Chapter 20
France

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20.1 The French National Forest Inventory

20.1.1 History and Objectives

The decision to launch a permanent programme of forest inventory in France dates back to 1958, when it was put into law. The aim was to assess the state of French forests after World War II and to evaluate the potential for sustainable wood harvesting. Prior to this, the last general survey on forest resources went back to 1912 (Daubrée 1912).

The National Forest Inventory (NFI) was then created in 1959 as a department of the French ministry in charge of the forests (until now, the Ministry of Agriculture). In 1994, the NFI was turned into a public institution supervised by this ministry. In 2012, the NFI merged with the National Geographic Institute (IGN) to form the *Institut national de l'information géographique et forestière* (in short still IGN).

Up until 2004, the French NFI used a two-phase stratified sampling design of temporary plots covering one administrative division (NUTS 3, called *département*) at a time. Nearly eight *départements* were inventoried each year. This methodology was developed in the late 50s and tested in the south-west of France (Gironde département) in 1960 and 1961. The entire country was covered for the first time in 1980 (first cycle). Two ten-year cycles followed in the 1980s and 1990s.

For each *département*, a systematic grid was used in the first phase. The points were analysed on aerial photographs (scale between 1:17,000 and 1:20,000) to determine the type of vegetation (stand type and main species). The second phase sample, which was assessed in the field, was a stratified sub-sample of the first phase.

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A mapping program using near-infrared aerial photographs was introduced in 1982. The entire French forest was mapped in 2000. Links created between the digital map and the statistical database made the combination of the map and statistics possible in 1988. The updating of the forest map continues today on a 10-year cycle.

The primary emphasis of the first two NFI cycles was on the assessment of the current status of wood resources at the *départements*' level. In 1985, a vegetation survey and soil description were introduced in part of the country to assess the ecological component of the forest estate. These botanical and ecological assessments were then extended to the whole country in 1992.

In 2004, the need for timely and updated forest information not only at a local level but also at the national level prompted the change to a continuous countrywide inventory design. The new sampling plan, still with two phases, was designed for 5 years (2005–2009) and covered the entire French metropolitan territory, with each annual sub-sample covering also the entire country. In the following 5-year period 2010–2014, a new similar 5-year sample was developed, while forest field plots sampled from 2005–2009 were revisited to assess cuttings after 5 years (Hervé et al. 2014). In the present 5-year sequence 2015–2019, it is planned both to re-assess completely the preceding sample (as a permanent or semi-permanent sample) and to assess new sample plots to simultaneously improve the state and change estimates and to ensure a continuous renewal of the sampled plots.

This continuous inventory design allows national forest statistics to be updated each year, with standard estimates based on the 5 more recent annual samples. It also facilitates the efficient assessment of the impact of major disturbance events as shown in January 2009 when storm Klaus damaged about 50 million m^3 of wood in the south-west of the country (IFN 2009).

In parallel, since 2005, efforts were made to introduce assessments aimed at enhancing the evaluation of sustainability, biomass availability and biodiversity (e.g. dead wood), and to provide data necessary to fulfil the reporting obligations of the land use, land-use change and forestry (LULUCF) sector of the Kyoto Protocol. The discussions on harmonisation at the European level (Tomppo et al. 2010) also led to the implementation of field assessments according to commonly agreed definitions in COST Action E43 (2010), for the forest definition since 2007 and more recently (2014) for other wooded land.

20.1.2 Sampling Methods and Periodicity

Since 2005, the sampling design of the French NFI is continuous in time with a systematic sample covering the whole country each year. It was originally designed as a regular square grid of 1 km^2 to cover two 5 year periods (Vidal et al. 2005). However since 2010 it was decided to revisit points measured 5 years previously, and squares of a year t were merged with the adjacent squares of year t-5.

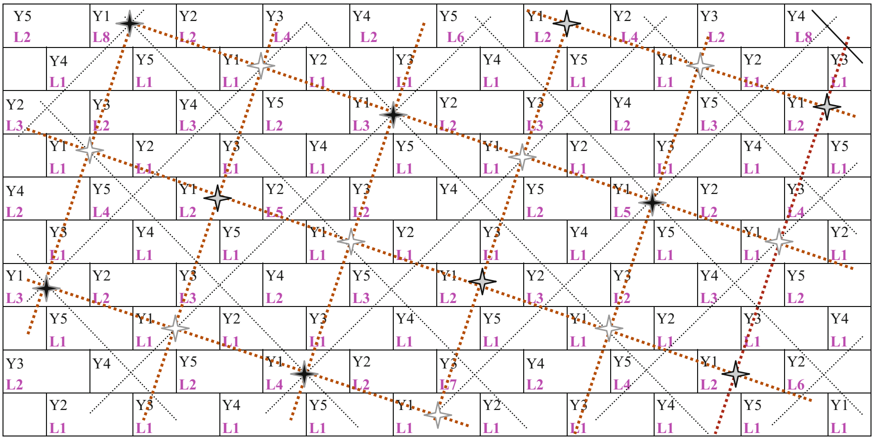

Fig. 20.1 The French NFI permanent sampling grid used to create annual samples (see explanations in the text)

The grid is thus formed using rectangular 2 × 1 km cells which are split into five years, as indicated in Fig. 20.1 by the number Yi in the top left corner of each cell. The points of each annual sample are placed at random in the corresponding year cells, which are arranged on a square annual 10 km^2 grid, as illustrated in Fig. 20.1 for year 1 (cells with a star and dotted brown grid). Each rectangular cell of the grid is divided in two 1 km^2 squares, the squares of one side being used to place new points of the annual sample t, while the squares in the other side contains plots of the t-5 sample to be re-assessed at t.

The 10 km^2 grid is also associated with a randomly oriented transect of one km centered on the point. The transect is used to sample linear tree formations and hedgerows that intersect it. In specific areas, additional points (without transect) may be added to the grid to locally increase the sampling rate. For example, in poplar areas (e.g. valley of the main rivers) where 4 points are placed on a 450 m side square. For more details on the continuous sampling design see Vidal et al. (2005) and Robert et al. (2009).

Each annual sampling plan is two-phase, and the first phase photo-interpreted sample is formed with the points of the level 1 annual grid (i.e., the whole annual grid). The size of each annual first phase sample is about 80,000 points covering all land classes including inland water. The level actually used depends on the land cover class (e.g., poplar plantations, other forests, other wooded lands, etc.) and may further vary according to specific areas defined independently of the permanent grid and that can change every year.

The sub-sample of any level is also organised in a square sub-grid that crosses each annual sub-grid in equal proportions and according to a square pattern again, as shown in Fig. 20.1 with the example of the level-3 sub-grid (black dotted network, intersections with Y1 sub-grid marked with a black star, while L2 stars are grey and L1 stars white). To vary the annual sampling rate, the grid is further divided into hierarchically nested levels, each containing half the cells of the preceding. The maximum level to which a cell belongs is indicated in the lower left corner of each cell i.e. level 2 or higher. The second phase field sample is then obtained by selecting forest plots from level 2 grid (one point out of two), other wooded land from level 3 (one point out of 4) and hedgerows from level 4 (one point out of 8). This is the standard field sampling rates, but in specific areas (homogeneous forests, mountains, low productive areas) the sampling rate is reduced to level 3 for forest plots. This leads to annual field samples of about 7500 points, of which about 6700 are located on forest land.

The forest field plots consist in a system of four concentric circular plots with radii of 6, 9, 15 and 25 m, centered on the sample points. The larger plot with radius 25 m (approximately 20 ares in area) is used to assess land cover, land use and stand-specific variables. Except in few special cases, stand-specific variables relate only to this 25 m radius plot and not to the entire stand where the plot is situated. Subdivisions of the plot into sub-plots are not used. Rather, when the land use, land cover or stand type are not homogeneous on the circular 25 m radius plot, the specific variables are assessed only on the stand where the centre of the plot has fallen. The extent of this stand on the plot is defined and the radius of the stand-assessment plot is increased to recover an equivalent area within the same stand.

The smaller plots of 6, 9 and 15 m are used for tree-specific variables: trees with circumference at 1.3 m larger than 23.5, 70.5 or 117.5 cm are measured on the 6, 9 or 15 m radius plot, respectively. In case of limit, these radii are not modified for the purpose of selecting trees, but the statistical weight of each tree is computed to correct for edge effects: the correction depends on the distance of each tree to the limit(s). A random diameter of the smaller plot is used as a 12 m transect for assessing dead woody debris. The 15 m radius plot, which is nearly 7 ares in area, is also used to survey flora.

20.1.3 Data Collection

Aside from geographic data such as the allocation of sample plots to administrative or ecological regions and ownership categories, which are obtained with GIS layers, the French NFI assesses in the field three main categories of data: stand variables, site variables and sample tree variables. Detailed and further information about the data collected by the French NFI, the assessments and measurements of variables is available from the field protocol (IGN 2014a).

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

- Stand composition (tree diameter >7.5 cm): Share of tree species in crown cover
- Forest structure: Crown coverage, vertical stand structure, development stage, coverage of woody plants under/above two-meter height
- Disturbance in the stand (less than 5 years, cutting excluded): type and importance
- Cutting (less than 5 years ago, if any): type and main species cut
- Plantation/Natural regeneration or coppice
- Age of the dominant stratum (from the age of 2 dominant trees)
- Dead woody debris (12 m transect): volume/species/decomposition stage.

The site 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
- Soil moisture
- Soil layer thickness
- Soil group
- Soil movement
- Humus layer thickness
- Humus type
- Soil group
- Assessment of all plant species present on the 7-are plot.

Sample tree assessments refer to the variables that are measured or assessed on the sample trees. They include:

- Species
- Circumference at breast height
- Tree height (sub-sample)
- Tree ring width of the last five years (sub-sample)
- Length of broken stem part (broken trees)
- Stem quality
- Dead standing tree
- Growth class
- Age at breast height (2 dominant trees)
- Share of dead branches in the functional crown
- Stem damage.

20.1.4 Data Processing, Reporting and Use of Results

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

For area-related estimates, the areas of the administrative divisions called *départements* are known and are assumed to be error-free. The standard area estimator is computed using the field data (land-use/land-cover) and the first phase data (photo-interpretation), post-stratified by the forest map, the map of the administrative divisions and the map of ownership categories. In specific cases, a post-stratification using other variables can be applied (e.g. limits of protected areas). The estimation takes into account the use of different sampling rates in specific parts of the country by varying the weight of each sample plot in accordance with the sampling rate.

The estimation of tree-related quantities like the total volume, biomass of standing stock, growing stock, increment or harvest, etc. includes several steps. After field-data collection, the data undergoes quality control procedures. The quantity (volume, biomass, volume increment, etc.) for each sample tree is then calculated using specific models. For a given quantity, different equations are applied depending on the species and size of the sample tree. For each plot, the represented volume per hectare is calculated as the sum of hectare values represented by individual trees. These estimates per hectare are aggregated to a mean per hectare and multiplied by the area of forest available for wood supply to obtain the total. Means per hectare and totals are also estimated for sub-domains within forest available for wood supply like ownership categories, age-classes or dominant tree species.

The French NFI provides estimates at different regional scales (both administrative and ecological divisions) and at the national level. The estimates include among others forest area, growing stock, increment, harvest, mortality, basal area, number of stems and dead wood (http://inventaire-forestier.ign.fr/spip/, in French, see also IGN 2014b). Specific topics and studies are summarised in a free periodic publication, *L'IF* (4 issues/year, http://inventaire-forestier.ign.fr/spip/spip.php?article54).

The results of the French NFI are used as a 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 French NFI. Reporting processes include: the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO 2010), the indicators and criteria for sustainable forest management for FOREST EUROPE (FOREST EUROPE, UNECE and FAO 2011) and at the national level (Ministère de l'agriculture 2011).

NFI data are a valuable data source for numerous research projects; they were used, for example, in scenario analyses to estimate the current and future potential of French forests for wood and biomass supply (Blaise et al. 2004; Vallet and Pérot 2011; Wernsdörfer et al. 2012), for the evaluation of forest productivity (Seynave et al. 2005, 2008; Vallet et al. 2009), to analyse forest ecology and dynamics (Charru et al. 2012; Bodin et al. 2013; Pellissier et al. 2013), storm damages to forest (Colin et al. 2009), global changes' impacts on forest growth (Charru et al. 2014) and understorey plant species distribution (Bertrand et al. 2011).

20.2 Land Use and Forest Resources

20.2.1 Classification of Land and Forests

20.2.1.1 General Land Classification

The land classification system used in the French NFI follows an analytical system that distinguishes land cover types and land use types. The land classes used for reporting are generally defined by combining land cover and land use as appropriate. For example, forest land is defined as the combination of a tree cover and a land use that is not predominantly agricultural or urban, in accordance with international definitions. This analytical system allows some flexibility to adapt the reporting to different definitions. Table 20.1 gives the land classification types that are the most commonly used in national and international reporting.

The definition of forest used in the French NFI is very close to the FAO (2004) definition, except that permanently unstocked parts of a forested area (e.g. forest roads, timber yards) are not classified as forest using the national definition. According to the French NFI definition, a forest requires a minimum area of 0.5 ha, a minimum width of 20 m, and a crown cover of more than 10 % with trees of more than 5 m height, or able to reach this height at maturity in situ, and the area must not be under predominant agricultural or urban use. Beside forest, smaller wooded area between 0.05 and 0.5 ha are distinguished as bosket. Bosket's definition still requires a width of more than 20 m and a tree cover of more than 40 %.

The areas of forest and non-forest land classes according to the French NFI are given in Table 20.1 and the classes are compared to the definitions of the Forest resources assessment of FAO (2004). The Other Wooded Land (OWL) of FAO is included in the non-cultivated vegetation class together with non-cultivated herbaceous lands, while other lands with tree cover (OlwTC) are included in the cultivated vegetation class which also contains some elements that belong to forest according to FAO (2004) like for example land for wood energy production and Christmas tree plantations.

Forthcoming improvements and changes are under consideration to make the national system closer to the international definitions, by identifying (i) permanently unstocked forested areas, (ii) OWL inside non-cultivated vegetation and

Table 20.1 Land use classes according to the national definition with area estimates (NFI 2009–2013) and correspondence with FRA classes

Class name	Description	Area (1,000 ha)	Corresponding FRA classes (FAO 2004)
Forest	Essentially the FAO definition, except that permanently unstocked parts of the forest domain are not included in the French NFI definition	16,543	Forest
Bosket	Small wood with 0.05 ha < area < 0.5 ha; width > 20 m; canopy cover > 40 %	241	OL
Other uncultivated vegetation (*lande*)	Mountain pastures, natural grasslands, heathlands, shrub, *maquis* or *garrigue* under 5 m of potential height	2159	OWL, OL
Cultivated vegetation	Cropland, fallow land, orchards and vineyards, land for wood energy production, Christmas tree plantations, grassland, sport fields and recreation, woodland with predominant agricultural or urban use	31,085	OL, OlwTC, intersection with forest (Christmas tree plantations)
Natural bare land	Rocks, areas of gravel and debris, landslides, glacier, permanent snow	3,574	OL
Artificialised land without vegetation	Buildings, paved roads including forest roads and other permanently artificialised parts of the forest without vegetation	516	OL, intersection with forest (forest roads)
Water	Rivers (more than 5 m wide), inland water bodies	763	OL
Prohibited area	Blacked-out areas on aerial photos	63	OL
Total land area		54,944	

The figures in this table and all others in this chapter may non significantly differ from official statistics provided by the French NFI because of small corrections made after the preparation of this chapter

(iii) OlwTC inside cultivated vegetation lands. Special cases like wood energy production and Christmas tree plantations will also be revised.

20.2.1.2 Forest Available for Wood Supply

A further very important distinction is made in the French NFI between forests available for wood supply where the actual inventory will be realised, and forests not available for wood supply which will not be further inventoried.

Forest available for wood supply includes not only productive forests, but also all forest lands where (i) any legal restrictions (e.g. environmental protection, biodiversity, protective role of forest, cultural or historical site, etc.), (ii) other use

Table 20.2 Forest available/not available for wood supply (NFI, 2009–2013)

Class name	Description		Area (1000 ha)		
Forest not available for wood supply	Protected forests or forests with protective function and without yield	Forest reserve	19	162	815
		Protective functions	143		
	Forests without yield because of a specific use	Networks (e.g. electric lines)	53	117	
		Military areas	48		
		Other specific use	16		
	Remote areas and not accessible forests		536	536	
Forest available for wood supply					15,728
Total forest land area					16,543

not compatible with wood production or (iii) physical constraints, do not preclude fellings and harvestings.

Besides sites where legal restrictions apply, forest not available for wood supply includes remote or inaccessible areas often in mountainous regions, and sites where a specific use such as military training precludes wood harvesting (Table 20.2). Forest not available for wood supply represent about 5 % overall of the total forest area.

Economic restrictions are not taken into account in this classification. Therefore, forest available for wood supply may include sites where harvesting is unlikely to occur due to poor yield or costly logging conditions.

Forests available for wood supply can be classified according to logging cost thanks to specific plot-level inventory data concerning presence of forest roads, logging distance and terrain's slope and unevenness. Forests difficult to access are concentrated in the mountainous regions (Alps, Pyrenees, Massif Central, Corsica). Low productivity sites can be identified with the inventory measurements (growing stock and increment), the ecological description of the site and the floristic inventory.

20.2.1.3 Classification by Ownership Categories

The French NFI distinguishes three forest ownership categories: state forests (including the forests attributed to the *Collectivité territoriale* of Corsica), municipal and other public forests, and private forests (Table 20.3). Public forests fall under the *Régime forestier* and are managed by the *Office National des Forêts*.

Table 20.3 Forest area (1000 ha) according to the national forest definition by ownership categories and availability for wood supply (NFI, 2009–2013)

Ownership category	Available for wood supply	Not available for wood supply	Total
State forest	1442	95	1537
Other public forest (municipalities)	2364	163	2527
Private forest	11,922	557	12,479
Total forest area	15,728	815	16,543

20.2.1.4 Classification of Forest Stands by Tree Species Composition, Stand Vertical Structure and Age Class of the Dominant Stratum

Further classifications of the forest area are used in national statistics and reporting. These classifications are only available on forests available for wood supply because other forests are not assessed in the field.

Commonly used stratification variables are tree species composition of the stand, stand vertical structure, and diameter or age classes. However, the compositional and structural diversity of the French forests is relatively high, which makes these kinds of classification sometimes difficult.

The stratifications of the forest area are based on the field assessment of the 1/10 shares of the 20 area plot covered by the species with trees with diameter greater than 7.5 cm, the relative importance of the vertical strata and the measurement of the age of two dominant trees. The share of blanks and gaps is included in the assessment. A forest plot is classified as pure if a single species represents more than three-quarters of the stand cover.

The detailed coverage of forests available for wood supply by tree species is given in Table 20.4. The French forests are dominated by broad-leaved species, and especially *Quercus* species. Over one-third of the area (37 %) is covered by four *Quercus* species (*Q. robur, Q. petraea, Q. pubescens and Q. ilex*). However, the tree species diversity is rather important, both within and between stands: at 20 area scale plot, pure stands represent only 51 %, and the 13 most dominant species represent only 80 % of the area (Morneau et al. 2008).

Forest stands are classified by vertical stand structure according to the importance of the coverage of the dominant stratum. Even-aged-like stands are closed stands (more than 40 % of canopy cover) with a rather closed dominant stratum (more than 2/3 of the stand cover). They represent only half of the area available for wood supply, as shown in Table 20.5. This reflects the relative importance in France of uneven-aged forest management and also of spontaneous new forests not managed at all.

Age is attributed to each plot (even in uneven-aged stand structure), based on the measurement of the age of two dominant trees, thus reflecting the mean age of the dominant stratum in uneven-aged stand. Table 20.6 details the forest area by 20 year age classes.

Table 20.4 Forest area available for wood supply by main species and proportion of pure stands (NFI, 2009–2013)

Tree species	Area (1000 ha)	Proportion in pure stands (%)
1. *Quercus robur*	2055	37
2. *Quercus petraea*	1610	49
3. *Quercus pubescens*	1432	64
4. *Fagus sylvatica*	1370	45
5. *Pinus pinaster*	925	83
6. *Pinus sylvestris*	908	59
7. *Castanea sativa*	728	49
8. *Quercus ilex*	704	67
9. *Fraxinus excelsior*	619	28
10. *Abies alba*	595	47
11. *Carpinus betulus*	587	13
12. *Picea abies*	580	57
13. *Pseudotsuga menziesii*	371	75
14. *Betula pendula*	262	30
15. *Pinus halepensis*	*222*	*71*
16. *Robinia pseudoacacia*	183	41
17. *Pinus nigra* subsp. *nigra*	183	69
18. *Cultivated Poplar* clones	181	90
19. *Pinus nigra* subsp. *laricio*	171	78
20. *Alnus glutinosa*	153	31
21. *Acer pseudoplatanus*	113	17
22. *Larix decidua*	106	70
Other broadleaved species	949	35
Other coniferous species	202	70
Blanks—gaps—young stands	519	–
Total FAWS	15,728	51

Table 20.5 Forest area available for wood supply by stand structure (NFI, 2009–2013)

Stand structure	Area (1000 ha)	Area (%)
Even-aged-like stand	7850	50
Uneven-aged stand	5359	34
Coppice stand	1709	11
Open stand	811	5
Total FAWS	15,728	100

20.2.1.5 Forest Management and Cutting Systems

The French forests are characterised by (i) a rather important tree species diversity within and between stands (Table 20.4) with a majority of broadleaved species

Table 20.6 Forest area available for wood supply by age-classes (NFI, 2009–2013)

Age class (years)	Area (1000 ha)	Area (%)
1–20	2284	14.5
21–40	2614	16.6
41–60	3006	19.1
61–80	2676	17.0
81–100	1865	11.8
101–120	1296	8.2
121–140	881	5.6
141–160	552	3.5
161–180	282	1.8
181–200	150	0.9
+200	164	1.0
Total FAWS	15,728	100

(about two-thirds broadleaved in standing volume, Table 20.8); (ii) by a private ownership for three-quarters of its area with a very important part of very small private forests; and (iii) by an important past increase in forest area: about half of the area is less than 150 years old, and these new forests are mostly a result of spontaneous colonisation rather than plantations.

French forests are managed in even-aged and uneven-aged management systems. However, coniferous forest are mainly managed in even-aged stands, except at the higher elevations in mountainous areas, while broad-leaved or mixed forests are generally managed in uneven-aged stands, except for state's forest for which even-aged management is the rule.

20.3 Wood Resources and Their Use

20.3.1 Standing Stock, Increment and Drain

Estimates of standing stock, increment and drain are based on the sample tree measurements on the plots. They are calculated as volume of stemwood overbark. The dbh is measured at 1.3 m height from the ground and along the stem. The minimum dbh is 7.5 cm over bark: trees below this threshold are not included in regular NFI estimates.

Stemwood according to the French NFI includes all stem parts above the stump up to a diameter of 7 cm, thus excluding stem top. The volume of the first 2.6 m from the ground is calculated as the volume of a cylinder with the dbh as diameter, ignoring the enlargement at the base of the trunk. The volume of standing stock includes the volume of living trees (the growing stock) and the volume of standing dead wood.

Table 20.7 Definitions for volume of standing stock, increment and cut trees

Attribute	Definition
Standing stock	Volume over bark of stem of standing trees with dbh ≥ 7.5 cm up, excluding stem top (top diameter of 7 cm), and excluding the above-ground part of the stump
Increment	Volume increment during the 5-year period preceding the inventory of living standing trees with dbh ≥ 7.5 cm over bark
Cut trees	Trees with dbh ≥ 7.5 cm over bark and living at the first measurement that were found to be cut 5 years later

Increment and drain are calculated as mean annual estimates for the 5-year period preceding the inventory. The estimation of increment is based on the measurement of ring width on increment cores taken at temporary sample plots. Recruitment is also estimated with the increment cores. The drain includes cut trees and natural mortality. The volume of cut trees is estimated by revisiting the plots measured 5 years ago (semi-permanent plots) while natural mortality is estimated by evaluating the year of death of dead trees (more or less than 5 years ago). In the near future, increment and natural mortality will be estimated like cut trees, by revisiting the plots measured 5 years ago. The national definitions for standing stock, increment and drain are compiled in Table 20.7.

Similar to volume estimation, biomass estimates are also calculated for various purposes. Stem volumes are converted to biomass by applying nationally valid whole above-ground volume models (Vallet et al. 2006), root expansion factors and wood densities (Pignard et al. 2000; Loustau 2004).

20.3.2 *Tree Species and Their Harvest*

Forests available for wood supply in France have a total growing stock of 2,567 million m^3 of stemwood overbark. This growing stock produces about 88 million m^3 of volume increment per year while 53 million m^3/year are removed, of which about 42 million are harvested on living trees and 11 million are lost through natural mortality (an unknown part can be harvested). Note that the natural mortality is artificially increased over the period because of the storm Klaus in January 2009, which blew down about 50 million m^3 of wood (90 % of maritime pines) in the South-West (IFN 2009). Without Klaus, natural losses would have been about 8 million m^3/year. The whole period was marked by this storm and the even bigger Lothar and Martin (1999, ca. 140 million m^3 of wood damages) which also disrupt the harvesting and the wood market.

The largest part of the growing stock volume consists of broadleaved species (64 %), with *Quercus* species (*Q. robur* and *Q. petraea*) for 23 %, followed by *Fagus sylvatica* (10 %), *Castanea sativa* (5 %), *Carpinus betulus* (4 %), *Q. pubescens* (4 %) and *Fraxinus excelsior* (4 %). The remaining broadleaved species altogether account for 14 % of the growing stock. Among conifers, *Abies alba* and *Picea abies* account for 8 % each, followed by *Pinus sylvestris* (6 %), *Pinus pinaster* (5 %), *Pseudotsuga menziesii* (4 %) and the remaining conifers species altogether for 4 %. For the increment the order of tree species is similar, although conifers tend to contribute for a larger share (39 % of the increment for 36 % of the growing stock), especially *Pseudotsuga menziesii* and *Pinus pinaster* which are the most productive species. Conifers are also harvested to a much larger extent than broad-leaves, so that the harvest is even slightly more important in conifers (21 million m^3) than in broadleaves (20 million m^3). The most important harvested species are *Pinus pinaster* (16 %), the two *Quercus Q. robur* and *Q. petraea* (16 %), *Picea abies* (12 %), *Fagus sylvatica* (9 %), *Abies alba* (8 %), *Pseudotsuga menziesii* (6 %) and *Pinus sylvestris, Carpinus betulus, Castanea sativa and Populus spp.* (4 % each). Table 20.8 gives the estimates of growing stock, increment and drain by tree species. Increment, cuttings and mortality are average annual values for the period 2004–2013.

Table 20.8 The volume of growing stock, increment, harvest and mortality on forest available for wood supply (2009–2013 NFI samples)

Tree species	Growing stock (1000 m^3)	Increment (1000 m^3/year)	Harvest (1000 m^3/year)	Mortality (1000 m^3/year)
Quercus robur	303,005	7241	3109	771
Quercus petraea	287,522	6499	3719	395
Fagus sylvatica	263,238	7331	3691	451
Castanea sativa	129,866	5097	1718	1472
Carpinus betulus	107,909	4271	1797	132
Quercus pubescens	105,222	2646	544	334
Fraxinus excelsior	98,553	3599	896	251
Betulus sp.	43,362	1927	731	282
Cultivated Poplar	32,546	2459	1580	92
Quercus ilex	31,625	769	54	101
Alnus sp.	30,459	1396	155	130
Robinia pseudoacacia	27,486	1349	483	284
Populus tremula	26,865	1506	391	267
Acer pseudoplatanus and A. platanoides	24,514	1045	206	15
Other *Acer sp.*	22,468	877	219	39
Prunus sp.	19,911	818	149	126
Other native broadleaves	84,658	4009	716	840
Other exotic broadleaves	7315	452	99	32

(continued)

Table 20.8 (continued)

Tree species	Growing stock (1000 m^3)	Increment (1000 m^3/year)	Harvest (1000 m^3/year)	Mortality (1000 m^3/year)
Total broadleaves	1 646,524	53,290	20,254	6013
Abies alba	197,168	6701	3203	443
Picea abies	197,025	7236	4996	944
Pinus sylvestris	145,486	3901	1783	921
Pinus pinaster	134,834	6521	6780	2242
Pseudotsuga menziesii	111,823	5744	2301	367
Pinus nigra subsp. *laricio*	32,603	1335	440	59
Pinus nigra subsp. *nigra*	25,634	815	216	45
Larix decidua	22,654	430	169	66
Pinus halepensis	17,030	507	100	100
Other native conifers	10,893	238	51	132
Other exotic conifers	24,845	1207	1140	186
Total conifers	919,993	34,635	21,180	5506
All	2 566,517	87,925	41,434	11,519

20.4 Assessment of Wood Resources

20.4.1 Forest Available for Wood Supply

20.4.1.1 Assessment of Restrictions

Forest stands not available for wood supply, as defined above in the French NFI (i.e. stands where harvests are strictly not possible), are not measured in the field and are identified as far as possible during the first phase on aerial photographs or by intersecting sample plot locations with GIS layers that contain areas with restrictions that prevent forest harvesting. If not detected like this, the remaining plots not available for wood supply are assessed in the field. In both cases, the reason for non-availability is recorded (main reasons are remote area, non-accessible terrain, legally protected area, other use such as military training camp or shooting range).

Any further restriction not taken into account during the survey, but available as geo-referenced GIS data, can be considered a posteriori in assessing the forest area available for wood supply.

On plots available for wood supply, harvesting possibilities are assessed in the field with several specific variables: distance to the next forest road, presence/

absence of skid trail, maximum slope to the next forest road, maximum slope on the plot, roughness and bearing capacity of the terrain.

20.4.1.2 Estimation

The French NFI does not describe stands and does not assess wood volume in forests where harvest is not possible. Thus, for these forests strictly non-available for wood supply, only areas can be estimated and reported. In other words, wood resources are assessed only in forests available for wood supply.

In these forests, wood resources can be further classified according to harvesting facilities/costs. Depending on specific aims, other restrictions on forest utilisation, where cuttings may be partly limited, can be taken into account if GIS layers are available.

20.4.2 Wood Quality

The stem quality of all sample standing trees with a circumference >20.4 cm is assessed in the field using a four-class system. The same quality classes are used for conifers and broadleaves, but the criteria defining each class depend on the species. The stem quality assessment concerns the lowermost part of the stem. The four stem quality classes are described in Table 20.9. In addition, the length of the stem without faults is assessed for all trees in the best quality class S+.

20.4.3 Assessment of Change

20.4.3.1 Assessment and Measurement

In the French NFI, increment and drain are calculated as mean annual estimates for the 5-year period preceding the year of the field inventory. The estimation of increment is based on the measurement of ring width from those increment cores

Table 20.9 Stem quality classes as assessed by the French NFI

Stem quality class	Description
S+	Exceptional sawn-quality timber, without any fault
S1	First quality sawn timber, stem upright, full-bodied, with some knots or little faults
S2	Second quality sawn timber
BI	Industrial or energy wood

that were collected at temporary sample plots. Recruitment is also estimated with the increment cores. The drain includes cut trees and natural mortality. The volume of cut trees is estimated by revisiting the plots measured 5 years ago (semi-permanent plots) while natural mortality is estimated by evaluating the year of death of dead trees (more or less than 5 years ago). In the near future, increment and natural mortality will be estimated like cut trees, by revisiting the plots measured 5 years ago.

In addition, estimates of the growing stock are independently available at year t and t-5. Consistency of stock and change estimates can thus be checked to verify, apart from sampling errors:

$$\text{Stock}\,(\text{t}) - \text{Stock}\,(\text{t} - 5) = \text{Increment} - \text{Cutting} - \text{Mortality} \qquad (20.1)$$

Assessments of changes are available in stem volume, total volume, biomass, basal area and number of trees. Although there are annual change estimates over the 5-year period before, there is no information on changes for a shorter period of time than 5 years.

20.4.3.2 Estimation of Increment

The increment over the 5-year period preceding the inventory is defined as the sum of three components:

1. the volume increment during the 5-year period of trees living at the end of the period and with dbh ≥ 7.5 cm at the beginning of the period;
2. the volume of ingrown trees that exceed the dbh-threshold of 7.5 cm during the 5-year period;
3. the volume increment of felled trees during the 5-year period, living and with dbh > 7.5 cm at the beginning of the period.

The volume increment of trees that died during the 5-year period is considered negligible and is not taken into account.

The first component contributes for more than 90 % to the total. It is calculated from radial increment measurements with the help of a specific model of stem volume Vi as a function of tree girth at 1.30 m: girth at t-5 is obtained from girth at t minus the increment between t-5 and t, which gives a first volume increment (IFN 2011):

$$\text{Vi}(\text{girth}_\text{t}) - \text{Vi}(\text{girth}_{\text{t}-5}) \qquad (20.2)$$

The final estimate of stem-volume increment is:

$$\text{Vi}(\text{girth}_\text{t}) - \text{Vi}(\text{girth}_{\text{t}-5})) \times \text{V}_\text{t}/\text{Vi}(\text{girth}_\text{t}) \qquad (20.3)$$

to make it consistent with the stem-volume of the tree at t, V_t.

Radial increment cores are also used to identify the ingrown trees that have exceeded the dbh-threshold of 7.5 cm during the 5-year period.

The third component is obtained from the survey of cut trees in the t-5 sample.

20.4.4 Other Wooded Land and Trees Outside Forests

20.4.4.1 Assessment and Measurement

The sampling grid of the French NFI covers all land-cover and land-use classes. A specific land-cover class called *lande* is defined for areas with natural vegetation and with less than 10 % tree cover. It includes 'other wooded land' as defined in FAO (2004), but also natural grassland. These two categories will be distinguished starting from the 2015 survey. 'Other land with tree cover' of FAO (2004) can be obtained as the combination of a tree cover with an agricultural or urban land use. No tree measurements are made on both *landes* and other land with tree cover, thus only areas are available for these land-cover classes.

Concerning trees outside forest, small woods (boskets) between 0.05 ha and 0.5 ha are assessed and trees measured exactly in the same way as forests. In addition, hedgerows and narrow stands within 20 m wide are assessed by a specific line sampling. They are not considered as a real land cover, but as unidimensional without area. The total length and wood quantities by unit length can be estimated by assessing and measuring hedgerows that intersect the randomly oriented 50-m transect associated with each sample plot.

20.4.4.2 Estimations

The area estimates of *landes* (including other wooded land for about the half) and bosket are given in Table 20.1: respectively 2.159 million ha of *landes* and 241,000 ha of bosket. The 127,000 ha of bosket are available for wood supply representing a total stem-volume of 17.4 million m^3. Estimators for hedgerows and narrow stands are under development and the results are not yet available.

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