

# Chapter 28

## Lithuania

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### 28.1 The Lithuanian National Forest Inventory

#### 28.1.1 History and Objectives

Forest inventory in Lithuania consists of two national inventories: a stand level forest inventory (SFI) and a national forest inventory (NFI) using statistical sampling methods. Both inventories cover the entire national forest estate on a regular basis. The SFI is supplemented with an inventory of the most valuable mature stands generally in state forests, which is based on sampling methods, similar to those used in NFI (Miškotvarkos 2012).

##### 28.1.1.1 Stand Level Forest Inventory

The main objective of stand level forest inventory is to obtain current data about every forest compartment, which can be used for the purpose of forest planning and organisation in a defined area or holding for a period of 10–20 years.

The first stand level forest inventory in Lithuania was started at the beginning of the 19th century (Brukas et al. 2002). Up to 2010 stand level forest inventory data

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was used not only for the forest management planning but also for regular forest resources assessment.

In the SFI, estimates are primarily obtained by ocular assessment. Certain elements are measured in the field, including angle count plots. The main inventory unit is a forest compartment. Approximately 1.5 million compartments are inventoried in country during 10 year period. Growing stock volume is one of the most important forest stand characteristics. Gross annual increment is estimated for every stand using yield model and stand parameters: dominant tree species, site index, age and growing stock volume (Kuliešis 1993).

The traditional forest inventory methods applied at an individual stand level aim to obtain relevant information on the current status of resources and to facilitate efficient planning as well as organisation of forest operations in a certain areas (Kuliešis and Zaunienė 1976; Poso 1983; Laasasenaho and Paivinen 1986; Tompo and Heikkinen 1999; Kangas and Kangas 1999; Швиденко 2002; Kangas et al. 2004; Holopainen and Talvitie 2006; Haara and Leskinen 2009; Islam et al. 2009; Kuliešis et al. 2009). However, the information collected is not sufficiently accurate to facilitate assessment of change in forests or to perform strategic forest sector planning and forecasting on a national level (Антанайтис and Репшис 1973; Кулешис 1971, 2009). Many important forest attributes, such as gross annual volume increment, volume of felled, dead trees, growth balance, cannot be reliably and cost efficiently ascertained by applying stand level inventory methods. The NFI is used to provide reliable estimates for these important attributes, while also being used as a tool to validate all other inventories.

### **28.1.1.2 National Forest Inventory by Sampling Method**

The aim of the NFI is to monitor thoroughly all Lithuanian forests, with known accuracy, and estimate the main forest parameters and their change at country or county level (i.e. NUTS 3 in European nomenclature of territorial units for statistics).

In 1969 all Lithuanian state forests (75 % of all forests) were inventoried first time using the NFI based on temporary plots (Кулешис 1971; Антанайтис and Репшис 1973). The results of the 1969 inventory allowed the estimation of growing stock volume changes in post-war Lithuanian forests, identifying forest inventory discrepancies of that time and obtaining a valid gross volume increment balance (Kuliešis 1994). In order to establish a regular system of forest monitoring and a method of forest management control, a pilot study of continuous NFI on a large forest scale was initiated in the Dubrava forest (5000 ha) in 1976 (Kuliešis 1994). As the result of five repeated inventories of Dubrava forest (Kuliešis 1993, 1994) together with a pilot inventory in Jūrė forest district (3000 ha) (Kuliešis 1996; Kasperavičius and Kuliešis 2002) a theoretical and methodical basis for NFI in Lithuania was established.

In 1998 a regular NFI was launched in Lithuania (Nacionalinė 1998). It is a continuous multistage sampling inventory based on a combination of permanent

and temporary plots, which were established using GIS and GPS technologies (Kuliešis et al. 2003, 2009, 2010). Since 2012, the field work was expanded from forest land to include all other land use categories by visiting every plot in field with the goal to assess all land use, land use changes, soil and biomass characteristics on the entire network of NFI permanent plots providing data for *Land use, Land-use Change and Forestry* (LULUCF) reports.

### **28.1.2 Sampling Methods and Periodicity**

The Lithuanian NFI is based on a systematic sampling, which comprised of 16,325 permanent sample plots on whole Lithuanian territory (Kuliešis et al. 2010). The ratio of permanent and temporary plots is three to one. Every plot located on the border of different land use categories, ownership categories, administrative regions or different stands are divided into sectors. Sectors of plots and entire plots are main units for data stratification.

Since the beginning in 1998 the NFI has been implemented on a continuous basis with an interval of 5 years remeasurement cycle. The 3rd NFI (2008–2012) is finished and 4th NFI (2013–2017) has started (Nacionalinė 2009).

### **28.1.3 Data Collection**

The NFI data consists of three main data categories: (1) area characteristics, (2) state and (3) dimensions of woody plants. Some land characteristics (ownership, land use category, forest group, subgroup, administrative region) are obtained from official digital data sources and others (site type, vegetation type) are estimated in the field or during calculations after measurement (age class, site index, stocking level, species composition). Area characteristics also include data on past and proposed silvicultural measures including: cuttings, reforestation and drainage.

Describing sample trees in a plot or sector of a plot, trees are divided into groups—forest elements by stand storey, tree species and tree age. Difference in the age of one homogenous tree group is described if it exceeds 20 years. For each tree the following attributes are recorded: species, storey, state (living or dead, standing or lying, felled—removed or left), quality class of stem (viable or not promising for trees up to 20 years and industrial or fuel wood for older trees), and damage (type, cause, position, and intensity). Diameter at 1.3 m height from root collar (dbh) is measured for every sample tree. Tree height and length of crown are measured for a systematically selected subsample trees (every fourth sample tree).

Age and increment of trees are measured on temporary plots by boring 1–3 mean trees per species and storey in a plot (or sector) for every forest element. Boring of trees on permanent plot is forbidden and mean trees for age estimation are selected outside plot.

After the field works checked and verified data are permanently stored in the NFI databases. This dataset is used to estimate forest statistics, as no further correction of the data is allowed. The data are published in yearly statistical reports.

### ***28.1.4 Data Processing, Reporting and Use of Results***

The area of all forests and every stratum is estimated using the number of plots and area expansion factors. Area expansion factors for all plots, assessed during the 5 year period, are: 400 ha for permanent, 1200 ha for temporary and 300 ha for permanent and temporary plots together (Kuliešis et al. 2010).

Height and stem volume are estimated for each tree on the plot using generalised height/diameter models and form factor functions. Dbh is measured for every tree, while height is measured for a subsample of trees. Then mean diameter and mean height of every forest element are assessed and these parameters are used for subsequent height estimation of every tree (Kuliešis et al. 2010, 2013b). Stem volume increment for each tree on permanent plots is equal to difference of tree stem volume, estimated at two successive inventories. Increment of tree stem volume on temporary plots is estimated by restoring previous tree dbh and height according to data from the bored sample trees and models (Kuliešis et al. 2010).

Two types of NFI statistics are presented for the five year measurement period: static and dynamic. Static statistics are derived from data of re-measured permanent plot, newly allocated permanent, temporary and felling plots during the last 5 years. These statistics represent the state of forest resources in the middle of the analysed period. Statistics are provided by ownership categories, administrative regions, forest sites and other divisions (Kuliešis et al. 2010).

The comparable data from measured and re-measured permanent plots during the decade facilitates the assessment of dynamic statistics for the main characteristics:

- forest land area including balance of felled and regenerated stands
- species composition including regenerated and newly planted forest
- area of cuttings and the types of cuttings
- volume of removed trees and its distribution by main assortments and their size
- volume and structure of dead trees, wind throws, windbreaks or otherwise dead trees
- gross volume increment and its structure
- productivity of stands, reserve of salvage cuttings.

To ensure the objectivity of all permanent plots, for the most important parameters, comparisons are made with data from temporary plots measured in the same year. The results of NFI, based on sampling methods, are used for strategic

planning, SFI data correction as well as for national and international FRA/FAO and SoEF reporting since 2010.

### ***28.1.5 Comparison of National and Stand Wise Forest Inventories Results***

The statistics obtained during the NFI are based on objective methods of sampling and are reliable with a predetermined accuracy. They can be used to validate stand level forest inventory results, especially growing stock volume, gross annual increment and its balance, the volume of dead and felled trees. Comparison of the main forest stand characteristics, estimated by SFI and NFI during fifteen years shows enough significant differences (Table 28.1). A forest stand is a homogenous component of a forest that is distinguished from nearby forest parts using the following criteria:

- the evenness of the structure of woody forest plants in a storey
- predomination of a certain tree species of a similar age
- forest type and forest site type.

In most cases the NFI forest stand area exceeds the SFI stand area. Forest stands area has increased by 4.2 % over the 10 year period. As the NFI is repeated every 5 years, it enables a new forest area to be estimated more accurately comparing with the SFI, which is repeated every 10 years. Changes in the area of mature stands during a 10 year period are more distinct (15 % by NFI—from 364,200 to 427,700 ha and 22 % by SFI—from 308,500 to 397,600 ha). Generally the area of mature stands, inventoried by SFI, is gradually approaching the area inventoried by NFI. Growing stock volume of all stands in SFI was underestimated by 9–15 % and 12–17 % in mature stands. Analysis of the differences between results of SFI and NFI identified some reasons for them:

- subjectivity of SFI methods
- differences in models and standards used in NFI and SFI
- limited experience of SFI surveyors, including their reluctance not to exceed some upper limits and to decrease respectively mean heights (5 to 12 %), stocking level (4 to 5 %).

Underestimation of growing stock volume decreases gradually in the last 5 years (2008–2012) period comparing with the first 5 years (1998–2002) period. This is a result of the application of objective inventory sampling methods in the most valuable mature stands in the SFI, as well as permanent training of SFI surveyors, harmonisation of models and standards used in SFI and NFI. Harmonisation of form factors (Kuliešis et al. 2011) and mean height estimation models (Kuliešis et al. 2013a, 2013b) used in NFI and SFI resulted the decrease in the difference of growing stock volumes obtained by these inventories by 1 to 3 % in general and by 5 to 10 % in young stands.

**Table 28.1** Comparison of main characteristics. (SFI and NFI during 1998–2012)

Characteristics	Inventory											
	1998–2002			2003–2007			2008–2012					
	NFI 1998–2002	SFI 2003, 01.01	Difference (%)	NFI 2003–2007	SFI 2008, 01.01	Difference (%)	NFI 2008–2012	SFI 2013, 01.01	Difference (%)			
Area of forest stands, 1000 ha	2005	1951	-2.7	2036	2040	+0.2	2092	2055				-1.8
Area of mature stands, 1000 ha	364	308	-15.3	380	361	-4.9	428	398				-7.0
GSV <sup>a</sup> of all stands (m <sup>3</sup> /ha)	228	196	-14.9	229	207	-9.6	244	222				-9.0
GSV <sup>a</sup> of mature stands (m <sup>3</sup> /ha)	304	251	-17.4	300	260	-13.3	315	276				-12.4
GAI <sup>b</sup> (m <sup>3</sup> /ha)	8.0	6.2	-22.5	7.8	6.7	-14.1	8.5	6.9				-18.8
Mean changes				1.4			2.8					
Fellings of living trees				4.7			3.9					
Natural losses				1.7			1.8					
From them felled				0.4			0.4					
Mean age	51	53	+3.9	52	53	+1.9	53	54				+1.9
Mean stocking level	0.74	0.71	-4.1	0.76	0.72	-5.3	0.76	0.73				-3.9

<sup>a</sup>Mean growing stock volume<sup>b</sup>Mean gross annual increment and its structure

## 28.2 Land Use and Forest Resources

### 28.2.1 Classification of Land and Forests

#### 28.2.1.1 General Land Classification

In the national land use classification system, land is divided into six main categories (Table 28.2). The agricultural land category is further divided into arable land, orchards land and grassland. Other land is divided into other wooded land, swamps, damaged land (e.g. flooded land) and not used land (Lietuvos 2013).

For UN Framework Convention on Climate Change carbon reporting Lithuania uses six land use categories: forest land, cropland, grassland, wetland, settlement and other land, keeping definitions according to Good Practice *Guidance* for Land Use, Land-Use Change and Forestry (IPCC 2003).

#### 28.2.1.2 Forest Classification by Use

According to the national definition Forest is a land area not less than 0.1 ha in size covered with trees, comprising stocking level not less than 0.3, and the height of which in natural site at maturity is not less than 5 m, covered by other forest plants as well as thinned or lost forest vegetation due to the acts of nature or human activities (cutting areas, burnt areas, clearings). Tree lines up to 10 m of width in fields, at roadsides, water bodies, in living areas and cemeteries, single trees and

**Table 28.2** Land use classes and forest area (2013)

Land use classes	Area (1000 ha)	Area (%)	Corresponding FRA classes (FAO 2004)
Agricultural land, total	3462	53.0	OL
From them—Arable	2928	44.8	OL
—Orchards	59	0.9	OL
—Grassland	476	7.3	OL
Built up land	182	2.8	OL, OlwTc (parks)
Roads	132	2.0	OL
Water	263	4.0	OL
Forest land	2129	32.6	Forest, intersection with other lands
Other land, total	363	5.6	OL, OWL, intersection with forest
From them—other wooded land	92	1.4	OL, OWL, intersection with forest
—Swamps	114	1.8	OL, OWL, intersection with forest
—Damaged land	21	0.3	OL, OWL, intersection with forest
—Not used land	136	2.1	OL, OWL, intersection with forest
Total	6530	100	

bushes, parks planted and grown by man in urban and rural areas are not defined as forests. Forest land is defined as area with forest (forest stand) and non-forest covered areas (cutting areas, dead forest stand areas, forest clearings, nursery areas, forest seed orchards, raw- material bushes and plantations). Forest roads (width 5 m and less), forest block and fire break lines, areas occupied by timber storage site and other forest related equipment, recreation areas, wild animal feed sites and land assigned for afforestation is ascribed to forest land as well (Table 28.3).

Forest land during NFI is classified as forested, non-forested, forest land for special use, linear objects and other forest land. Non-forested area contains clear-cut areas, dead stands, gaps and lands for afforestation. Forest land for special use contains nurseries and seed orchards. Linear objects contain block lines, firebreak belts, ditch routes, electricity routes, forest roads, and other objects. Other forest land contains wood yard, forest recreation sites, feeding places, landscape sites and other land.

### 28.2.1.3 Classification by Ownership Categories

There are three ownership categories used in the NFI: state, private and forests reserved for restitution (Table 28.4). State forests account for 48.6 % of all forest land, are especially valuable and cannot be privatised. The remaining 41.4 % of forests are in private ownership. Forests reserved for restitution will be returned to the original owner, sold or be left in state ownership.

### 28.2.1.4 Forest Management and Cutting Systems

The majority of forests in Lithuania are managed according to the even-aged silvicultural system. In this system forest management practice usually entails: (i) establishment of stand with planting or natural regeneration depending on soil

**Table 28.3** Forest land area by forest land use classes (NFI, 2008–2012)

Land use classes	Area (1000 ha)	Area (%)
Forest land, total	2184	100
Forest stands	2092	95.8
Not covered by forest, from them	57	2.5
– Clear cut areas	28	1.3
– Dead stands	4	0.2
– Blanks	20	0.9
– Lands to afforestation	4	0.2
– Seeds orchards, nurseries	1	0.1
Lands for logistical needs (various lines, belts, roads)	30	1.4
Lands for other purposes	5	0.2



**Table 28.4** Forest stands areas by ownership and dominant tree species (NFI, 2008–2012)

Dominant tree species	State forests		Private forests		Reserved for restitution		Total	Error of estimation (%)
	1000 ha	%	1000 ha	%	1000 ha	%		
Scots Pine <i>Pinus sylvestris</i> L.	374.4	37.0	262.9	30.2	51.9	24.5	689.2	32.9
Norway Spruce <i>Picea abies</i> L.	221.9	22.0	123.9	14.3	23.1	10.9	368.9	17.6
Birch <i>Betula</i> spp.	186.4	18.4	186.3	21.4	56.4	26.6	429.0	20.5
Aspen <i>Populus tremula</i> L.	60.0	5.9	66.0	7.6	13.5	6.4	139.5	6.7
Black alder <i>Alnus glutinosa</i> L.	96.1	9.5	87.4	10.1	26.4	12.4	209.8	10.0
Grey alder <i>Alnus incana</i> L.	21.4	2.1	85.3	9.8	30.7	14.5	137.5	6.6
Oak <i>Quercus robur</i> L.	23.3	2.3	22.0	2.5	3.2	1.5	48.5	2.3
Ash <i>Fraxinus excelsior</i> L.	11.7	1.2	13.3	1.5	2.3	1.1	27.3	1.3
Others	15.7	1.6	22.1	2.5	4.5	2.1	42.4	2.0
Total	1011	100	869	100	212	100	2092	100
Error of estimation (%)	1.8		1.9		4.1		1.1	

type and owner decision, (ii) early tending for seedling stand, no harvesting, (iii) pre-commercial thinning of a seedling stand, possible use of felled trees for energy wood, (iv) 2–3 commercial thinning during the rotation, (v) final cutting.

Final cuttings are realised by clear-cut, shelterwood (partial) with 2–3 cutting stages and selective cuttings. Clear cutting area usually is regenerated artificially. The purpose of shelterwood and selective cuttings is to obtain natural regeneration and to maintain the management area permanently covered by forest. Only shelterwood and selective cuttings are allowed in forest of special purpose (II forest group).

#### 28.2.1.5 Legal and Other Restrictions for Wood Use

The various forest management activities, especially felling, are regulated by national *Forest Law*. The main legal act specifies for each forest group predetermined silvicultural regimes, forestry operations, protection measures and site specific conditions around the timing of cutting operations.

Forest groups (I–IV) and subgroups (A, B) are designated for every forest compartment, which are on average 1.5 ha in size, by government decision. In total there are 18 categories. For every forest group or subgroup, silvicultural and environmental requirements, with varying restrictions are assigned. These requirements define the level and conditions of availability for wood supply on the forest territory, for which corresponding forest group or subgroup is prescribed. Restrictions for wood supply in forests of II–IV groups vary: the most in forests of II group and the least in forests of IV group. According to *Forest Law* of the Republic of *Lithuania* final fellings are allowed in stands of II–IV forest groups where a minimum age has been achieved (Brukas et al. 2011).

All types of fellings are usually prohibited in strict reserves (I forest group) as well as in all sites close to nests of rare birds. Final felling is restricted in protected and protective forests depending on the year of season. Clear cut felling is allowed in forests of IV group—on area up to 8 ha, in forests of III group on area up to 5 ha area, but they are not allowed in stands of water protective forests (III group), growing on slopes exceeding 45° as well as in forests of III–IV groups of national parks with exception of swampy sites and worse sanitary state forests. Stands, bordering clear felled areas, cannot be felled for at least 4 years after the adjoining clear cut when regeneration is planned by soft broadleaves species or at least 6 year, when regeneration is planned by coniferous or hard broadleaves species.

#### 28.2.1.6 Further Classification of Forests

The following attributes are commonly used to classify forests resources:

- ownership and forest group
- dominant tree species (8 main from 24 total native forest tree species, Table 28.4)

- site indices according to growth of stands to height and diameter, age classes (10 and 20 years)
- stocking level of stands
- diameter distribution of groups of trees in 12 cm diameter intervals.

Analysis of forest stand area distribution by age classes and parameters of stand in each class allows estimating potential wood use—final and intermediate.

## **28.2.2 Wood Resources and Their Use**

### **28.2.2.1 Growing Stock, Increment and Cuttings**

Most stands, especially those consisting of broadleaved species are mixed. The growing stock volume of the dominant tree species contains from 55–57 % (oak, ash stands) up to 83 % (pine stands) of stand volume (Table 28.5). This means, that oak and ash stands are mostly mixed, while pine stands are mostly pure. Spruce trees are mostly spread in stands of other tree species. Spruce stands contain 16 % of the growing stock volume, while the total volume of spruce trees in all stands is 21 % of the national growing stock volume. The main tree species in country forests are pine, (37 % of volume), spruce (21 %), birch (17 %), black and grey alder (12 %) and aspen (6 %) (Table 28.5).

The mean growth rate of Lithuanian forests, i.e. gross volume increment divided by the total growing stock volume, reaches 3.5 % (Table 28.5). The least growth rate (3.0–3.2 %) is characteristic for pine, oak and ash stands, due to the longer rotation lengths. The medium growth rate (3.6–4.0 %) is typical for stands of spruce and soft broadleaved species, having 50–80 year rotation length. The highest growth rate (5 %) is typical for grey alder stands, having a 40 year rotation length.

According to NFI data (2008–2012), approximately half of the total increment is utilised in various types of cuttings (Table 28.5). At species level, the largest portion of the increment used by cuttings (50–73 % of gross increment), was in spruce, birch and aspen stands. The medium part of increment used by cuttings (42–46 % of increment) is typical for pine and oak stands. Pine stands do not have a sufficient area of mature stands at harvest age currently. Only 33–37 % of increment is felled in alder stands, due to complicated harvesting conditions in black alder stands and the low quality of wood in grey alder stands. The amount of felling significantly exceeds the increment in ash stands, as a result of heavy damage to ash during the last decade due to diseases.

### **28.2.2.2 Tree Species and Their Commercial Use**

Approximately 9 million m<sup>3</sup> are felled annually (Table 28.6). Over half (56 %) of the removals are from final or regeneration cuttings, 10 % from thinning and 34 %

**Table 28.5** Wood resources of Lithuania and their use (NFI 2008–2012)

Dominant tree species	Growing stock volume (GSV)				Species composition <sup>a</sup> (%)											Gross mean annual increment (GAI)			Total cuttings of living and dead trees		
	Total		Error of estimation (%)		P	S	B	Ap	BA	GA	O	Ah	Oh	Total		Error of estimation (%)		Total			
	Mill m <sup>3</sup>	%												Mill m <sup>3</sup>	% from GSV	Mill m <sup>3</sup>	% from GSV	Mill m <sup>3</sup>	% from GSV	Error of estimation (%)	
Pine (P) <sup>a</sup>	212.9	42	2.5		83	10	5	0	0	0	1	0	1	6.29	3.0	2.63	42	2.63	42	9.1	
Spruce (S)	82.4	16	3.7		7	72	9	3	2	1	3	1	2	3.20	3.9	2.16	68	2.16	68	10.3	
Birch (B)	86.5	17	3.4		5	15	61	5	6	2	2	1	3	3.14	3.6	1.57	50	1.57	50	10.1	
Aspen (Ap)	35.4	7	5.9		1	12	11	61	3	2	4	2	4	1.37	3.9	1.00	73	1.00	73	17.2	
Black alder (BA)	47.2	9	4.9		1	8	13	2	70	3	1	1	1	1.89	4.0	0.69	37	0.69	37	16.7	
Grey alder (GA)	21.9	4	6.0		0	5	8	2	4	73	1	2	5	1.09	5.0	0.36	33	0.36	33	18.9	
Oak (O)	11.5	2	9.8		2	17	7	5	1	2	55	3	8	0.35	3.0	0.16	46	0.16	46	28.7	
Ash (Ah)	5.0	1	13.2		0	7	4	6	3	5	6	57	12	0.16	3.2	0.25	156	0.25	156	25.1	
Others (Oh)	7.5	2	11.4		1	6	8	4	2	3	8	6	62	0.31	4.0	0.12	39	0.12	39	35.0	
Total	510.2	100	1.4		37	21	17	6	8	4	3	1	3	17.8	3.5	8.97	50	8.97	50	4.7	

<sup>a</sup>Dominant tree species: P—*Pinus sylvestris*, S—*Picea abies*, B—*Betula pendula*, BA—*Betula pubescens*, Ap—*Populus tremula*, BA—*Alnus glutinosa*, GA—*Alnus incana*, O—*Quercus robur*, Ah—*Fraxinus excelsior*

**Table 28.6** The structure of annual cuttings in Lithuanian forests (NFI 2008–2012)

Dominant tree species <sup>b</sup>	Total cuttings		Final cuttings				Intermediate cuttings <sup>a</sup>					
	Area, 1000 ha	Stem volume (mill m <sup>3</sup> )	Total		From them clear-cut		Total		Pre-commercial		Commercial	
			Area, 1000 ha	Stem volume (mill m <sup>3</sup> )	Area, 1000 ha	Stem volume (mill m <sup>3</sup> )	Area, 1000 ha	Stem volume (mill m <sup>3</sup> )	Area, 1000 ha	Stem volume (mill m <sup>3</sup> )	Area, 1000 ha	Stem volume (mill m <sup>3</sup> )
Pine	46.7	2.64	4.4	1.17	3.0	1.00	42.7	1.46	1.5	0.00	7.7	0.50
Spruce	29.8	2.16	5.6	1.42	4.0	1.19	24.4	0.75	6.5	0.02	3.7	0.21
Birch	26.6	1.58	4.7	0.99	3.5	0.89	22.0	0.59	3.4	0.01	2.4	0.09
Aspen	10.4	1.01	2.5	0.63	1.8	0.56	8.1	0.38	1.0	0.00	0.3	0.01
Black alder	11.2	0.69	1.7	0.43	1.5	0.41	9.5	0.26	2.0	0.01	1.0	0.03
Grey alder	7.0	0.36	1.0	0.18	0.9	0.17	5.8	0.18	0.7	0.00	0.4	0.01
Oak	3.5	0.16	0.4	0.05	0.1	0.02	3.1	0.11	0.2	0.00	0.1	0.00
Ash	2.7	0.25	0.5	0.14	0.4	0.11	2.2	0.11	0.1	0.00	0.1	0.00
Other	2.6	0.12	0.3	0.02	0.1	0.01	2.3	0.11	0.5	0.00	0.2	0.00
Total	140.6	8.97	21.1	5.02	15.4	4.35	120.3	3.94	16.0	0.04	15.9	0.85

<sup>a</sup>The main area of intermediate cuttings contains area of salvage cuttings

<sup>b</sup>Tree species: Pine—*Pinus sylvestris*, Spruce—*Picea abies*, Birch—*Betula pendula*, B. *pubescens*, Aspen—*Populus tremula*, Black alder—*Alnus glutinosa*, Grey alder—*Alnus incana*, Oak—*Quercus robur*, Ash—*Fraxinus excelsior*

from other, mainly salvage, cuttings (Table 28.6). The share of clear cuts in regeneration (final) cuttings makes approximately 73 % of area and 87 % of felled wood volume, the rest are shelterwood and selective with 2–3 occasions of cuttings and successive natural regeneration. The majority (84 %) of all thinnings are found in pine, spruce and birch stands.

Private forest owners have the right to decide on the cuttings, i.e. cuttings are not compulsory. Final cuttings are allowed, when trees in the stand have achieved appropriate cutting age and final cuttings have been specified in the forest management plan (Brukas et al. 2011). After a regeneration cutting, the new forest must be re-established by planting or natural regeneration during the 3 year period following cutting. The necessity of thinning is determined in stands older than 20 years by assessing the stocking level and mean height of trees in stands. Thinning may not exceed the limits set by the cutting rules, but the forest owner decides also whether to do the thinning or not.

## **28.3 Assessment of Wood Resources**

### ***28.3.1 Forests Availability for Wood Supply***

#### **28.3.1.1 Assessment of Restrictions**

Basic forest resource statistics are typically reported by forest groups. Group I contains strict reserves and account for 1.3 % of all forests. No silvicultural practices are allowed. The main objective is to maintain the natural growth, development and to enhance biodiversity. Group II contains forests of special purpose. They are divided into two subgroups: IIA—ecosystem protection forests, occupy 9.3 % and IIB—recreational forests occupy 2.9 % of all forests. Ecosystem protection forests are used to preserve or restore forest ecosystems or its components. Recreational forest areas are used to preserve and improve the recreational forest environment. In group II forests wood production is not the primary objective, harvesting is allowed at the age of natural maturity only and as a result wood quality is lower due to the absence of thinnings and selective cuttings. Group III contains protective forests: geological, geomorphological, hydrographical and cultural reserves, forests for soil, water, human living surroundings and infrastructure protection. Forests in group III occupy 15.7 % of all the country forests. The main objective is to form productive forest stands, capable to perform various protection functions. Group IV contains commercial forests, which occupy the main part of all forests (70.9 %). The main objective is to form productive forest stands that continuously supply the industry and energy sectors with wood, while at the same time following environment protection requirements (Table 28.7). Forests of III and IV groups contain forest available for wood supply.

**Table 28.7** Forest land area by ownership and forest legal groups (NFI 2008–2012)

Forest groups and subgroups	State forests		Private forests		Reserved for restitution		Total		Error of estimation (%)
	Area								
	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%	
Total	1062.0	100.0	903.7	100.0	218.1	100.0	2183.8	100.0	1.1
Error of estimation (%)	1.7		1.9		4.1		1.1		
Forests of I group	28.2	2.7					28.2	1.3	11.5
II group	157.8	14.9	78.0	8.6	30.0	13.8	265.8	12.2	3.7
A. Ecosystems	112.2	10.6	62.6	6.9	28.3	13.0	203.2	9.3	4.2
B. Recreational	45.6	4.3	15.4	1.7	1.7	0.8	62.7	2.9	7.7
III group	111.7	10.5	181.8	20.1	48.9	22.4	342.3	15.7	3.2
IV group	764.3	72.0	644.0	71.3	139.2	63.8	1547.5	70.9	1.4

The annual forest stand area available to be cut annually is estimated at 23,300 ha, taking into consideration the forest stand area distribution by tree species, forest groups (Table 28.7), silvicultural and environmental restrictions, forest stand age. For the current decade the annual cutting area can be increased up to 25,000 ha, considering the large amount of accumulated mature stands. Meanwhile over-mature stands, which are 20–40 years older than minimum allowable cutting age, are characterised by high natural losses. An extra 3–5 m<sup>3</sup>/ha of stem wood could be obtained annually by final felling as a result of decreasing natural losses due to decreasing areas of over-matured stands. Implementation of 3–4 thinnings during the rotation will allow stands to gain an additional volume of stem wood and to decrease natural losses up to a minimum (0.7–1 m<sup>3</sup>/ha, Kuliesis et al. 2011).

### 28.3.1.2 Estimation

For each NFI sample plot, restrictions for wood supply are assessed, indicating forest group and subgroup, site index, presence of rare birds' nests, wood key habitats, forest research and forest training and other possible valuable objects. NFI plots, assuming restrictions for forestry and environment protection are divided into three classes:

- (1) Plots in forests with optimal rotation length and corresponding silvicultural system to attain the optimal parameters of trees per stand
- (2) Plots in forests with a primary objective to maintain and enhance the biodiversity with growing of stands up to natural maturity (thinning in these forests, usually of II group are used for increasing stand stability, regeneration felling at natural maturity age for stand reestablishment)
- (3) Plots in forests where cuttings are not allowed.

Elevation and slope are not an issue restricting timber production in Lithuania. Some forests have poor productivity and forest operations are not economically feasible. These unproductive areas are ascribed to site productivity class “Va” for coniferous stands and to site productivity class “V” in stands of soft broadleaved species. Part of the forest resources is growing on peat land, where logging is possible only in winter time.

Other restricted areas contain areas of key forest habitats, where it is compulsory for the owner to exclude the site from final clear cut. Other restricted areas also include reserves of forest genetics, forest research areas and forestry training objects.

## 28.3.2 *Wood Quality*

### 28.3.2.1 **Stem Quality and Assortments**

Wood quality is assessed during sample tree measurements on NFI sample plots. For each sample tree, stem quality is recorded. All trees are subdivided into living, dead and felled.

**Living trees.** Tree classes are different for trees up to 20 years and those over 20 years. Trees up to 20 years are subdivided into two quality classes:

I class trees—are viable, dominating and sub dominating, not overtopped, evenly distributed on territory, desirable trees with straight, undamaged stems;

II class trees—are overtopped, unviable without future trees, with damaged, forked, crooked stems or allocated in dense tree groups.

Depending on the quality of stem, trees over 20 years are distributed into two groups: industrial wood trees and fuel wood trees. Trees are ascribed to the group of industrial wood trees if the lower part of stem can be used for industrial assortments and is not less than 4 m in length. Also included are trees less than 20 m in height and at least one fifth of the whole tree length suitable for industrial assortments. Living branches are not limited for commercial assortments on the basis of size. Decaying branches are limited by size (only those that have a diameter at the base of branch over 5 cm for coniferous and over 7 cm for broadleaved species, are included) as well as the types and extent of stem rot. Curvature is allowed for commercial assortments in stems of coniferous trees up to 2 % and up to 3 % for broadleaved trees. All living trees that do not satisfy the above requirements are ascribed to fuel wood stems.

**Dead trees** can be standing, lying and broken. Trees are classified as dead if they have lost needles or leaves during growing season or lost living bark at any time. Freshly fallen trees with green needles or leaves are ascribed as dead, if the crown of such trees touch the ground. Freshly broken trees are ascribed as dead where the



standing part of stem doesn't contain living branches or shoots. Dead trees, with exception of freshly fallen or broken trees, are ascribed to fuel wood trees or unusable trees. A tree is unusable if stem wood according to its quality does not satisfy the fuel wood criteria. Other trees that belong to unusable category include: stems lying on the ground more than 3 years, standing less than 20 cm dbh, dead trees 5 years and more (one re-measurement period or more) and standing more than 20 cm dbh 10 years and more (two re-measurement periods or more).

The decomposition class for every dead tree stem on permanent plot is registered during every re-measurement. Six wood decomposition classes are divided according to decayed share of wood:

- stems without signs of decay
- decayed up to 10 % of wood, wood is hard
- decayed 11–25 % of wood, evident changes of wood substance
- decayed 26–75 % of wood, wood is soft
- decayed 76–99 % of wood, wood is very soft
- completely decomposed wood—100 %, signs of wood disappeared, monitoring of trees with such wood is closed.

### 28.3.2.2 Estimation

Industrial wood is divided into three sizes by the log top diameter; large—over 25 cm, medium—13.6–25 cm and small—less than 13.6 cm. Fuel wood and felling residues are estimated over bark (Table 28.8). Wood over 25 cm is usually used for sawn wood and veneer production, less than 13.6 cm—for pulpwood. Wood of intermediate size (13.6–25 cm) is used for sawn wood production as well as for pulpwood and panels.

Fuel wood is used for fuel, as well as for panel production. Felling residues, obtained from stems (tops, above ground stumps, bark of industrial wood) are potentially available for energy production. Offcuts, allowances for length of assortments, left on site contain real losses of felling. The volume of branches and dead tree stems, as well as estimated fuel wood assortments from stem of living trees, potentially contain wood for energy supply. Estimation was done using data from tree measurements, models for tree stem overbark volume and models of stem volume by assortments and residues. Approximately 3–4 % of stem volume are left in the forest as biodiversity trees. The volume of branches as well as the volume of dead trees is estimated as a percentage of the living tree felled stem volume. In the same way industrial wood in stands felled by final cuttings contains 78 % and in stands felled by intermediate cuttings—73 %, fuel wood over bark—8 and 12 % respectively (Table 28.7). Felling residues comprise 14 and 16 % respectively, from which stumps make up about 1 to 2 %, the bark of industrial wood 8–9 %, tops and off cuts up to 1 %, trim allowances (5–10 cm additional length) and felling losses around 2–3 %.

**Table 28.8** The structure of trees wood, felled by final and intermediate felling (NFI 2008–2012)

Cutting type	Felled living stem volume (mil. m <sup>3</sup> )	Wood structure				Fuel wood over bark	Total merchant-table	Felling residues <sup>a</sup>	Volume of stem	Branches	Dead trees
		Size of industrial wood (cm)									
		>25	13.6–25	6–13.5	Total						
		Wood volume, % from stem volume									
Final	4.82	32	36	10	78	8	86	14	100	16	4
Intermediate	4.15	21	33	19	73	12	85	16	100	14	22
Total	8.97	27	35	13	76	10	85	15	100	15	11

<sup>a</sup>Excludes logging losses ≈ 2.5 % of stem volume

The portion of industrial wood, removable by intermediate cuttings, was ascertained to be 5 % lower than the portion removable by final cuttings, while that of fuel wood 4 % higher. The volume of dead trees in intermediate cuttings comprises 22 % from the total volume of stems, while in final cuttings only 4 %.

Pine and spruce wood is mainly used for sawn timber (60 %) and fibre production (30 %). Birch is used for veneer, sawn timber and fibre production, but also increasingly for house-hold heating. The use of wood for bioenergy is increasing. In 2012, 2.2 million m<sup>3</sup> of stem wood is used for energy production including: heat and energy production plants, household use, excluding the side products of industry such as bark and chips. Additionally, 0.2 million m<sup>3</sup> of cutting residues (branches, tops) are harvested for bioenergy.

### 28.3.3 Assessment of Change

#### 28.3.3.1 Estimation of Increment

The gross mean periodical increment is estimated on permanent and temporary plots. Variables related to increment estimation using data from permanent plots are the same as for volume estimation.

The volume of all trees estimated on the permanent plot  $n$  years ago, ( $M_{A-n}$ ) can be differentiated into 3 groups:

trees that have survived between two successive inventories during  $n$  years ( $l$ —number of trees)

$$m_{A-n} = \sum_{i=1}^l V_{A-ni}, \quad (28.1)$$

trees that have felled between two successive inventories during  $n$  years ( $k - l$ —number of trees)

$$M_K = \sum_{i=l+1}^k V_{A-ni}, \quad (28.2)$$

trees that have died between two successive inventories during  $n$  years ( $t - l$ —number of trees)

$$M_0 = \sum_{i=k+1}^t V_{A-ni}, \quad (28.3)$$

$V_{A-ni}$ —volume of  $i$ -th tree  $n$  years ago.

Then volume of trees per plot  $n$  years ago

$$M_{A-n} = m_{A-n} + M_K + M_0. \quad (28.4)$$

Volume of trees, surviving from the previous cycle at the moment of remeasurement after  $n$  year

$$M_A = \sum_{i=1}^l V_{Ai}. \quad (28.5)$$

$V_A$ —current volume of  $i$ -th tree.

Gross periodical increment of surviving trees per permanent plot

$$Z_M = \sum_{i=1}^l V_{Ai} - \sum_{i=1}^l V_{A-ni} = M_A - M_{A-n} + M_K + M_0. \quad (28.6)$$

Indicating change of volume ( $M_A - M_{A-n}$ ) on permanent plot during  $n$  years by  $\Delta$ , finally the gross periodical increment of comparable plots, stands, forest areas is equal to sum of growing stock volume change ( $\Delta$ ), volume of felled ( $M_K$ ) and volume of dead trees ( $M_0$ ) during a period of  $n$  years

$$Z_M = \Delta + M_K + M_0. \quad (28.7)$$

For temporary plots gross periodical increment

$$Z_M = M_A - m_{A-n}, \quad (28.8)$$

where  $M_A$  is the current volume of trees,  $m_{A-n}$  is the volume of trees  $n$  years ago, estimated by restoring diameter and height of trees  $n$  years ago, using diameter increment data and corresponding models.

The volume of all living trees on temporary plots  $n$  years ago is estimated by modelling diameter and height of trees. Diameter is modelled using data from bored sample trees. The height of trees  $n$  years ago is estimated by regression depending on the site index estimated during inventory, and the relationship between mean diameter, mean height, diameter and height of trees, used in NFI data processing system (Kuliešis et al. 2014). The weakness of gross increment, estimated using temporary plots (Eq. 28.8), is the impossibility to estimate dead and removed trees volume as well as their increment directly. Using permanent plots the estimation of net annual increment from Eq. 28.7 is very simple

$$NAI = \Delta + M_K \quad (28.9)$$

Estimation of net annual increment, using data from temporary plot requires additional information about the volume of dead trees during the period of analysis.

The increment of felled and dead trees (before their removal/dying) can be included both in the gross and net increment estimates, using measurements on

permanent plots. Increment of felled and dead trees is estimated according to increment of similar sized remaining trees in permanent plots. The volume of dead and felled trees, estimated  $n$  years ago is increased by half of the periodical increment of trees of a similar size. Estimation of increment of dead and felled trees on temporary plot is complex and has a lower accuracy. It is problematic to estimate not only increment but also the volume of dead and felled trees during the specified period due to difficulties identifying time of felling and especially of death trees. The total gross increment (used in national statistics) is estimated by summing the change of trees volume as well as volume of felled and dead trees. The net increment (for some international statistics) is estimated by subtracting the volume of dead trees from the gross increment in the period of analysis.

### 28.3.3.2 Estimation of Cuttings, Removals and Mortality

The volume of felled and dead trees contains an important part of gross increment. Cuttings are estimated using measurements on permanent plots. Data are presented for a 5 year period for all forests, forests by ownership, types of cuttings, dominant tree species. Felled tree volume is distributed by four tree dbh groups' 12 cm in size: up to 14, 14.1–26, 26.1–38 cm and over 38 cm.

Information on dead trees from permanent plots of NFI is presented by two types. Firstly, the volume of dead (during the last 5 years) trees is a very important component of the gross increment estimation. It is an important indicator on the intensity and efficiency of forestry measures such as intermediate fellings. The next point is the total volume of dead trees, suitable for fuel wood, accumulated per stand for the inventory moment. Since 2008, the level of decomposition of all dead trees wood is assessed and results are presented.

Total drain consists of felled stem wood by various types of felling and natural losses i.e. unused dead trees (Table 28.9).

One third (33 %) of total gross increment is accumulated in forest stands (volume change); 1.47 million  $\text{m}^3$  are in forests of I–II group (strict reserves and special purpose forests) and 4.43 million  $\text{m}^3$  in forests of III–IV group—exceptionally in forests, available for wood supply (Table 28.9). Cuttings of living trees contain 45 % of all gross increment, from them in forests III–IV groups—7.70 and 0.36 million  $\text{m}^3$  in forests of II group. Mortality or newly dead trees contain 22 % of gross increment. Intensity of mortality approximately is of the same size in forests of I–II group (1.9  $\text{m}^3/\text{ha}$ ) and III–IV group (1.8  $\text{m}^3/\text{ha}$ ). Only 0.4  $\text{m}^3/\text{ha}$  of dead trees are felled and removed from forest, what contain 5 % from gross increment. It means, that 17 % of gross increment remains in forest unused, as natural losses, the biggest share—in forests reserved for restitution (26 %) and the least—in private forests (15 %) (Table 28.9).

An estimate of 6.4  $\text{m}^3/\text{ha}$  for dead trees, suitable for consumption, was recorded during the establishment of permanent plots between 1998 and 2002 years (Table 28.10). During the next 10 years, 2003–2012, 17.6  $\text{m}^3/\text{ha}$  of new dead trees were recorded. The least mortality rate was ascertained in coniferous stands,

**Table 28.9** Mean annual gross increment, mortality and cuttings in Lithuanian forests (stem volume over bark, mill. m<sup>3</sup>) (NFI 2008–2012)

Indicator	Forest groups	All forests	State forests	Private forests	Forests reserved for restitution
Gross annual increment	Total	17.80	8.08	7.81	1.92
	I + II group	2.36	1.39	0.72	0.25
	III + IV group	15.44	6.69	7.08	1.66
Area (1000 ha)	Total	2092.1	1010.4	869.3	212.0
	I + II group	284.1	178.7	76.3	29.1
	III + IV group	1808.0	832.2	793.0	182.9
Volume change, (mill. m <sup>3</sup> /year)	Total	5.89	2.28	2.42	1.21
	I + II group	1.47	0.87	0.44	0.16
	III + IV group	4.43	1.41	1.98	1.04
Total cuttings, including dead trees	Total	8.97	4.50	4.23	0.22
	I + II group	0.43	0.24	0.17	0.02
	III + IV group	8.53	4.26	4.06	0.21
Final cuttings, living trees	Total	4.82	2.69	2.10	0.04
	II group	0.04	0.04	0.00	0.00
	III + IV group	4.79	2.66	2.09	0.04
Intermediate cuttings, living trees	Total	3.24	1.38	1.69	0.15
	II group	0.32	0.16	0.15	0.02
	III + IV group	2.91	1.22	1.55	0.14
Total cuttings, living trees	Total	8.06	4.07	3.78	0.19
	II group	0.36	0.19	0.15	0.02
	III + IV group	7.70	3.88	3.64	0.17
Cut dead trees	Total	0.91	0.43	0.44	0.03
	II group	0.07	0.05	0.03	0.00
	III + IV group	0.83	0.38	0.42	0.03
Mortality	Total	3.85	1.72	1.60	0.52
	I + II group	0.54	0.32	0.14	0.08
	III + IV group	3.31	1.40	1.46	0.45

**Table 28.10** Dynamic of dead trees in Lithuanian forests (permanent plots of NFI) during 1998–2012 years

Forest type <sup>c</sup>	Volume <sup>a</sup> of dead trees (m <sup>3</sup> /ha) 1998–2002		Newly dead trees <sup>a</sup> (m <sup>3</sup> /ha)				Felled dead trees <sup>a</sup> (m <sup>3</sup> /ha)				Dead trees what wood became unusable (m <sup>3</sup> /ha)					Volume <sup>a</sup> of dead trees (m <sup>3</sup> /ha) 2008–2012		Structure <sup>b</sup> of wood volume (%)	
	1998–2007	2003–2012	1998–2007	2003–2012	1998–2012	2003–2012	1998–2007	2003–2012	1998–2012	Total	Completely	Partially	Volume	Share of decayed wood (%)	From them decayed	2008–2012	2012	Unusable trees	Completely decayed
Pine	6.2	6.6	12.8	2.0	2.4	4.4	2.5	2.6	5.1	0.4	4.7	59	9.9	16	9.9	16	16	16	
Spruce	6.6	7.4	14.0	2.3	2.5	4.8	2.7	3.4	6.1	0.4	5.7	60	9.6	11	9.6	11	11	7	
Birch	8.4	9.6	18.0	1.2	1.5	2.7	3.8	6.6	10.4	0.7	9.7	59	9.7	22	9.7	22	22	12	
Aspen	13.7	13.5	27.2	3.0	3.9	6.9	4.7	7.0	11.7	1.2	10.5	60	17.4	7	17.4	7	7	12	
Black alder	10.1	11.6	21.7	1.9	1.6	3.5	5.0	6.3	11.3	0.7	10.6	61	13.1	10	13.1	10	10	5	
Grey alder	13.1	14.6	27.7	0.8	1.2	2.0	8.5	11.7	20.2	1.7	18.5	59	11.4	25	11.4	25	25	31	
Oak	9.4	11.6	21.0	2.4	2.6	5.0	3.6	5.1	8.7	0.6	8.1	60	15.6	1	15.6	1	1	1	
Ash	15.7	30.0	45.7	2.8	7.1	9.9	4.2	4.3	8.5	1.1	7.4	70	34.2	3	34.2	3	3	12	
Other	5.0	11.2	16.2	0.6	1.0	1.6	2.3	4.2	6.5	0.6	5.9	61	13.3	5	13.3	5	5	4	
Total	8.3	9.3	17.6	1.9	2.2	4.1	3.6	4.9	8.5	0.6	7.9	61	11.2	100	11.2	100	100	100	

<sup>a</sup>Trees, of which wood is suitable, as minimum, for fuel wood

<sup>b</sup>Data presented by tree species independently on stand in which tree is growing

<sup>c</sup>Tree species: Pine—*Pinus sylvestris*, Spruce—*Picea abies*, Birch—*Betula pendula*, B. *pubescens*, Aspen—*Populus tremula*, Black alder—*Alnus incana*, Grey alder—*Alnus glutinosa*, Oak—*Quercus robur*, Ash—*Fraxinus excelsior*

ranging from 12.8 (pine) to 14.0 (spruce) m<sup>3</sup>/ha/10 years. The largest mortality rate was recorded in aspen, grey alder stands, ranging from 27.2 (aspen) to 27.7 (grey alder) m<sup>3</sup>/ha/10 years. Mortality in ash stands was high as a result of heavy disease damage, totalling 45.7 m<sup>3</sup>/ha/10 years, (Table 28.10).

The increase in the volume of dead trees during 10 years (NFI 2008–2012 compared to the NFI 1998–2002) is ascertained as the result of accumulation of over-mature stands (more than 20 % of total matured stand area) and leaving biodiversity trees in clear cut areas up to 12–15 m<sup>3</sup>/ha. Only 23 % of dead trees were felled and utilised. Nearly half (48 %) of all new dead trees during the 10 year period became unusable natural losses, the remaining 29 % added to the volume of dead trees in stands. The volume of all unusable trees decomposed completely by 7 % during 10 years, while others partially decomposed losing 61 % of wood. The usable dead tree volume, accumulated in stands, increased by 1.75 times during 10 years (Table 28.10). The largest shares of unusable trees volume and completely decayed volume consisted of broadleaved species trees (64 and 60 %, respectively), especially of grey alder trees—25 and 31 %. The proportion of unusable pine and spruce trees volume in total unusable trees volume was 27 %. Amongst the completely decayed trees volume of pine and spruce trees contained 23 %, while oak trees contained only 1 % (Table 28.10).

#### ***28.3.4 Other Wooded Land and Trees Outside Forests***

All woody plants, growing on OWL or all other trees growing outside forest are measured using the same methodical principles, applied on NFI forest plots: diameters of trees at breast height and heights of sample trees are measured. The volume of trees is the main characteristic estimated as result of inventory and is used for biomass estimation in the process of carbon and energy wood reserve assessment (Table 28.11). The volume of trees, growing outside forests, contains 4.5 % of the total volume of trees growing in forests stands. Broadleaved tree species dominate (90 %). According to IPCC land use categories (IPCC 2003) the largest part of trees grows on natural and cultural grasslands (53 %) and in settlements including roads (34 %).

### **28.4 Discussion and Conclusion**

Amongst SFM indicators the most important are Growing stock volume (1.2), Carbon stock (1.4, Criterion 1), Increment and felling (3.1), Roundwood (3.2, criterion 3), Deadwood (4.5, Criterion 4). These indicators are very important components of the wood supply and carbon accumulation chain as well as maintaining forest biodiversity. Gross increment includes all these indicators as separate



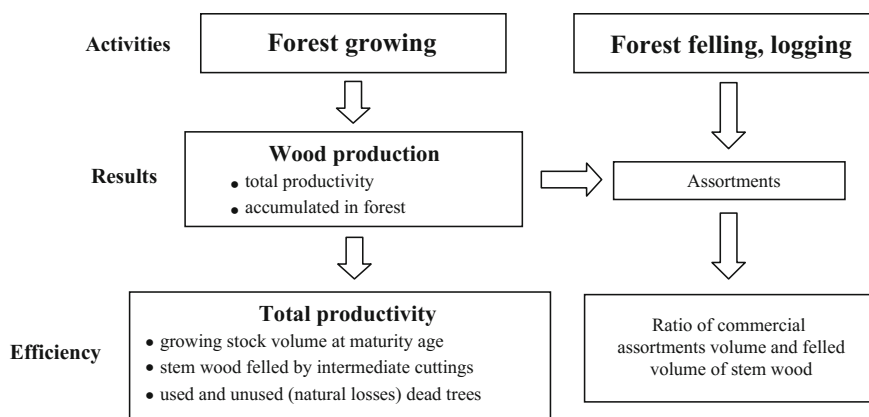
**Table 28.11** Volume of tree stems, growing outside forests (NFI 2012–2013)

Land use category (IPCC 2003)	Area (A)		Volume of living trees V (mill. m <sup>3</sup> )			
	Total		Coniferous	Broadleaves	Total	
	A (mill. ha)	P <sub>A</sub> <sup>a</sup> (%)			V	P <sub>V</sub> <sup>a</sup> (%)
Cropland	2.16	1.8	0.08	0.74	0.82	51.0
Grassland	1.46	2.3	1.25	10.96	12.21	13.8
Wetlands	0.28	5.8	0.06	2.24	2.29	31.5
Settlements	0.41	4.8	0.84	6.91	7.75	20.3
Total	4.32	1.3	2.23	20.85	23.08	10.6

<sup>a</sup>P<sub>A</sub>, P<sub>V</sub>—accuracy of estimation corresponding area and volume

components of total increment: intermediate yield, dead trees, from them used during felling and final yield (Fig. 28.1).

Gross increment is the main and the most important indicator of the potential productivity on a forest site. Depending on the forest management system applied the total productivity and its structure will differ. Total productivity is defined as the sum of gross increment over the stand rotation. The proportion of dead trees per total productivity and especially the share of unused stem volume of dead trees demonstrate the efficiency of the forest management system and identify ways to improve silviculture and wood utilisation. Gross increment is a very important indicator for the assessment of forest resources as well as for estimating and controlling the efficiency of all forest management system. These estimations indicate aspects where forest management systems may be improved. The ratio of growing stock accumulated in stands at maturity (growing stock of mature stands) and total productivity depends on the silviculture practices applied in the stand and indicates efficiency of forest management practices. The carbon stock directly depends on gross increment and its components: volume of accumulated, felled and dead trees.

**Fig. 28.1** Scheme of wood flow and its monitoring

Harvesting is the final stage in the forest cycle and the output can be evaluated by the ratio of main wood products—round wood, energy wood and total growing stock volume at maturity age. Harmonisation of gross increment and its assessment components is an essential step to improve data on total productivity and its use in forests of every individual country and all Europe forests. Analysis of regular and reliable information on total productivity and its use allow us to identify ways to improve forest management and wood utilisation practices. It also identifies ways to improve the regulation of total productivity balance and to achieve sustainability in multifunctional forest use system.

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