information on forest areas and growing stock and their distribution by geographical or administrative units, for example. However, the census provided only limited information on growth, changes in forest management practices as well as information on other aspects and functions of forests for example forest stability and health, biodiversity and environmental functions, carbon stocks and sequestration and social benefits of forests. Further, the assessment of growing stock and wood production were not reliable enough for today's requirements.

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In 2002, a new sample-based National Forest Inventory (NFI) was initiated, replacing the National Forest Census (Nord-Larsen et al. 2008). This type of forest inventory is very similar to inventories used in other countries, e.g. Sweden or Norway.

17.1.2 Sampling Methods and Periodicity

The NFI is a continuous sample-based inventory with partial replacement of sample plots based on a 2 × 2 km grid covering the Danish land surface. At each grid intersection, a cluster of four circular plots (primary sampling unit, PSU) for measuring forest attributes (e.g. wood volume) are placed on a 200 × 200 m grid. Each circular plot (secondary sampling unit, SSU) has a radius of 15 m. When plots are intersected by different land-use classes or different forest stands, the individual plot is divided into tertiary sampling units (TSU).

About one third of the plots are assigned as permanent and are re-measured in subsequent inventories every five years. Two thirds are temporary and are moved randomly within the particular 2 × 2 km grid cell in subsequent inventories. The sample of permanent and temporary field plots has been systematically divided into five non-overlapping, interpenetrating panels that are each measured in one year and constitute a systematic sample of the entire country. Hence all the plots are measured in a 5 year cycle.

Based on analysis of aerial photos, each sample plot (SSU) is allocated to one of three basic categories, reflecting the likelihood of forest or other wooded land (OWL) cover in the plot: (0) Unlikely to contain forest or other wooded land cover, (1) Likely to contain forest, and (2) Likely to contain other wooded land. All plots in the last two categories are inventoried in the field.

In the most recent five year rotation of the NFI (2009–2013) the average number of clusters (PSU) and sample plots (SSU) were 2192 and 8597 year^{-1}, respectively. On average 1900 year^{-1} plots (SSU) were identified as having forest or other wooded land cover based on the aerial photos and were thus selected for inventory. The number of clusters and sample plots assessed in the five year rotation 2009–2013 are detailed in Table 17.1. Forest covered sample plots not inventoried in the field are denoted “Missing”.

Each plot is divided into three concentric circles with radius 3.5 (38.5 m^2), 10 (314.2 m^2) and 15 m (706.9 m^2). A single calliper measurement of diameter is made at breast height (dbh) for all trees in the 3.5 m circle. Trees with a dbh larger than 10 cm are measured in the 10 m circle and only trees with dbh larger than 40 cm are measured in the 15 m circle. On a random sample of 2–6 trees further

Table 17.1 Number of clusters and sample plots assessed in the five year rotation 2009–2013. Forest covered sample plots not inventoried in the field are denoted "Missing"

Year	Clusters			Sample plots		
	Total	Forest	Missing	Total	Forest	Missing
2009	2195	783	0	8604	1800	0
2010	2196	793	0	8614	1855	0
2011	2173	850	0	8520	1896	0
2012	2200	908	0	8617	1978	0
2013	2197	905	0	8630	1973	0
Total	10,961	4239	0	42,985	9502	0

measurements of total height, crown height, age and diameter at stump height are made and the presence of defoliation, discoloration, mast, mosses and lichens are recorded.

The presence of regeneration less than 1.3 m tall (but taller than approx. 20 cm) on the plots is registered on two 10 m^2 (radius 178 cm) plots, 500 cm from the plot centre. Within these plots, the number of seedlings, the species and average height of the regeneration are recorded. Regeneration age is assessed by counting whorls, counting annual rings or by visual appraisal.

Deadwood is measured on the sample plots. Standing deadwood with a diameter at breast height diameter larger than 4 cm is measured according to the same principles as live trees. Lying deadwood with a top diameter of more than 10 cm is measured within the 15 m radius sample plot. The length of the lying deadwood is measured as the length of the tree that exceeds 10 cm in diameter and is within the sample plot. The diameter is measured at the middle of the lying deadwood measured for length. In addition to the size measurements of deadwood, the degree of decay is recorded on an ordinal scale and the position of dead wood is recorded on permanent plots.

Stumps are measured as part of the deadwood assessment procedure. Stumps are defined as standing deadwood with a height of less than 130 cm. The species is recorded and stumps are calipered at normal cutting height (approx. 15 cm above ground) and are measured for height. To conform to measurements on standing live and dead trees, stumps with a diameter larger than 140 mm (corresponding to dbh > 100 mm) are measured within the 10 m radius plot and stumps with a diameter larger than 500 mm (corresponding to dbh > 400 mm) are measured within the 15 m radius plot. The procedure on stumps measurements were changed in 2014. Before this, all stumps with a diameter of more than 50 mm were calipered within the 10 m radius plot.

On each plot the presence and state of ditches and drainage conditions are recorded. Further, the presence of peat land is recorded and the depth of the peat is measured. Finally, the depth of the humus layer is measured on all plots.

17.1.3 Data Collection

The data collected in the Danish NFI may be divided into three main categories: site, stand and sample tree variables.

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

- Geographical position
- Subplot mapping (for plots covering more than one land use or forest stand)
- Owner (assisted by GIS information)
- Slope gradient
- Distance to forest edge
- Forest edge composition
- Litter layer thickness
- Humus layer thickness
- Peat land (cover of sample plot)
- Soil parent material
- Soil layer thickness
- Soil texture
- Soil moisture
- Soil drainage
- Land use
- Vegetation type (cover of bare land, moss, grass, sedge, forbs, ferns and trees).

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

- Stand origin (planted, naturally regenerated, afforestation, natural succession)
- Stand structure
- Stand management
- Latest stand treatments
- Crown cover
- Stand age
- Share of different species
- Stand basal area and stem number (by relascope)
- Description of canopy layers (species composition, age of layers, height)
- Stand damages (including damage type, causing agent and time since damage)
- Regeneration
- Deadwood.

Sample tree-specific assessments refer to the variables that are measured or assessed on the sample trees. Some variables such as tree height, crown height or forking height are only assessed on a sub-sample of the measured trees and the values of non-measured sample trees are predicted using data models (Johannsen et al. 2013a, b). Tree variables measured on sample trees include:

- Position (only on permanent plots)
- Species
- Diameter at breast height
- Tree height
- Height to the living crown base
- Height to forking
- Age
- Tree social class
- Damage (including type of damage, causing agent, severity and time since damage)
- Seeding
- Defoliation
- Crown discoloration
- Mosses or lichens on the stem
- Registration of missing trees (only on re-measured permanent plots).

Detailed and further information about the data collected by the Danish NFI, the assessments and measurements of variables are available from the field protocol (Jørgensen et al. 2014).

17.1.4 Data Processing, Reporting and Use of Results

A wide range of forest related statistics are being calculated from the data collected in the Danish NFI. The different estimates may be grouped into area-related and volume- or biomass-related.

The forest area estimates are based on the assessment of forest cover from aerial photographs (full sample of plots), information collected on the 15 m sample plots (forested plots measured in the field) and the Danish land area. On each plot, the forest area is estimated based on the registrations of the field crews. Plots with no forest cover (based on aerial photographs) which were not measured in the field are assumed to have no forest cover. Plots which had forest cover, but for some reason were not measured in the field are assumed to have the average forest cover of measured plots. The forest area is then estimated as the average forest cover fraction of the full sample of plots times the Danish land area. The Danish land area is obtained from the official statistics of Statistics Denmark (2013) and is assumed to be error-free. The procedure is described in detail in Martinussen et al. (2008).

When estimates of forest area are required for different geographical subdivisions of the country (regions, natural-geographic zones, protected areas, owner types, species cover etc.), the forested plots or parts hereof are assigned to the different strata. The fraction of the forested plot area covered by each stratum is estimated as its share of the total forest covered plot area. Subsequently, the forest area covered by each stratum is estimated as its share of the forested plot area times

the estimated forest area. The procedures are described in greater detail in Johannsen et al. (2013a, b).

The estimation of the volume and biomass of standing stock, growing stock, increment and harvest is of particular interest for the assessment of available forest resources. The estimation procedure includes several steps. First, species specific functions for estimation of tree height from the measured breast height diameter are estimated based on the sample trees measured for height. Subsequently, volume and biomass of each sample tree is then estimated using species specific volume (Madsen 1987; Madsen and Heusèer 1993) and biomass (Skovsgaard et al. 2011; Skovsgaard and Nord-Larsen 2012; Nord-Larsen and Nielsen 2015) functions.

For each plot or sub-plot, the volume or biomass per hectare is calculated as the sum of individual tree volumes or biomass scaled according to the area of the circular plot within which the tree is measured (3.5, 10 or 15 m circle). The overall biomass per hectare is estimated as the area weighted average, using the subplot areas as weights. Finally, overall volume or biomass is estimated as the overall volume or biomass per hectare times the forest area. When estimates are desired for different strata of forests or trees (management types, ownership categories, age-classes, tree species, etc.), trees and plot areas are allocated to the different strata and mean volume or biomass per hectare are estimated for the individual strata according to the procedure described above and estimates of overall volume or biomass is obtained by multiplying stratum means with the forest area estimated for that stratum.

Estimates of change, increment and harvest are obtained from the assessments of two consecutive NFIs based on the full sample of both permanent and temporary sample plots. The gross annual volume and biomass increment is estimated as the difference between the second and the first occasion divided by the interval between assessments (5 years). Sample trees that have exceeded dbh-thresholds between the two NFIs are also included in the increment estimation. The drain (harvest and mortality) is assessed by estimating the volume of sample trees that have been harvested or that have disappeared naturally since the previous field assessment on permanent sample plots, assuming that these have been removed at the midpoint of the NFI period (after 2.5 years). Expected growth of thinned trees is estimated using species specific growth models based on observed growth from re-measured trees. The drain is allocated to harvest and mortality. Finally, net annual increment is estimated as the sum of gross annual increment and annual thinning volume.

Due to an increasing forest area, per hectare values using either the forest area at the beginning or end of the cycle as reference may not reflect actual per area productivity. Hence, more stable estimates of average gross annual increment are obtained as the difference between per hectare estimates of volume or biomass using only data from permanent sample plots measured in both consecutive NFI periods. The average annual drains are estimated using the forest area in the first period as reference and the average net annual increment is then estimated as the sum of average annual gross increment and drain.

The Danish NFI provides estimates at different regional scales, the national level (NUTS1), the five basic regions (NUTS2), the 11 smaller regions (NUTS3) and the 99 municipalities. The estimates include among others forest area, growing stock,

carbon pools, increment, number of harvested stems, stem damages, regeneration, and dead wood (see for example Johannsen et al. 2013a, b). The results of the Danish NFI are used as basis for decision-making in forest and environment policy, forest management, forest products 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 Danish NFI. Reporting processes include: the Forest Resources Assessment (FAO 2010) 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 (Nielsen et al. 2013), the indicators and criteria for sustainable forest management for Forest Europe (2011), and on the conservation status of natural habitat types under the Habitats Directive (Council of the European Communities 1992).

Further, NFI data provide a valuable data source for numerous research projects; they were used as ground truth data for development of remote sensing tools for forest resource assessment (Nord-Larsen and Riis-Nielsen 2010; Nord-Larsen and Scumacher 2012; Schumacher and Nord-Larsen 2014), in scenario analyses to estimate the current and future potential of Danish forests for wood and biomass supply (Nord-Larsen and Suadicani 2010; Graudal et al. 2013), and for the evaluation of initiatives for the protection of biodiversity (Johannsen et al. 2013a, b).

17.2 Land Use and Forest Resources

17.2.1 Classification of Land and Forests

17.2.1.1 General Land Classification

The Danish NFI only includes forest and other wooded land. Sample plots with either of these land use classes are identified on aerial photographs prior to the measurement season and only these plots are inventoried in the field. Forest and other wooded land are identified by the international forest definition by FAO. To qualify as forest, a piece of land requires a minimum area of 5000 m^2, a minimum width of 20 m, and a crown cover of more than 10 % of forest trees species, which can attain a height of more than 5 m in situ. Forest land include all areas included in the above definition irrespective of their function (i.e. including Christmas tree plantations and poplar plantations for energy) as well as temporarily unstocked areas and auxiliary areas necessary for forest management (e.g. fire breaks, work sites, landings, etc.).

Other wooded land is defined in accordance with the FAO definition as areas included in the forest definition but with a crown cover of more than 5 % and less than 10 %. Other wooded land also include areas with a crown cover of more than

10 % of forest tree species and bushes which cannot attain a height of more than 5 m in situ. The latter areas mostly include mountain pine (*Pinus mugo*) plantations in the western part of Denmark where growing conditions are harsh.

Although, the Danish NFI does not constitute the basis for estimating the distribution of the land to other classes than forest and other wooded land, such land classification is conducted in relation to international reporting such as the Global Forest Resource Assessment (FAO 2010) and emission inventories under the UNFCCC and the Kyoto protocol (Nielsen et al. 2013). In such reporting, the land classification system follows a hierarchical system of land management types. At the highest level, the land area is divided into forest, other wooded land and non-forest by applying the FAO definitions provided above. For the reporting to the Global Forest Resource Assessment, non-forest land is divided into other land, other land with tree cover and Inland water bodies (Table 17.2). The total land area and area of inland water bodies are provided by Statistics Denmark (2013) and the area of other land is estimated as the residual area. The other land area with tree cover is provided by Statistics Denmark as the area with fruit orchards (pears, apples and cherries).

Other types of international reporting also use land classification schemes. For the annual reporting of greenhouse gas emissions related to the LULUCF, forest lands are classified into forests established before (forest remaining forest) and after

Table 17.2 Land use classes according to the national definition by area (NFI 2008–2012) and correspondence with FRA classes

Class name		Description	Area (1000 ha)	Corresponding FRA classes
Forest	Forest land	All forest land with a crown cover of more than 10 % Temporarily unstocked forest Permanently unstocked auxiliary areas	608	Forest
OWL	Other wooded land	All forest land with a crown cover of more than 5 % and less than 10 %	45	OWL
Non-forest	Other land	Cropland, grassland, wetland and settlements	3585	OL, OLwTC
	… of which with tree cover	Fruit orchards	3	OLwTC
	Inland water bodies	Lakes, rivers, streams	66	OL
Total land area			4309	

1990 (afforestation). Non-forest land is classified into cropland, grassland, wetland and settlements according to the definitions by UNFCCC. The distribution of land use classes is based on the analysis of recent satellite images and a set of maps and other types of geographic information (Nielsen et al. 2013). The classification of the forest area to forest remaining forest and afforestation (according to articles 3.4 and 3.3 of the Kyoto protocol) is completed using LandSat satellite images from 1990.

17.2.1.2 Forest Classifications by Use

In the Danish NFI, forest land may be sub-divided according to land-use classes, forest management systems, the productive and protective forest function, stocking characteristics, ownership categories, etc.

Nearly all of the forest land (97 %) is stocked and only 3 % is temporarily or permanently unstocked (Table 17.3). Permanently unstocked parts of the forest are typically forest roads, fire belts and timber yards. Deciduous and coniferous forests each cover about 40 % of the forest area and 11 % are mixtures of conifers and deciduous trees. About 5 % of the forest area is covered with Christmas trees.

17.2.1.3 Classification by Ownership Categories

The Danish NFI distinguishes forest ownership into five main categories: Private persons, Private companies, Foundations, State forest (owned by the Nature Agency), Other state owned (mainly the military) and Other public (mainly municipalities). The NFI does not distinguish between different sizes of estates, as this information is not consistently provided by The Danish Geodata Agency and thus cannot be attributed to the individual NFI plots. The distribution of forest estates to different size classes is provided by Statistics Denmark and is based on a questionnaire survey.

About 62 % of Danish forest land is owned by private people (Table 17.4) and 8 % are owned by private companies. About 18 % are state forests, managed by the Danish Nature Agency. Unknown ownership accounts for about 3 %.

Table 17.3 Land use classes within forest land (NFI 2008–2012)

Land use class	Description	Area (1000 ha)
1	Coniferous	239
2	Broadleaves	249
3	Mixed	69
4	Christmas trees	31
5	Temporarily unstocked	12
6	Permanently unstocked	8
Total		608

Table 17.4 Forest area according to the national forest definition by ownership categories (NFI 2007–2009)

Owner type	Description	Area (1000 ha)
Private persons	Private persons	376
Private company	Private companies (A/S, I/S, Aps.)	51
Foundations	Privately owned foundations	22
State forest	Managed by the Danish Nature Agency	109
Other state owned	Mostly the military	8
Other public	Mostly municipalities	27
Unknown	Unknown owner	15
Total		608

Table 17.5 Distribution of management types (NFI 2008–2012)

Management type	Description	Area (1000 ha)
Even-aged, planted	Clear felling system	403
Even-aged, natural regeneration	Shelterwood systems with natural seeding	55
Uneven-aged, operational	Uneven-aged, managed forest	48
Uneven-aged, nature	Uneven-aged, unmanaged forest	40
Ancient management forms	Including grazing forest, coppice forest and selection forest	6
Protective forest	Forest protecting from sand drift, shielding buildings, roads or construction	15
Other	Other types of management	22
Unknown	Type of management unknown	20
Total		608

17.2.1.4 Forest Management and Cutting Systems

The forest management systems practised is evaluated visually by the NFI field teams and includes their assessment of present and future forest management. The majority of the forest (66 %) is planted and managed in even-aged systems (Table 17.5) and only about 14 % may be characterised as uneven-aged.

17.2.1.5 Legal and Other Restrictions for Wood Use

In Denmark, forests within forest reserves have to be managed in accordance with the Danish Forest Act ("Fredskovspligt" in Danish). The forest act specifies the obligation to ensure reforestation of clear-cut areas and the restriction of management activities within certain environments in the forest. The forest act provides strong protection against the conversion of forest to other types of land use. In Denmark, about 72 % of the forest area is forest reserve.

In addition to the specifications of the Danish Forest Act further legal restrictions can apply for nature protection areas, most noticeably the protection provided by The Nature Protection Act (in Danish: Bekendtgørelse af lov om naturbeskyttelse) and of forest habitats within Natura 2000 areas. The availability of wood resources is also restricted in military training areas, research forests, etc.

17.2.1.6 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 and age classes. The stratifications of the forest area are based on the field measurements of trees and assessment of plot variables.

Stratification into tree species cover is based on the distribution of the cross sectional area of the stems, which is supposed to be correlated with the share of canopy cover (Table 17.6). The predominant tree species in Danish forests is Norway spruce (*Picea abies* (L.) H. Karst) (16 %), European beech (*Fagus sylvatica* L.) (13 %) and pedunculate oak (*Quercus robur* L.) (10 %). Nordmann fir (*Abies nordmanniana* (Steven) Spach) and noble fir (*Abies procera* Rehder), predominantly used for Christmas trees and greenery take up about 7 % of the forest area.

The age-class distribution is based on the assessment of forest stand and individual tree ages. At the forest stand level, an average age is recorded for each canopy layer. The age is assessed from counting annual rings on stumps or

Table 17.6 Forest tree species distribution (NFI 2008–2012)

Tree species	Area (1000 ha)
Norway spruce (*Picea abies*)	100
Sitka spruce (*Picea sitchensis*)	35
Other fir species (mostly silver fir (*Abies alba*) and grand fir (*Abies grandis*))	41
Pine species (mostly French mountain pine (*Pinus mugo*) and Scots pine (*Pinus sylvestris*))	17
Nordmann fir (*Abies nordmanniana*)	71
Noble fir (*Abies procera*)	30
Other conifers	13
Beech (*Fagus sylvatica*)	85
Oak (*Quercus robur*)	63
Ash (*Fraxinus excelsior*)	19
Sychamore (*Acer pseudoplatanus*)	22
Birch (mainly *Betula pubescens* and *Betula pendula*)	45
Other broadleaves	44
Temporarily unstocked	12
Permanently unstocked	8
Total forest land	608

Table 17.7 Age-class distribution (NFI 2008–2012)

Age class (years)	Area (1000 ha)
1–20	123
21–40	159
41–60	137
61–80	46
81–100	24
101–120	12
121–140	8
>140	10
Other	90
Total forest land	608

increment cores, counting of whorls on conifers or from a visual appraisal. The age is further measured or assessed using the same techniques on up to 6 individual trees on each plot. For estimating the age-class distribution of the forest area (Table 17.7), each individual plot is allocated to one age-class according to the age of the dominant canopy layer on the plot. The age class 21–40 years has the largest share of the forest area (26 %) and the area hereafter decrease with decreasing age class. The class "Other" contains temporarily and permanently unstocked areas and areas for which the age class could not be established.

17.3 Assessment of Wood Resources

17.3.1 Wood Resources and Their Use

17.3.1.1 Standing Stock, Increment and Drain

Estimates of growing stock, increment and drain are based on the sample tree measurements on the plots. Growing stock according to the Danish NFI is defined differently for broadleaves and conifers. For broadleaves, growing stock includes all stem parts above the stump i.e. the bole with bark and stem top. For conifers, growing stock includes the above-ground stem volume. The top diameter limit is 0 cm and all volume is measured over bark.

Estimates of gross change are calculated as the mean annual change between estimates from two consecutive periods of NFI measurements, usually using the data from full 5-year rotations. The estimation of drain is based on observed change on permanent sample plots between two consecutive periods of NFI measurements, referring to the sampling probability of the first measurement. The volume of drain is further stratified into harvest and natural losses. The national definitions for growing stock, increment and drain are compiled in Table 17.8.

Table 17.8 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Growing stock	Volume of trees with dbh ≥ 0 cm over bark. For conifers including the above-ground stem volume with a top diameter limit of 0 cm. For broadleaves including above-ground stem and branch volume with a top diameter limit of 0 cm
Increment	Volume increment of surviving trees with dbh ≥ 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 ≥ 0 cm over bark at the first measurement that were found to be harvested in the subsequent NFI

Similar to volume estimation the Danish NFI provide biomass estimates for various purposes. Above ground and total tree biomass are estimated using species specific biomass functions (Skovsgaard et al. 2011; Skovsgaard and Nord-Larsen 2012; Nord-Larsen and Nielsen 2014) to the extent such functions are available. For tree species where no local biomass functions are available, stem volumes are converted to biomass by applying nationally valid wood densities (Moltesen 1988) and biomass expansion factors specific for broadleaves and conifers respectively (Skovsgaard et al. 2011; Skovsgaard and Nord-Larsen 2012).

The growing stock in Denmark is 125 million m^3 and is increasing by 2.6 million m^3/year. Annual drain amounts to 4.5 million m^3/year of which 3.3–4.1 million m^3/year are harvested. Thus, the annual drain is 63 % of the annual increment. The largest proportion of the growing stock is made up by European beech (25 %), Norway spruce (18 %) and pedunculate oak (10 %) but other species account for 47 % of the growing stock (Table 17.9).

17.3.1.2 Tree Species and Their Commercial Use

According to questionnaire surveys conducted by Statistics Denmark (2013), conifers made up 69 % of the marketed wood in 2012 (Table 17.10). About 49 % of the coniferous wood was used for sawn wood and 51 % for energy, as chips or round wood. In 2012, 23 % of the deciduous wood was marketed as round wood and 77 % was used for energy purposes 42 % was used for firewood. In total, 41 % of the harvested volume was used as sawn wood or industrial round wood, 16 % as firewood, 35 % for wood chips and 7 % for round wood for energy.

In 2011, the economic value of the forest production totalled about 1 billion DKK (Table 17.10). Coniferous timber assortments made up about 33 % of the value, deciduous timber assortments made up 13 % and different forms of wood for energy made up 54 %.

Table 17.9 The volume of standing stock (NFI 2008–2012), increment, and drain based on consecutive five year measurement rotations (NFI 2004–2008/2009–2013)

Tree species	Standing stock (1000 m^3)	Increment (1000 m^3/year)	Drain (1000 m^3/year)
Beech (*Fagus sylvatica*)	31,464	1569	535
Oak (*Quercus robur*)	12,358	383	177
Ash (*Fraxinus excelsior*	5406	194	257
Sychamore (*Acer pseudoplatanus*)	6113	413	105
Birch (mainly *Betula pubescens* and *Betula pendula*)	4828	245	108
Other broadleaves	9199	615	325
Norway spruce (*Picea abies*)	22,041	1426	1336
Sitka spruce (*Picea sitchensis*)	7537	565	512
Other fir species (mostly silver fir (*Abies alba*) and grand fir (*Abies grandis*))	5833	402	345
Pine species (mostly French mountain pine (*Pinus mugo*) and Scots pine (*Pinus sylvestris*))	8384	509	333
Nordmann fir (*Abies nordmanniana*)	1432	96	95
Noble fir (*Abies procera*)	1942	229	148
Other conifers	8705	505	256
Total	125,241	7150	4534

17.4 Assessment of Wood Resources

17.4.1 Forest Available for Wood Supply

17.4.1.1 Assessment of Restrictions

The field assessments of the Danish NFI include all forest covered sample plots in the sampling grid, with the exception of inaccessible plots (commonly due to flooding, wind throws, and roads) which are assessed using aerial photographs. The existence of legal restrictions are 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 with restricted harvest. Any restriction available as a geo-referenced GIS-layer can be considered in assessing the forest area available for wood supply.

Other than legal restrictions, very few areas are restricted regarding harvesting possibilities due to e.g. slope of the terrain or distance to roads. Consequently, analyses on the forest available for wood supply include only legal restrictions due to nature protection and conservation. The vast majority (98 %) of Danish growing stock is available for wood supply.

Table 17.10 Harvested volumes and economic value (Statistics Denmark www.statistikbanken.dk)

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
Harvested volume (1000 m^3) (*Statistics Denmark, SKOV6: felling in forests and plantation in Denmark by region, species of wood and area*)											
Total	2018	1926	3672	2962	2349	2550	2371	2405	2655	2565	3111
Beech	484	489	491	225	219	231	236	246	249	234	234
Oak	70	75	56	69	64	64	47	48	51	56	48
Other broadleaves	135	143	94	116	125	117	106	113	163	238	330
Conifers	1329	1220	3031	2529	1885	2110	1917	1847	2030	1876	2160
Economic value (*million DKK*) (*Statistics Denmark, SKOV9: economic accounts for forestry by type*)											
Total	847	725	1044	826	717	915	927	801	962	1003	
Beech timber	160	159	212	35	40	44	53	42	48	49	
Oak timber	34	35	36	37	38	39	28	15	25	27	
Other broadleaved timber	29	25	24	25	28	32	27	23	35	56	
Conifer timber	427	275	495	324	242	423	406	235	357	331	
Firewood	86	85	94	97	88	83	68	78	94	86	
Wood chips and other energy wood	30	49	57	129	101	118	162	226	222	269	
Forest plants	81	98	127	178	180	177	183	182	182	184	

17.4.2 Wood Quality

17.4.2.1 Stem Quality and Assortments

The Danish NFI records very basic variables related to stem quality, including tree species, stem diameter (at breast height) and length of the branch free stem for the subsample trees. The distribution of growing stock to species and size classes is estimated as the share of different tree species and sizes of the total volume.

17.4.3 Assessment of Change

17.4.3.1 Assessment and Measurement

The estimation of increment and drain in the Danish 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 plot at the second occasion are recorded in the field assessments and the type of harvesting (harvested, dead, wind thrown or missing) is determined. On a subsample of the recorded trees, additional variables are measured including total tree height, height to the living crown base and possible forking height.

17.4.3.2 Estimation of Increment

The gross increment estimated by the Danish NFI is defined as the difference in growing stock between two consecutive measurement periods. The drain is estimated from permanent sample plots as the volume of trees that are missing in second measurement period. Finally net increment is estimated as the sum of gross increment and drain. As the forest area is currently increasing in Denmark, per hectare increment and drain estimates are not representing actual tree growth only but also a fraction related to the change in forest area. Hence, the estimation described above is also carried out based on permanent sample plots for which the forest area was unchanged between the two measurement periods.

Sample tree volumes are calculated using species specific volume functions (Madsen 1987; Madsen and Heusèer 1993) of the general form: V = f(dbh, h), where dbh is the diameter at breast height and h the tree height. The volume functions provide estimates of total tree volume for broadleaves and total stem volume for conifers, both including bark.

Estimates of change include increment of trees that between cycles die, are felled or fall over naturally as well as for trees that grow into the sample. Also the increment or volume of trees on land areas converted to forest or changing from forest to other land uses are included in increment estimates. The increment estimates of the Danish NFI are commonly reported as average annual increments for the time period between two field assessments. Scaling-up from the sample trees to increments per hectare and total increment, is completed by using the number of trees represented by the sample trees at the time of the first measurement. 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 may include other tree parts apart from the stem, like increment in branches and needles, and increment of the below-ground parts. The biomass estimates for these tree elements are obtained by applying species specific biomass models (Skovsgaard et al. 2011; Skovsgaard and Nord-Larsen 2012; Nord-Larsen and Nielsen 2014).

17.4.3.3 Estimation of Drain

The drain estimated by the Danish NFI is defined as the volume of trees that have disappeared on permanent sample plots between two field assessment periods. The trees are identified using the distance and bearing measured from the plot centre for all sample trees on permanent sample plots. Permanent sample plots make up about one third of the total number of plots. For trees that have disappeared between measurements, the possible reason is identified (from stumps or presence of dead trees) and recorded as harvested, dead, wind thrown or missing (reason unknown).

The volume of the sample trees that are no longer present in the second measurement period is calculated by using the tree measurements at the first occasion and adding an estimated growth for half the time span (2½ years) between measurements. Individual tree volumes are estimated using the previously mentioned volume functions and half period length, species specific growth is estimated using the observed growth of trees measured at both measurement occasions. The volume of felled trees on land areas converted to other land-uses is included in the drain estimates.

The drain estimates of the Danish NFI are average annual volumes of drain for the time period between two measurement periods. 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 may include other tree parts like branches and needles, and the stump and root biomass of felled trees, although these figures are not part of standard estimation procedures.

Besides the yearly drain estimates provided by the Danish NFI, annual statistics on harvested wood based on questionnaire surveys are provided by Statistics Denmark. 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 20 ha and a full census in forest properties larger than 100 ha.

17.4.4 Other Wooded Land and Trees Outside Forests

17.4.4.1 Assessment, Measurement and Estimation

The sampling grid of the Danish NFI covers all land-use classes and ownership categories. However, field assessments include only areas with forest or other wooded land. Measurements on forest and other wooded land are identical and the corresponding estimators are thus identical for the two land-use classes. Other land with tree cover is currently not included because it is not considered as primary domain of the NFI. Estimates of trees outside forests are thus currently limited to the area of fruit orchards provided by Statistics Denmark.

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