Chapter 8
Belgium (Wallonia)

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8.1 The Belgian Regional Forest Inventory (Wallonia)

8.1.1 History and Objectives

Responsibility for forest policy in Belgium is at a regional level, Flanders, Brussels-Capital Region and Wallonia. Each region has developed its own inventory procedures for data collection and data processing but methodologies share strong similarities. National data can be delivered from regional inventories (e.g. FRA reports see Laurent et al. 2014) but if they are not available, some of the national statistics can be issued from other sources outside regional forest inventories such as LULUCF study, land registry, map of the forested areas in Flanders.

In 2010, the national forest area was just over 680,000 ha or 22 % of national area (Laurent et al. 2014). Over half, 55 %, of the forests are privately owned. More than 75 % of the forest area is located in Wallonia which represents 55 % of the total national area. Forests represent 32 % of the area in Wallonia, 11 % in Flanders

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and 10 % in Brussels-Capital. All further information presented in this report relate only to Wallonia.

Before 1980, for more than a century, data about forest were collected through general national census using different rough estimates form both private and public forests. In the early 80s, the first regional forest inventory based upon a systematic sample with temporary plots was set up in order to get an overview of the whole forest. The first permanent systematic Regional Forest Inventory (RFI1) was launched by Wallonia in 1994 and ended in 2008. In 1997 several new parameters were integrated in the inventory especially to assess the sustainability of forest management in Wallonia (Rondeux and Lecomte 2010). The second inventory (RFI2) is in progress since 2008 using the same permanent sample plots.

The main aim of the RFI is to characterise the state and evolution of forests with special regard to wooded areas, growing stock, stand composition, regeneration, forest health and biodiversity.

8.1.2   Sampling Methods and Periodicity

The ongoing inventory (RFI2) is a single-phase, non-stratified inventory using a systematic sampling design based on plots located at the intersections of a 1000 (east-west) × 500 m (north-south) grid. This grid is covering the entire region with 33,000 sample plots of which 11,000 are located in the forest. Each year 10 % of all plots are assessed. They are scattered throughout the region but always selected on a systematic basis, on a grid 10 times larger than the previous one.

In the inventory design each sample unit consist of concentric circular plots comprising (Rondeux et al. 2010):

– three main circular plots (radii of respectively 4.5, 9 and 18 m) are used for measuring living trees, with a minimum circumference at 1.50 m above ground level (c150) of respectively: 20, 70 and 120 cm according to the different plot sizes
– standing dead trees are measured in the same way as living trees while lying dead trees (or pieces of wood) of at least 20 cm circumference and 1 m long are measured in the plot of 9 m radius
– near the plot centre general observations dealing with physical soil properties are collected. Further information is collected in 10 % of the forest plots assessed annually. Twenty-one soil samples are taken in each of those plots to perform qualitative and quantitative soil analysis (pH, cation exchange capacity, nutrients content, etc.)
– one cluster of four circular sub-units are established for natural regeneration measurements (radius of 2.25 each), one of them being centred on the centre plot

– one circular plot with a 12 m radius is used to describe all vascular plants (abundance, frequency, etc.)
– one circular area with a 36 m radius is used for the visual diagnosis of health conditions, game, storm and fire damages, types of silviculture, main forest functions, etc.

All those data are collected only in plots located in productive forest land. All forest stands and clear cuts are considered as "productive" forest land. All other land considered as forest land by the RFI are classified as "unproductive". Remote sensing techniques are currently used only to define land use for each plot. All forest plots from the previous RFI and new forest plots (detected on aerial photos) are assessed on the field.

According to the RFI2 sampling design, 50 % of the plots visited annually are re-measured after 5 years, for the purpose of increment calculation. The remaining 50 % are re-measured after 15 years, which to some extent are akin to temporary plots (Rondeux et al. 2010). Those plots re-measured after 5 years/15 years will be re-measured after 15 years/5 years next time. For a given plot there is thus an alternation of intervals. The first years of RFI2 are however a transitional phase in which interval between measurements can be slightly different. Mean increment calculation period is currently close to 7 years instead of 5.

8.1.3 Data Collection

Data assessed by the Walloon RFI can be divided into four main categories:

– general variables: administrative information, ownership, date of measurement, plot location and identification
– site variables: land use, topography, soil characteristics, ground vegetation and forest edges
– stand variables: description of the stand within a 36 m radius around the plot centre. Stand description focuses on: structure, age, composition, stage of development, previous land use, regeneration (species, ground cover and development stage), deadwood, management activity traces, various types of damages and diseases, global stand quality and health status
– tree variables dealing with trees and coppice shoots (dead or alive) which are measurable from 20 cm upwards (c150). Sample trees assessment variables are: location, species, c150, total height (all trees for hardwood tree species, dominant trees only for coniferous tree species), stem quality, damage, flaw (low branches, fork, etc.) and general health status.

8.1.4 Data Processing, Reporting and Use of Results

A first data quality control is made in the field via an electronic field recorder. After data are transferred into the main database, they are subject to a new verification conducted by the inventory staff. Finally during data processing, an automated procedure takes into account calculated variables to verify the likelihood of the results. Various parameters are then computed from raw data at three distinct levels: sampling unit, tree species and individual tree.

Numerical data grouping and comparison require two kinds of expansion factors. Firstly, an expansion factor (k) is calculated for each sub-plot according to its area (see Eq. 8.1). This expansion factor is used to express results per unit area (1 ha, fixed by convention).

$$k_i = \frac{10,000}{\pi r_i^2} \tag{8.1}$$

where k_i is the expansion factor and r_i is the horizontal radius (in meters) of the subplot i.

Secondly, for total values, an expansion factor (t) is calculated at plot level according to the sampling grid size. With a 1000×500 m sampling grid covering the entire Region, each plot represents an area of 50 ha (Rondeux et al. 2010). This value is valid for RFI1 ($t_1 = 50$ ha) but has to be adapted for RFI2. For the second inventory (RFI2), data are currently collected and validated for 30 % of plots. In this context, one sample is representing a bit less than 167 ha ($t_2 = 167$ ha). Plots measured each year are distributed throughout the whole territory thus, even if RFI2 data collection is not completed, some results can be produced with an increasing precision over time.

For each tally tree, basal area, wood volumes (with/without branches or bark, to various upper circumference limits up to min. 22 cm), biomass and carbon content are estimated. Variables calculated at tree level are multiplied by their corresponding expansion factor (according to the tree's circumference) and then aggregated at the species and stratum level for each plot.

Sample tree volumes are obtained by means of volume equations based on regression models (Dagnelie et al. 2013). Circumference (c) at 1.50 m (or at 1.30 m) above ground and, total height (h) or top height (h_{top}) are used as regressors (Rondeux et al. 2010). Volume can be calculated with the circumference only [$v = f(c)$] circumference and total height [$v = f(c, h)$] or circumference and top height [$v = f(c, h_{top})$] depending on available data and required precision.

Areas are estimated using the dot grid method (Bouchon 1975). When a forest area has to be calculated, it is determined by multiplying the number of forest sample plots by t_1 or t_2 according to the data source (RFI1 or RFI2).

Change estimation of growing stock increment is obtained from the comparison of the two RFIs. Only the plots re-measured within a five year period and which were already located in forest land at RFI1 are selected for the calculations (50 % of

the re-measured plots). Plots which changed their location and plots which were not forest land at RFI1 but become forest land at RFI2 are excluded. All trees of the selected plots measured at the first and/or second inventory are included in estimations. Increments per hectare are obtained by referring to the measurement at the first occasion.

Living trees measured during the first inventory that have died, been felled or disappeared are recorded to assess the drain. Volume and biomass of drain are calculated using their c150 at the first inventory and the mean increment estimated from stems measured at both occasions.

Forest administration and forest authorities in charge of regional forest policy are the main users of the RFI data and results. The RFI is also a source of information for scientific research (e.g. estimation of the carbon stocks of all forests pools (Latte et al. 2013), forest future evolution simulation platform), forest industries, national (State of the Walloon Environment) and international reporting (FRA, FAO, LULUCF, UNFCCC, etc. Currently, if data about forest growing stock in Wallonia are needed, the RFI is nearly the only available source. However, the use of aerial photo-interpretation is growing and will become a very interesting complementary source of data in the near future.

The RFI is the major tool for the assessment of the criteria and indicators for sustainable forest management: FOREST EUROPE and conservation status of natural habitat types under the Habitats Directive (Council of the European Communities 1992). Data are used for environmental decisions where special algorithms or supplementary calculations are necessary to satisfy increasingly sophisticated information requirements. The RFI has been used, to some extent, as a tool to identify and describe most Natura 2000 sites as in helping to launch the forest certification process. Finally, the Walloon RFI is contributing to forest health monitoring through collaboration with the Observatoire Wallon de la Santé des Forêts (Walloon Forest Health Observatory).

8.2 Land Use and Forest Resources

8.2.1 Classification of Land and Forests

8.2.1.1 General Land Classification

The Wallonian land use classification system is conventionally divided into four land major categories: forest, agricultural, built-up and other. Land use classification used in RFI is however slightly different with a more detailed classification of wooded areas to meet specifically the RFI objectives. Other land has been split into two distinct classes: non-forest land with tree cover and other non-forest land (Table 8.1).

Forest land includes forests used for the purposes of production, protection, conservation and multiple-use. Referring to threshold parameters a forest land has a

Table 8.1 Land use classes according to the regional definitions as used by the RFI with area estimates of the RFI2 (2008–still ongoing) and correspondence with FRA classes

Class name	Description	Area (1000 ha)	Corresponding FRA class (FAO 2004)
Forest land –Productive forest land –Unproductive forest land	All stands and clear cuts, no productivity threshold, includes protected areas Temporary or permanent by unstocked parts of the forest: roads, nurseries located in the forest, and moors	479.5 74.5	Forest, partly TOF (land with tree cover but less than 0.50 ha) Partly forest land, partly OWL, partly other land
Non-forest land with tree cover	Parks, tree lines (along the river bank), hedgerows, isolated trees, orchards, Christmas trees plantations, wooded banks, trees in rows. The area with tree cover can be less than 0.1 ha	67.8	OLwTC, TOF, Forest (Christmas tree plantations)
Agriculture land	Agricultural buildings, croplands, grasslands, nurseries, fallow lands	821.6	OL
Built-up land	Settlements shops, industrial estates, major roads infrastructures, minor roads infrastructures, on duty railway infrastructures, disused railway infrastructures, mining, military properties, others	225.9	OL
Other lands	Navigable rivers, non-navigable rivers, bodies of water (ponds, lakes, dams), wetlands, nature reserves and other protected areas, slag heaps/dunes, unstocked slopes along highway or railway lines, others	20.6	OL

minimum area of 0.1 ha with tree crown cover of more than 10 %, comprising trees with the potential to reach a minimum height of 5 m at maturity. No minimum width threshold is considered for strips of forest. The forest land total area is estimated by GIS and categorised into nine classes (nine area classes). Since RFI2 has started, these area classes have been designed to allow the selection of plots which are specifically located in a forest area less than 0.5 ha. All forest stands and clear cuts are considered as "productive" forest land. Other lands which are part of the forest area but permanently unstocked are identified as unproductive forest land. It includes elements such as: forests roads, firebreaks, muds, moors, grazing lands, pools, rivers, etc. Some of these areas do not satisfy the forest definition established by FAO (2004).

Agricultural land is divided into: agricultural buildings, cropland, grassland, nursery and fallow land. The nine classes which compose the built-up land are: settlements, shops, industrial estate, major road infrastructure, minor road infrastructure, on duty railway infrastructure, disused railway infrastructure, mining, military property, others. The non-forest land with tree cover is divided into: parks,

tree lines (along the river banks), hedgerows, isolated trees, orchards, Christmas trees plantations, wooded slope, and trees alignments.

Among other non-forest land one can distinguish: navigable rivers, non-navigable rivers, bodies of water (pond, lake, dam), wetlands, nature reserves and other protected areas, slag heaps/dunes, unstocked slopes along highways or railway lines and others.

Land use classes according to the Walloon RFI are presented in Table 8.1. The corresponding Forest Resources Assessment class (according to FAO 2004) is also provided in the table.

The minimum area (0.1 ha) used in the Walloon forest definition (without any minimum width threshold) is smaller than that established by FAO (2004). Thus, some areas considered as trees outside forests (TOF) by FAO (2004) are included as forest land by the Walloon RFI. Nevertheless, area of forest containing RFI plots is estimated on aerial photographs through area classes. Forest area less than 0.5 ha are specifically identified since RFI2. Data already available show that forest areas less than 0.5 ha (but at least 0.1 ha) represent less than 1 % of the total forest area.

There is no official regional Other Wooded Land (OWL) definition. Some unproductive forest land areas, specifically identified by the Walloon RFI match the FAO (2004) OWL definition. However, as tree cover is not recorded for them there is no possibility to assess the extent of these areas.

8.2.1.2 Forest Classifications by Use

All forest stands even if they are temporary unstocked (clear cuts) are considered as "productive". The RFI does not consider any subdivision based on the suitability for forestry. Protected forest areas where the quantity of wood is low or not available are not common and as such these areas cannot be estimated precisely.

Resource-related estimates (volume, growing stock, increment and harvest, etc.) are provided for all productive forest lands. However, coppice trees are frequently treated separately. In addition, some data are collected to partly identify forest stands that are not available for wood supply (topographic data, soil bearing capacity, accessibility, etc.). The RFI checks if the stand belongs to a Natura 2000 habitat. This status does not exclude these areas from harvesting but may reduce wood availability.

8.2.1.3 Classification by Ownership Categories

The Walloon RFI identified two main types of forest ownership: private and public. Forest area is nearly equally shared between these two categories, 48 % public and 52 % private. Public ownership can be divided into seven subcategories: Walloon region, Province, Commune, CPAS (Public Centre of Social Aid), natural reserve, national defence or other property of State, other public owner. However, results are

Table 8.2 Forest area according to the national forest definition by ownership categories (RFI2 2008–present)

Ownership category		Area (1000 ha)
Private forest		287
Public forest	Walloon region	62
	Provinces	1
	Communes	193
	CPAS (Public Centre of Social Aid)	5
	Natural reserves	5
	National defense—other properties of the State	2
	Other public owners	0 (less than 500 ha)
Total forest area		555

usually presented for the two main categories. Communal ownerships represent nearly three quarters (72 %) of public forests (Table 8.2). Private forests generally consist of small forest holdings. Their area is estimated indirectly using cadastral databases. Additional pieces of information about private owners are available from a questionnaire which is sent to each sampled private forest owner. More than 40 % of private owners answer the questionnaire but small property owners are under-represented.

8.2.1.4 Forest Management and Cutting Systems

Three main types of stand structure can be distinguished: high forest, coppice with standards and coppice forest which represent respectively 68, 29 and 3 % of the forest area. In Wallonia, most of the high forests are even-aged stands with one single story (73 %). Forests with two stories represent 10 % and uneven-aged 11 % of high forests. Over two-thirds (71 %) of the even-aged stands are coniferous stands whose area represents 43 % of the total productive forest area.

The initial RFI2 first results suggest a noticeable increase of the uneven-aged stands area compared to the RFI1 results which should also mean that a more close to nature silviculture is in progress. This tendency has however to be confirmed in the future when more data from the RFI2 will be available.

Natural and artificial regeneration are both regularly used to regenerate stands. The area of young plantations is nearly as high as stands area with viable natural regeneration, respectively 45,500 and 46,000 ha. Viable natural regeneration is present in 13 % of mature forest stands and 84 % of this regeneration is located in broadleaved stands. As often as possible, natural regeneration is preferred particularly in public forests but game browsing can be a significant issue for seedling development.

According to the RFI2 data already available, 56 % of stands had harvesting activities since RFI1, of which 9 % of felled high forests were clear-felled and 91 % were thinned. Three types of thinning are carried out: systematic, selective and

sanitation. Three thinning intensities are also distinguished; light, medium and strong. More than 90 % of thinnings are selective. The aim of the thinnings is not described in the field.

Harvesting operations are regulated by conditions outlined in the Walloon Forest Code. Clear cuts are not allowed for an area of over 3 ha in broadleaved stands and 5 ha in coniferous stands.

8.2.1.5   Legal and Other Restrictions for Wood Use

Restrictions on the use of wood arise from three main sources: Walloon Forest Code, Walloon government laws concerning Natura 2000 habitats, Walloon government biodiversity circular (Branquart and Liegeois 2005). The biodiversity circular guidelines are mandatory in public forests. For private forests it should be treated as advice.

There are few restrictions on the use of existing growing stock and their impact is low. Nevertheless clear cut sizes limitation is obviously one of the main constraints. Some forest policies created to promote biodiversity preservation and enhancement also have an influence on harvesting. Maintaining two standing dead trees (c150 > 125 cm) per ha, one tree of biological interest per 2 ha and two broken or dried coniferous trees per ha are rules which are only applied in public forests. Forest owners with broadleaved stands greater than 100 ha have to turn 3 % into an integral reserve where no harvesting is permitted. Nevertheless, those forest reserves are generally located in the less productive and less accessible areas. On the contrary, restrictions applied to afforestation and reforestation will have more of an impact on the wood production potential. The main measure is that tree species, where artificial regeneration is carried on have to follow the so called "fichier écologique des essences"—an official document describing the adequacy species/site conditions based on slope, climate, soil group, soil moisture, acidity, elevation above sea level, exposition and relief that has to be respected by law. In the future this measure could, for instance, lead to a replacement of many Norway spruce stands by less productive broadleaved stands. It is estimated that as a result of these restrictions a decrease of wood production will progressively reach 300,000 m³/year after one rotation (Philippart 2010).

Other minor rules have to be respected which includes the banning of planting conifers within 12 m of a stream. In public forests, this distance reaches 25 m for places with insufficient soil drainage. Furthermore, coniferous and exotic broadleaves can not be introduced in moors and in permanently water-logged soils.

Beyond legal rules, the wood resources availability is also influenced by the harvesting feasibility. Logging distance and forest road network, slope and soil bearing capacity have a great impact. In Wallonia, the average distance between stand and forest road is close to 200 m and there are only few stands located on steep slopes (≥30°) or on weak bearing capacity soils (<5 % of productive forest area). Generally, harvesting conditions do not restrict timber supply.

8.2.1.6 Further Classification of Forests

In reporting (regional or international), the most frequently used variables referring to forest area categories, other than those previously described, are stand types (based on tree species composition), age classes and ecoregions (six different ecoregions in Wallonia define by their geological, soil and climatic conditions).

Stand type is more used than tree species. It relates to stands overstory composition which is based on relative basal area (BA) of the species. A stand is categorised as "coniferous stand" if the main tree species BA reaches at least 80 % of the total BA of the stand overstory. For broadleaved stands the threshold percentage is 67 %. For stand types with several main tree species their BA is combined. High value hardwoods stands are stands where indigenous oak (*Quercus robur* L. and *Quercus petraea* Lieblein), beech (*Fagus sylvatica* L.), wild cherry (*Prunus avium* L.), sycamore (*Acer platanoides* L.), European ash (*Fraxinus excelsior* L.), red oak (*Quercus rubra* L.) and/or elm (*Ulmus spp.*) alone or together reach the relative BA threshold of 67 %. If oak or beech BA reaches alone 67 % or more of the total BA the stand is considered respectively oak stand or beech stand.

Stratification of the forest productive area by forest stand types is given in Table 8.3. Some stand types have been merged because of the too low number of sample plots.

Wallonia is divided into six ecoregions from the north to the south and from the west to the east: Sandy-loamy region, Silty region, Condroz, Famenne, Ardenne, Jurassic region. Altitude, afforestation rate, proportion of high forest stands and coniferous stands are significantly lower for the first two regions. The Ardenne is by far the most forested region (representing 45 % of the productive forest area) with a forest rate of 58 % (Table 8.4).

The age class distribution of the productive forest area is only provided for even-aged coniferous stands. The stand age corresponds to the age of the dominant tree species growing in the overstorey. Age is most frequently estimated through tree sampling with an increment borer, forest owner information, whorls counting or by counting growth rings on stumps. Up to 80 years a ten-year age interval is commonly used. Ages higher than 80 years are aggregated in a last class (Table 8.5). The pattern of the age class distribution is widely influenced by

Table 8.3 Productive forest area according to the Walloon RFI definition by stand type (RFI1, 1994–2008)

Stand type	Area (1000 ha)	Area (%)
Oak (*Quercus robur*, *Quercus petraea*)	85	18
Beech (*Fagus sylvatica*)	44	9
High value Hardwoods	61	13
Other broadleaves	66	14
Norway spruce (*Picea abies*)	163	34
Douglas fir (*Pseudotsuga menziesii*)	14	3
Other coniferous stand	46	10

Table 8.4 Productive forest area according to the Walloon RFI definition by ecoregion (RFI1, 1994–2008)

Ecoregion	Total area (1000 ha)	Productive forest area (1000 ha)	Productive forest area (%)
Sandy-loamy region	53	6	11
Silty region	469	30	6
Condroz	354	67	19
Famenne	156	55	35
Ardenne	574	291	51
Jurassic region	84	31	37

Table 8.5 Even-aged coniferous stands by age-classes (RFI1, 1994–2008)

Age class (years)	Area (1000 ha)	Area (%)
1–10	28	14
11–20	20	10
21–30	24	12
31–40	36	18
41–50	34	17
51–60	18	9
61–70	16	8
71–80	9	5
>80	10	5

Norway spruce stands and its predominance in the 30–50 year age-classes. These stands are a result of the massive planting campaigns originating in the 1960s. Today, they are nearly reaching their maximum productivity level.

8.2.2 Wood Resources and Their Use

8.2.2.1 Standing Stock, Increment and Drain

Standing stock, increment and drain are expressed in volume of stem wood over bark. Volume calculations are based on field measurements. All RFI plots are used for estimating the standing stock and half of the plots (only plots re-measured every 5 years) for increment and drain estimates.

The stem volume of a tree corresponds to the volume of the stem over bark from the stump level to an upper circumference of 22 cm. The volume of branches and bark thickness can also be calculated through appropriate volume equations (Dagnelie et al. 2013). Only models providing stem and branches volumes to the

Table 8.6 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with circumference 1.50 m above ground (c150) ≥ 20 cm over bark, including bole wood and bark and, excluding branches, stem top (above 22 cm in circumference) and stump above ground. Large branches volume is known. Estimates are based on all productive forest plots
Increment	Volume increment of trees with c150 ≥ 20 cm over bark at the 2nd measurement. All surviving and ingrown trees are included. The increment of trees which have been felled or died during the period between the two measurements is included
Drain	Volume of trees with c150 ≥ 20 cm over bark at the first measurement and missing (harvested) at the next measurement

limit of 22 cm of circumference are currently used in the RFI. Nevertheless, volumes to a great variety of limitations in circumference or in height or expressed in proportion of the above volume can also be taken into account. Volume of standing dead wood is estimated using the same volume models as living standing trees. The Huber equation (cylinder formula) is used for estimating lying deadwood volume (logs and pieces of wood of at least 20 cm in circumference and 1 m in length).

Increment and drain values relate to the period between RFI1 and RFI2. The estimates are calculated as mean annual estimates (m^3/ha/yr). The standing stock, increment and drain definitions used by the Walloon RFI are presented in Table 8.6.

Trees biomass and carbon stock are also estimated. Those estimates are based on the standing stock volume including large branches (until the limit of 22 cm of circumference). Volumes are converted to biomass by applying expansion factors (Vande Walle et al. 2005) and mean wood density factors. Those factors are species specific and are necessary to integrate below ground trees parts, stump above ground, small branches and stem top (foliage is excluded). The amount of carbon stock in each tree is deduced from the biomass. The biomass is converted into carbon mass using a carbon content of 50 % (Vande Walle et al. 2005).

The overall standing stock volume of stem wood over bark (large branches excluded) amounts around 113 million m^3 (from RFI2) with 1 % of dead standing trees. The annual volume increment is about 3.9 million m^3 and more than 4 million m^3 are harvested annually (Table 8.7). This means that the drain (removal between two successive inventories) is about 105 % of the increment for the period from 2001/2005 to 2008/2012. Drain is particularly important for privately owned coniferous forests. Increment and drain are balanced in public forests where 79 % of drain is constituted by coniferous tree species. This over exploitation of wood is mainly due to the age structure of the Norway spruce stands which have reached their productivity peak (numerous planting in the 1960s) in many places. Drain is

Table 8.7 Volume of growing stock, increment, and drain on productive forest land (RFI2 started in 2008, still ongoing)

Tree species	Standing stock (Million m³)	Increment (1000 m³/year)	Drain (1000 m³/year)
Norway spruce (*Picea abies*)	45.8	2126	2842
Other conifers	13.4	530	426
Oak (*Quercus robur*, *Quercus petraea*)	23.7	386	243
Beech (*Fagus sylvatica*)	16.1	448	427
Other broadleaves	14.8	433	206
Total	113.1	3923	4144

Increment and drains are average annual values for the period 2001/2005–2008/2012

more than 130 % of the increment for Norway spruce. The strong demand in periods of favourable wood market for Norway spruce is the reason of increased harvests sometimes before the normal harvest age. As a consequence, a shortage of raw material for softwood sawmills is expected in a near future (20–30 years).

Norway spruce remains the main tree species in Wallonia, despite the level of drain. It represents 41 % of the standing stock volume. It is followed by indigenous oak species (20 %) and European beech (14 %). As increment and drain are based only on 30 % of the plots (RFI2 is still ongoing), their volume can only be estimated with sufficient precision for the three main tree species. Their drain rates amount to 130, 95 and 63 % of the increment of Norway spruce, oak and beech, respectively.

8.2.2.2 Tree Species and Their Commercial Use

Tree species with a significant commercial value in Wallonia in order of importance are: Norway spruce (*Picea abies* (L.) Karst.), oak, beech, Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), poplar (*Populus* spp.), Scots pine (*Pinus sylvestris* L.), larch (*Larix* spp.), ash and sycamore. Norway spruce is the most important tree species for wood industries in Wallonia and neighbouring regions. It is mainly used for sawntimber and industrial roundwood.

In Wallonia, the wood industry imports most of the wood it uses, sawnwood as well as roundwood. Data available (inside and outside the RFI) are not sufficient to identify how Walloon wood is used. However some general tendencies can be provided. As in other countries in Europe, the share of wood dedicated to energy production is growing putting pressure on the small roundwood market especially for industrial beech wood and to a lesser extent for oak wood of industrial quality.

8.3 Assessment of Wood Assessment of Wood Resources

8.3.1 Forest Available for Wood Supply

8.3.1.1 Assessment of Restrictions

All sample plots identified as forest plots at the previous RFI (RFI1) are assessed in the field as well as new forest plots identified on aerial photographs before measurement campaign. Legal restrictions for wood use are not assessed by the RFI. Harvesting feasibility is assessed visually by field operators keeping in mind the context where the stand is located. In order to further refine the assessment several variables measured in the field can be compiled: slope, relief, distance from the sample plot to the nearest forest road, soil drainage (which is an indicator for the soil bearing capacity).

8.3.1.2 Estimations

To date, no estimation of forest available for wood supply has been made. Currently, all stands are considered available.

Concerning the legal restrictions linked to protection and conservation functions, the only corresponding data available is the location of the sample plots in a Natura 2000 forested habitat according to the Habitats Directive (92/43/CEE) and the Birds Directive (79/409/CEE). This status is generally seen as a constraint especially in private forests where other legal obligations are less restrictive for harvesting. The area of forest where harvesting is not allowed cannot be determined directly, as there is no GIS layer available concerning these areas for the whole Wallonia. Nevertheless, the area where harvesting is forbidden is very low and primarily located in the less productive forest sites.

Harvesting costs can sometime be prohibitive and even be higher than the expected revenue in some circumstances. Restrictions on wood availability due to difficult harvesting conditions are not a common occurrence in Wallonia. Furthermore, less than 5 % of the productive forest area is concerned by such harvesting conditions.

8.3.2 Wood Quality

8.3.2.1 Stem Quality and Assortments

In Wallonia, timber is sold standing in the forest. Sales of logs are very scarce except in private forests. Assortments are based on circumference (150 cm above ground) only. The current standards comprise seven commercial classes for broadleaves (100–119 cm, 120–149 cm, 150–179 cm, 180–199 cm, 200–219 cm, 220–249 cm, 250 cm and more) and eight commercial classes for conifers (20–39 cm, 40–59 cm,

60–69 cm, 70–89 cm, 90–119 cm, 120–149 cm, 150–179 cm, 180 cm and more) (Fédération nationale des experts forestiers 2014).

Regarding the quality classes, they are defined separately for broadleaves and conifers. The classification is based on the types of wood products. For broadleaves 4 classes are generally identified in order of decreasing quality: A (veneer logs), B (sawn timber), C (industrial wood) and D (energy wood/pulpwood). Veneer logs require a minimum c150 of 180 cm. That circumference can slightly vary from one tree species to another. Three quality classes have been defined for coniferous logs: A (top-quality wooden roof, possibly carpentry), B (ordinary wooden roof, lesser quality cuttings), C (various cuttings after flaw removal).

8.3.2.2 Assessment and Measurement

Quality assessment is conducted at two levels by the Walloon RFI. At the stand level, trees quality is assessed as a whole using the frequency and the kind of apparent defects detected in a 36 m radius around the plot centre. Assessment of stand quality is done independently from tree circumference and four classes are distinguished according to the proportion of trees with flaws.

At the tree level, each deciduous tree with a minimum c150 of 120 cm and each coniferous tree with a minimum c150 of 90 cm are assessed. The number of quality classes and classification criteria are different for broadleaved and coniferous tree species (Table 8.8). The quality concerns the portion of the stem from the base of

Table 8.8 Stem quality classes as assessed by the Walloon RFI at tree level

Stem quality class	Circumference threshold (c150 in cm)	Description
Coniferous tree species		
A	90	Straight stem, no spiral-grained-wood, circular stem section, tiny knots (tolerated), without defects, no stand border trees
B		Light sweep tolerated, oval stem section, spiral-grained-wood tolerated, knots(living, numerous or big), bad pruning, little damages and/or defects, stand border trees
C		Strong sweep, spiral-grained-wood, no stem section requirement, big knots and scars, bad damages or defects, visible rotting, bad shape
Broadleaved tree species		
A	180	Straight stem, low stem taper, circular stem section, no spiral-grained-wood, no frost crack, free of knots, no damages or defects
B	120	Straight stem, medium stem taper, oval stem section tolerated, no spiral-grained-wood, no damages or defects, medium knots tolerated (if sound)
C	120	Medium stem straightness, high stem taper, stem section is not important, spiral-grained-wood, frost crack and harvesting damages tolerated, rotting and lightning damages forbidden, knots (not rotten)
D	–	All other stems

the bole above the stump to a circumference of around 65 cm ($\approx$20 cm diameter) or until the upper girth limit corresponding to a commercial value.

To analyse more deeply the stem quality, several other parameters are recorded by the Walloon RFI. At the tree level, other defects such as branching, rottening, curvature, edge location and stem splitting as well as tree condition (dead or alive), tree health, game damage, harvest damage are also inventoried. At the stand level, indirect parameters can be used to evaluate overall stand quality. For instance, traces of past silvicultural operations (pruning, space enlargement around elite trees, etc.) or specific site conditions which can interfere with trees health and growth rate (altitude, soil description, etc.).

8.3.2.3   Estimation and Models

No models are used to estimate the volume by stem quality and no assortments estimates have been developed in Wallonia. Each forest operator estimates the stem quality classes visually in the field. RFI data concerning stem quality are rarely requested. Only the stem volume by quality class has been processed (Alderweireld et al. 2014). Each stem is characterised by only one quality class which also refers to a commercial wood volume. For broadleaves in RFI1 this volume is divided into the following quality classes: 1 % level A, 19 % level B and 80 % level C. Commercial volume is not calculated for trees of level D quality. In terms of standing volume (without branches), 4 % is represented by trees of level D quality. For coniferous volume: 83 % level A, 15 % level B and 1 % level C. Quality categories can not be compared between broadleaves and coniferous.

8.3.3   Assessment of Change

8.3.3.1   Assessment and Measurement

Increment and drain estimations are based on the comparison between RFI1 and RFI2 measurements. The RFI2 being in progress, the available data in 2014 is limited and only major trends of wood increments can be estimated. The reference periods for wood increment and drain are from 2001–2005 (RFI1) to 2008–2012 (RFI2). All sample trees (c150 $\geq$ 20 cm) are used in the calculations.

Changes are assessed at tree level. Tree variables needed for estimations are circumference (150 cm above ground) and the tree status at both inventories: survivor (tree measured twice), ingrowth (tree measured only at the RFI2), harvest, missing and dead trees (trees with interrupted growth between the two inventories). Total tree height is recorded for each tree and commercial height for each broadleaved tree with c150 $\geq$ 20 cm but is not used for volume calculation. The volume equation used requires only c150 (Dagnelie et al. 2013).

8.3.3.2 Estimation of Increment

Increment estimation between RFI1 and RFI2 is made through the following steps:

1. Plot selection
2. Circumference (c150) determination for each sample tree at the start and at the end of the growth period
3. Estimation of increment.

Firstly, the productive forest plots (at RFI1) with a short interval between consecutive measurements (around seven years) are selected.

Secondly, the mean periodic circumference growth is calculated for sample trees located in the selected plots. According to the size of the sample tree at either of the two measurements many subcases are defined to establish the correct extension factor value. Due to the use of concentric circular plots the extension factor corresponding to each sample tree can vary between the two inventories. Basically, two circumferences are determined for each tree according to its status (survivor, ingrowth, forgotten, harvested/missing/dead tree): the circumference at the beginning of the growth period and the circumference reached at the end of the growth period. As survivor trees have been measured at each inventory no circumference estimation is needed. The circumference (c150) of harvested, missing and dead tree at the end of their growth period (moment of death or harvest) is based on the c150 in RFI1 and the circumference growth estimated for survivor trees growing in the same conditions ($C150_{miss}$). If the harvest or death time is not known, it is assumed that the tree stop to grow at mid-term. The same method is used for not measured trees (forgotten and inaccessible trees) in RFI1 by applying the estimated growth for survivor trees reversely from the c150 in RFI2 ($C150_{nm}$). For ingrowth trees the first c150 is assumed to be the c150 threshold ($C150_{thres}$) which is established according to the distance between the tree and the plot centre: 20 cm, 70 cm or 120 cm if the tree is located at a distance (i) <4.5 m, (ii) ≥4.5 and <9 m, (iii) ≥9 m).

Thirdly, increment is also expressed in volumes using circumferences as previously defined. The volume of each sample tree is calculated by applying the following volume function:

$$V = f\left(c, c^2, c^3\right) \tag{8.2}$$

where V is the volume of the stem (over bark until 22 cm of circumference without branches) and c is the circumference 150 cm above ground. Species specific coefficients are used in the equation.

To estimate the volume growth of a tree, several volumes have to be determined:

- the volume at the beginning of the growing period based on the c150 in RFI1. An estimated value of c150 is used if the tree was not measurable ($C150_{nm}$) or was not measured ($c150_{thres}$) during RFI1;
- the volume at the end of the growing period based on the c150 in RFI2 or the estimated c150 ($c150_{miss}$) when the tree stopped to grow (time of harvest, death, removal);

Then, increment of each sample tree is calculated. If the tree reached no inventory threshold between the two measurements the following equation is used:

$$I = k(VB - VA)/p \tag{8.3}$$

where I is the annual volume increment of the tree, k is the tree expansion factor (Eq. 8.1), p is the number of growing periods between the two measurements, VA the tree volume at RFI1 and VB the tree volume at RFI2.

In some cases, k is varying during the tree growth. For instance, if the c150 of the tree was 65 cm at the first measurement (RFI1) (if 20 cm < c150 < 70 cm the tree belongs to the 4.5 m radius subplot) and becomes 74 cm at the second measurement (RFI2) (if 70 cm < c150 < 120 cm the tree belongs to the 9 m radius subplot) increment is calculated with the following equation:

$$I = (k_1(V1 - VA) + k_2(VB - V1))/p \tag{8.4}$$

where k_1 is the 4.5 m radius subplot expansion factor, k_2 the 9 m radius subplot expansion factor, V1 the volume corresponding to the c150 threshold of the 9 m (70 cm) radius subplot and p the number of growing periods between the two measurements.

According to the tree status and the number of c150 threshold crossed during the tree growth, 18 different cases (each formulated via a specific equation) can be determined as presented in Hébert et al. (2005). The sum of each individual volume growth gives a local estimation of the mean periodic increment per hectare.

Survivor trees and ingrowth trees (reached the c150 threshold of 20 cm between the two measurements) are included in the increment estimation. Increments of trees that died, were felled, fell over naturally, grow into sample as non-growth are also part of the increment estimate (Hébert et al. 2005). The increment of trees on land areas where land use change from forest to another kind of land use is included but those of areas converted to forest is excluded.

Walloon estimates are gross increment and they are calculated for stand types, ownership categories and tree species. Data collected and estimated are used to calculate the gross increment of the woody biomass but are not part of the standard procedures. Biomass increment of branches, stump and below-ground parts are estimated by applying expansion factors (Vande Walle et al. 2005) and mean wood density factors to the sample tree volume.

8.3.3.3 Estimation of Drain

The Walloon RFI defines drain as the volume of the felled trees between the two measurements periods. The volume of those trees is based on the c150 at the moment of harvest (see Sect. 8.3.3.2 for the c150 estimation procedure). Volume is calculated with the Eq. (8.2). The volume estimates concern the stem part above

stump with bark but without stem top and without branches. The volume of branches until the 22 cm circumference threshold can be added if needed. The volume of trees which have reached the c150 threshold after RFI1 and have been harvested before RFI2 are excluded from the drain estimate. The volume of felled trees on land areas converted to other land-uses is included in the drain estimates. The drain estimates are referring to mean periodic volumes of drain calculated for the period between RFI1 and RFI2. The first assessment is considered as the reference situation for the total drain calculation. Walloon drain estimates are calculated for stand types, ownership categories and tree species.

While data collected by the Walloon RFI facilitate the estimation of woody biomass drain, this has never been done. The estimates would include the entire stem over bark, the stump, the below-ground part, large and small branches excluding the foliage. The calculation procedure for drain biomass is similar to the one used for increment biomass.

8.3.4 Other Wooded Land and Trees Outside Forests

8.3.4.1 Assessment and Measurement

The whole Walloon region is covered by the RFI sampling grid regardless of the land-use class or the ownership category. Some of the areas classified as unproductive forest by the Walloon RFI are other wooded land (OWL) according to the FAO definition (2004). For all unproductive forest plot, land-use and the area of the forest in which they are located is recorded. Therefore, it is possible to identify precisely plots which could be considered as belonging to OWL. Although it is impossible to guarantee that the width threshold of 20 m is fulfilled neither the canopy cover threshold of shrubs and tree. Non-productive forest categories that could be classified as OWL are: moors, barren lands, mire and pioneer vegetations. Trees on these plots are not measured and no data are currently available (even outside the RFI) to estimate their volume or their biomass.

As the Walloon RFI forest definition uses a 0.1 ha as area threshold and no width threshold (lands that are predominantly under agricultural or urban land use are excluded), some trees outside forest according to FAO Forest definition (2004) are measured. Land use assessment based on aerial photographs realised for LULUCF project provides some pieces of information on trees outside forest (ToF) and Other Wooded Land with tree cover (OLwTC) in Wallonia (Bauwens 2010, 2011). The forest definition from FAO (2004) has been taken as a reference with the exception of the canopy cover component which is 20 % for the LULUCF project in Wallonia compared to the 10 % in FAO canopy cover threshold. Subcategories of land use have been created inside non-forest categories to specify the existence of trees outside the forest area. Thus, a gross estimation of the area with trees outside the forest land could be done for the entire country (Table 8.9).

Table 8.9 Specific land use with tree cover outside forest from LULUCF Belgian report (Bauwens 2010)

Land use	Definition	Area (1000 ha)
Wooded area	Land spanning less than 0.5 ha, width >20 m, Canopy cover >20 %, trees able to reach more than 5 m	22.4
Wooded strip (TOF)	Width 10–20 m, length >100 m, canopy cover >20 %, trees able to reach more than 5 m	12.4
Orchard	Fruit tree stand in agricultural production systems	21.2

Data for the 2008 period

8.3.4.2   Estimation

According to the forest definition used in the Walloon RFI, non-productive forest plots are included in the forest area estimate and some of them could be considered as OWL. Nevertheless, the area of all unproductive forest subcategories is estimated which makes it possible to have a gross estimation of the OWL area. Trees and shrub volume is not available for OWL.

One of the land-use classes of the Walloon RFI is dedicated to wooded land outside forest, the so-called "non-forest land with tree cover". During field work preparation, land use is assessed on aerial photograph for each non forest plot at the previous RFI. If a wooded area containing a plot is clearly not a forest area according to the Walloon RFI forest definition (predominant land use, canopy cover or forest area criteria not satisfied), it is not assessed in the field. However, the area covered by the sample wooded patch is not recorded. It is therefore impossible to know if the 0.5 ha area threshold of the 2004 FAO definition is satisfied.

RFI data collection is limited to forest land. No estimations could be done apart from a gross estimation of the area covered. Furthermore, no current monitoring program could produce results specifically for trees and wooded land outside forest land.

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