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Chapter 15
Croatia

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15.1 The Croatian National Forest Inventory

15.1.1 History and Objectives

In Croatia, the first forest area mapping and forest inventory date to the eighteenth and nineteenth century in some regions. However, these early inventories were local-level surveys for the preparation of management plans. A large-scale forest survey on the entire area of the former state was conducted after World War II. The aim was to assess the state of forests after the war (1946–1952) and to provide spatial information for forests on a regional scale and to facilitate sustainable forest management. However, since this inventory, a consistent national level forest inventory had not been conducted until 2009. Since the foundation of the Republic of Croatia in 1990, the state of the national forest resources has been assessed using stand-wise management plans for all management units ("bottom-up approach"). The State General Forest Management Plans (GFMP 1996, 2006), which are based on the stand-wise inventory and compiled every 10 years, were the basis of national reporting for Forest Resources Assessment by FAO (FAO 2005).

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The first Croatian NFI started as a pilot project in 2005 and was conducted during the years 2006–2009 (Vedriš et al. 2010). Field assessments were based on a permanent systematic sampling grid as a base for monitoring changes in forests. The planned time interval between inventories is 10 years and the period for field assessments of the entire area of the Republic of Croatia should take no more than 2 years. Due to increasing national and international requirements, new ecological parameters, and assessments of sustainability, biomass, biodiversity, protective function of forests as well as activities in the land use, land-use change and forestry, will be considered in subsequent NFIs. The Croatian NFI is the main information source and tool for large-scale forest management planning and forest industry at the national level. It is also used for forest resource information for reporting obligations and international statistics such as the Global Forest Resource Assessment by FAO (2005, 2006), the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2007) and LULUCF reports of the United Nations Framework Convention on Climate Change (UNFCCC 2007).

15.1.2 Sampling Methods and Periodicity

The 2005 Croatian NFI was the first assessment of forest resources covering all forests within the national territory. The field measurement period lasted for 3 years, including data processing, analysis, reporting and publication of results. The planned time span between the first and second NFI is 10 years (initially set as 15 years). Only forest areas were assessed in the first NFI. However due to demands for comprehensive landscape monitoring, the second NFI will cover all the national territory including field and aerial photo assessment of other wooded land on inventory plots and the remote assessment of other land use categories.

The design of field sample plots is based on sampling grid of 4 × 4 km. The sampling grid consists of approximately 4376 squares (16 km^2), of which 1932 squares are located within forest area. At the corners of the squares within forest land a quadratic cluster of sample plots are established. The concentric circular sample plots are located at the corners of the clusters and arranged in quadratic order with a side-length of 150 m (Vedriš et. al 2010). The grid size, cluster size and shape are the same all over Croatia. In the first NFI 6232 permanent forest plots were established.

The cluster square, with an area of 2.25 ha, was used for the assessment of land use categories: forest, other wooded land, pasture, other non-wooded land (urban, agriculture, water surfaces, barren lands), linear features and forest roads. The type and category of forest road was assessed according to: road width, pavement, condition, longitudinal inclination and length of road within the cluster square. However, this sample of land use categories assessment is not representative for the whole territory.

The sample plots consist of a large circular plot of radius 25 m, four concentric circular plots with radii 3.5, 7, 13 and 20 m, and a small circular plot with radius

2 m. At least 50 % of the plot has to be covered by forest to include the plot into sample, and at least one group of concentric plots of each cluster has to be sampled. The large circular plot (r = 25 m) is the basis for assessment of management-(ownership categories, restriction of wood use, accessibility, logging technologies and skidding distance), stand- and site-specific variables. The smaller plot (r = 13 m) is used for the assessment of stand regeneration (coverage, plant origin, species mixture, quality, cause and degree of damage) of plants up to 1.3 m height. The smallest circular plot (r = 2 m), located 10 m northwards of the plot centre, is used for the assessment of small trees dbh 0–10 cm by diameter classes (0–3.9, 4–6.9, 7–9.9), tree species, number of trees and average height. The four concentric circular plots (radii 3.5, 7, 13 and 20 m) are used to assess and measure tree-specific variables. The 3.5 m plot is used for measuring trees of dbh 5–10 cm in all selection and uneven-aged forests, Mediterranean forests and young even-aged stands due to expected significant presence of this diameter class in the forests. Trees with dbh ≥ 10 cm were measured on the second plot (r = 7 m), trees with dbh ≥ 30 cm on the third plot (r = 13 m) and large trees with dbh ≥ 50 cm were measured on the largest plot (r = 20 m). Measurement and assessment of trees on the concentric plots include the following variables: tree species, azimuth, horizontal distance, inclination, tree height, dbh, stump diameter, girth at breast height, bark thickness, tree canopy layer, stem quality, bole damage, crown damage, crown defoliation, status of tree (standing alive, recumbent alive, standing dead). Forest plots covered by different stands were subdivided to describe and assess separately for each stand. The trees felled during the 5 years prior to field measurement were assessed on the 13 m radius plot [tree species, azimuth, horizontal distance, inclination, two stump diameters, stump status (1–2, 3–5 years)]. The plot (r = 13 m) is used for the assessment of lying dead wood according to: number of stems, diameter classes, degree of decomposition and tree species (conifers, broadleaved).

15.1.3 Data Collection

The Croatian NFI provides basic data such as the distribution and allocation of forest area, sample plots, forest roads and categories of land use by counties (Forest Administrations), bioclimatic zones according to Trinajstić et al. (1992) and Antonić et al. (2000), forest types and ownership categories. Besides the basic data, there are usually three main categories of data assessed and provided by Croatian NFI: stand-specific variables, site-specific variables and sample tree-specific variables.

Based on field inventory of stand-specific variables, the forest stand in which the sample plot is located can be described as follows:

- Origin and stand establishment (seed stand, coppice, mixed seed and coppice, plantation)
- Management system (even-aged, uneven-aged, selection system)
- Age assessed by visual expertise and ancillary data such as those contained in management plans, growth yield tables (age classes in 10-year and 20-year intervals for even-aged stands)
- Stand structure (even-aged one-storied, even-aged two-storied, single stem selection, group stem selection, irregular, old-growth)
- Development stage of even-aged stand: young stand (up to 10 cm dbh), pole stage (10–20 cm), stage of grown trees (up to half of rotation), middle aged stand (1/2–2/3 of rotation), older stand (2/3 of rotation up to upper border of penultimate age class), coppice <10 cm dbh, coppice 10–20 cm dbh, coppice >20 cm dbh, shrubs, *macchia* and *garigue*
- Tree species composition
- Crown cover
- Stand quality
- Ground perennial vegetation
- Damage (abiotic, biotic, anthropogenic)
- Naturalness (virgin forest, managed stands with natural regeneration, managed stands with supported natural regeneration, forest plantation)
- Homogeneity (one stand on plot, two or more stands, heterogeneous stand structure)
- Shrub cover
- Regeneration
- Deadwood.

The assessment of site-specific variables includes the following variables:

- Elevation above sea level
- Aspect (i.e. slope direction)
- Slope gradient
- Relief categories (plain, ledge, bottom of hollow, brow, ditch)
- Soil layer thickness
- Soil degradation (litter, humus, rockiness)
- Erosion (soil movement)
- Waste in forest.

The Croatian first NFI provides basic tree-specific variables assessed and measured on sample trees. The inclusion of several new tree-specific variables into the next inventory cycle will be considered, including: age class, growth class, height to the living crown base, crown radius, tree assigned for felling. The tree-specific variables assessed and measured on sample trees are:

- Species
- Tree position (horizontal distance and azimuth)
- Tree height

- Diameter at breast height
- Girth at breast height (for large trees)
- Bark thickness
- Tree canopy layer
- Stem quality
- Bole damage
- Crown damage
- Crown defoliation
- Dead standing tree.

More detailed information and description of the data collection by the first Croatian NFI, the assessments and measurements of site, stand and tree-specific variables can be found in the field protocol (Čavlović and Božić 2008).

15.1.4 Data Processing, Reporting and Use of Results

Forest area and field assessments were the basis of the estimation and classification (stratification) of Croatian forest resources. The input variables of these assessments (spatial data base, field data base) were integrated into the computer program ANFORRES (Analysis of Forest Resources) for data storing, processing and reporting (Čavlović 2010).

Forest area was estimated as a continuous variable through the classification of satellite images (IRS P6 LISS III multispectral images of 20 m resolution) and delineation of the border between forest and non-forest land. The spatial distribution of forest areas according to different spatial categories was obtained by overlaying the delineated forest boundaries with other spatial layers (e.g. county, Forest Administration, forest type, etc.).

The estimation of forest area by several categories (e.g. forest area by ownership categories, categories of management-, stand- and site-specific variables) was based on the estimated spatial distribution of forest area and the relative portions of each of the categories. The "relative" forest area was estimated by multiplying share of each category assessed on the field sample plots (quotient of sample plots in each category and total number of plots) and the forest area for the defined spatial entity (e.g. county, Forest Administration, forest type, etc.).

As well as category variables, ANFORRES provides estimates of forest open area and road density (m ha^{-1}) as average values by comparing the assessed length of forest roads and area of cluster square (2.25 ha).

Sample tree-specific variables were basis for the estimation of the volume of standing stock (including both growing and dead standing stock), growing stock and harvest, which is of particular interest for productive forest area. Therefore, quality control procedures were performed during field-data collection, data entering and storing. The estimation of average measured, modelled and derivative variables was based on the field data (tree height, dbh, stump diameter, bark

thickness, tree height/dbh models, dbh/stump diameter models, tree volume/dbh-height models, stem number per ha, basal area per ha, volume per ha). The volume of each sample tree is calculated using appropriate national volume equations specific to tree species, size and status of the sample tree. Each sample tree, depending on its size and concentric plot position represents a corresponding per hectare value for stem number, basal area and volume. Consequently, for each group of concentric plots the total volume per hectare is calculated as the sum of hectare values represented by the individual sample trees. Depending on the strata (e.g. forest type, age-class, county, etc.), these per hectare estimates are aggregated to a mean volume per hectare and multiplied by the corresponding area of productive forest to obtain the total volume of standing stock or growing stock. Based on the volume estimations and using general biomass expansion factors and coefficients, the carbon sequestration in above-ground and below-ground biomass, dead wood, litter and forest soil was also estimated. The structure of the database is shown in Fig. 15.1. This determines data processing and reporting of results using the ANFORRES software.

The first Croatian NFI provides estimates of forest resources (forest area, tree species composition, tree-specific variables, characteristics of stand structure, standing and growing stock, management and harvest, deadwood, carbon sequestration, stand regeneration, health status and vitality of stands, and site characteristics) at the national level and different regional scales (5 bioclimatic zones, 16 forest types, 16 Forest Administrations, 21 counties). Change estimates are not available due to the fact that only one NFI has been conducted.

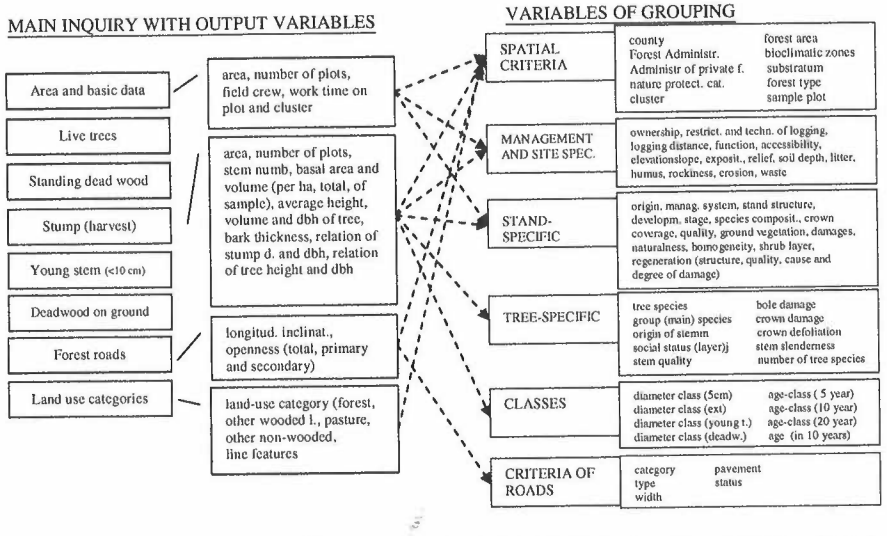

Fig. 15.1 The main structure of inquiry for variables, data processing and reporting of results provided in the ANFORRES computer program

The NFI obtained results have a significant potential at national level as a basis for decision-making in forest and environment policy, forest management planning and monitoring of forest resources, changes and effects of forest management. At an international level the results are required to satisfy reporting obligations in processes such as the Forest Resources Assessment by FAO (2005, 2006) the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC). Likewise, the NFI provides a valuable data source for different research projects and scientific publications (e.g. Čavlović et al. 2012; Temunović et al. 2012). Finally, the first NFI provides a basis for preparing and improving methods for the next NFI.

15.2 Land Use and Forest Resources

15.2.1 Classification of Land and Forests

15.2.1.1 General Land Classification

The first Croatian NFI did not include an assessment of the total national area. Satellite image classification included two phases:

- forest/non-forest classification (delineation of border between forest and non-forest land) with a minimum mapping unit of 0.2 ha (5 pixels)
- classification of forest land on sub-strata (broadleaved, conifers, mixed, young stands, unstocked parts of forest).

Forests are defined as an area that has a minimum area of 0.5 ha, a minimum width of 20 m, and a minimum crown cover of woody plants of 10 %. The classes of forest functions (i.e. productive forest, protective forest, multifunctional, nature protection, other) were assessed on the sample plots (Čavlović and Božić 2008).

The total national classification area by land-use classes is available according to CORINE nomenclature with reference years. The total national area according to the classification is distinguished into continental land area (64 %) and sea surface (36 %), while continental land is distinguished into forest and non-forest land. The area and description of classes with corresponding FRA classes are given in Table 15.1. In this table the category of forest covers 3123 thousand ha while the NFI assessed the area forest and other wooded land to be 2581 thousand ha. The difference in the two forest estimates is due to the definitions of forest applied and differences between the assessment methods with corresponding FRA classes. It is notable that the CORINE forest land includes other land and other land with tree cover, and conversely, the FRA non-forest land classes include forest land and other wooded land.

Table 15.1 Land use classes according to the Corine Land Cover (CLC) classification and correspondence with FRA classes

Class name		Description	Area (1000 ha)	Corresponding FRA classes (FAO 2012)
Forest	Forest land	Forests, shrubs and/or grassland vegetation, unstocked parts of the land	3123	Forest, intersection with OWL, intersection with OL and OLwTC
Non-forest	Agricultural land	Cultivated agriculture land, orchards and vineyards, plantations, grazing land, other agriculture land	2284	OL, OLwTC, intersection with forest
	Natural land	Water bodies, reed beds, bogs, heath lands, rocks, areas of gravel and debris, landslides, other natural lands	74	OL, OLwTC
	Built-up land	Industry and commerce, mining, traffic and transport, disposal sites, tourist facilities, dwellings and parking sites, gardens and parks	177	OL, OLwTC
Total continental land area			5659	
Sea surface			3159	
Total state area			8818	

15.2.1.2 Forest Classifications by Use

The second phase of classification on satellite images distinguished total area of forest land on stocked forest area (2378 thousand ha) and permanently or temporarily unstocked forest land (203 thousands ha). The assessment includes shrub and *macchia* land as forest land. Using the assessed stocked forest area and field assessments on sample plots, forest land can be further sub-divided according to the forest management system, the forest function, and origin and type of forest cover. About 78 % of the forest area is covered with high forest while the remaining area includes relative high share of coppice forest (15 %) and shrub and *macchia* land (7 %). Subdividing the forest area according to forest function is relevant with regard to availability of wood resources. Based on the field assessment, three categories of forest function are defined as follows:

Table 15.2 Classes within forest land and their areas (first NFI, 2006–2009)

Class of forest land	Description		Area (1000 ha)	
Productive forest – high forest – coppice forest	Forests available for wood supply, includes multipurpose forests	Stocked or temporarily unstocked	2141	2312
		Shrub and *macchia*-land	171	
Protective forest – high forest – coppice forest	Forests with protective function and without available yield	Stocked or temporarily unstocked	40	45
		Shrub and *macchia*-land	5	
Nature protection and biodiversity	Forests of nature protection and social purpose, and without available yield	Stocked or temporarily unstocked	20	21
		Shrub and *macchia*-land	1	
Permanently and temporarily unstocked parts of the forest	Unstocked due to – Forest management (e.g. forest roads, timber yards) – Natural reasons			203
Total forest land area				2581

1. Productive
   Forest areas with primary economic function and fully available for wood supply. This category includes also multipurpose forests with significant ecological and social functions, in which commercial harvests are allowed.
2. Protective
   Forests located in poorly accessible or inaccessible locations, on very poor productivity sites. They have significant role in soil protection and are not available for wood supply.
3. Nature protection and biodiversity
   Forests protected by law for ecosystem services, nature protection and conservation of biological diversity.

The accessibility of the forest was not assessed during field assessment. In forests under protection of nature and biodiversity, due to their strict role and management restrictions, there is no availability for wood supply. All classes include coppice forest and shrub and *macchia* land. The distribution of forest area according to classes is shown in Table 15.2.

15.2.1.3 Classification by Ownership Categories

The Croatian NFI distinguishes forest ownership into two main categories: private forests regardless of property size (small-scale private forest property <1 ha is

Table 15.3 Forest area by ownership categories (first NFI, 2006–2009)

Ownership category		Area (1000 ha)	Area (%)
Private forests		593	23.0
State forests	Enterprise "Hrvatske šume" Ltd.	1692	65.5
	Other state (public) forests	296	11.5
Total forest area		2581	100

dominant), and state forests managed by the state enterprise "Hrvatske šume" ("Croatian forests") Ltd. These categories have been assessed in the field at plot level, and the area of each category is estimated using the proportion of field plots corresponding to the specified category and total forest area. The total area of state forests can be divided into the following categories using GIS: forests with public access, the different forest categories of nature protection (nature parks, national parks, strict reserves), educational and military forests, out of management or under restricted management (nature parks) within the state enterprise "Hrvatske šume" Ltd. Nearly one quarter (23 %) of the Croatian forest estate belongs to category of private forests. Forests of high ecological and social use (other state forests) comprise about 11 % of the Croatian forest area (Table 15.3).

15.2.1.4 Forest Management and Cutting Systems

Even-aged forest management was assessed as dominant management system in Croatia, covering 75 % of total forest area (78 % in state and 63 % in private forests), while different uneven-aged management systems and irregular (transitional) stand structures were assessed on the rest of the forested area (Čavlović et al. 2003, 2012; Čavlović 2010). Selection management, primarily single stem selection covers almost 6 % of the total forest area and mostly relates to the spatial distribution of silver fir. Sub-Mediterranean forests, protected forests, coppice forests and small-scale private forests are characterised by different uneven-aged and irregular structures. Recently, uneven-aged forest management forming of stands composed of mosaic of developmental stages, stage size between 0.25 and 1.00 ha has been applied in small private forests and forests within nature parks (RFMP 2006), which will gradually lead to an increased share of uneven-aged forest stands. The development of even-aged stands and their regeneration usually include the following management activities: stand establishment with natural regeneration or planting, enlargement of growing space and cleaning, thinnings and regeneration fellings. Selection management of cursiv? (silver fir) stands is characterised by single stem and small group felling of mature trees and thinning in gaps of small and medium sized trees, every 10 years, with average 10-year cutting intensity of 21 %. The design of uneven-aged stands is based on regenerating up to 10 % of stand area by harvesting of small areas, up to 1 ha, and thinning of rest stand area on a 10 year interval.

Although types of harvesting have not been assessed, rough estimates of harvested wood volume are available. These can be distinguished by the type of

harvesting through the stratification of plots and assessed harvests (amount and structure) by forest types, owner categories, management systems, diameter classes and age classes. The harvested wood volume can be distinguished as: regeneration fellings and thinnings in even-aged stands, single stem and small area felling in uneven-aged stands, clear cuts and sanitary (salvage) fellings. Harvested wood volume in broadleaved plantations, coppice stands with vegetative regeneration and high intensive fellings in non-mature even-aged stands and uneven-aged stands are assessed as clear cuts. Regeneration fellings including final cutting of remaining trees (44 %) and thinnings (25 %) account more than two thirds of total harvested wood volume, while cutting of single stems and of small areas in uneven-aged forests amounts about 20 % of the total harvest. About 6 % of harvested wood was felled in clear cuts, and the remaining 5 % is salvage logging. Considering the diameter structure of harvested wood volume, the share of harvested trees dbh > 50 cm amounts to 65 %, or trees dbh > 60 cm amounts to 50 % and trees >70 cm amounts to 35 %, while volume of harvested trees of dbh < 20 cm amounts to 2 %.

According to the Forest Act (FA 2006) and Regulation for forest management planning (RFMP 2006), harvesting operations must be prescribed. A deviation from the prescribed harvested volume of 10–20 % is allowed, depending on the type of harvest. For uneven-aged stands a 10-year harvest is limited to maximum 30 % of standing volume. A new even-aged stand has to be established either by natural regeneration or planting latest at the end of the third year following the year of the final cutting. Clear cut areas larger than 0.2 ha (salvage logging) have to be re-established by seeding or planting in the same vegetation period or at beginning of the next vegetation period.

15.2.1.5 Legal and Other Restrictions for Wood Use

Forests are of extraordinary significance to the Croatian state. This is obvious from the fact that the forest is mentioned in the Croatian Constitution in article 52 as a resource of particular interest which enjoys a special state protection. Furthermore, the treatment of the entire forest is regulated by the Forest Act (FA 2006). This Act regulates the silviculture, protection, use and management of forests and forest land as a natural resource, in order to maintain biodiversity and ensure management based on the principles of economic viability, social responsibility and environmental acceptability. Depending on the management objective, forests can be commercial forests, forests with protective functions and special purpose forests.

Forests within protected areas or areas of natural value are protected by regulations on nature protection which are the basis of specific management plans for these areas. Forests of all categories may have certain restrictions for the wood supply. In commercial forests the dominant function is the production of wood, but in a way that production is balanced with other functions of forests. Within protective and protected forests, depending on their purpose, harvesting can be totally forbidden or limited. Harvesting is not allowed in strict forest reserves and national parks. In all other categories, the harvesting of wood is permitted in accordance

with the characteristics and degree of protection afforded (historical sites, water protection areas, military training areas, research forests, nature parks, etc.). The silvicultural treatment applied to environmental and production characteristics of habitats also causes some restrictions for wood supply. For example, clear-cutting is prohibited in Croatia except in forest plantations. In mountainous areas due to significance of soil protection from erosion, there are also some limitations and requirements for harvesting, management system and intensity of logging within commercial forests. A maximum of 30 % of the existing growing stock can be harvested every 10 years.

15.2.1.6 Further Classification of Forests

Besides land use classes and ownership categories, further classification of forest area has usually been based on tree species, age classes and growth classes. The forest area stratifications by these variables for the first NFI are described in this section.

The stratification of the productive forest area by tree species is based on the field assessment of basal area of sampled trees and assessed forest area within several spatial levels (national level, forest bioclimatic zone, county, Forest Administration, forest type). The forest area of each tree species is estimated as a product of relative portion of tree species, using sampled basal area of each tree species divided by the total basal area of all tree species sampled and the assessed productive forest area, which is adjusted downwards to take into consideration the area of young stands (115 thousand ha). The age of stands (rounded to 10 years) has been assessed only for even-aged forests while age of individual sample trees has not been assessed. Thus, forest area stratification by age classes for total forest area is not available for selection and uneven-aged forests. Likewise, categories of growth classes (stage of stand development) have been assessed on sample plots only within even-aged forests. Productive forest area for the selection and uneven-aged forests can be stratified by diameter classes. The stratification of forest area by age classes was based on proportion of sample plots on which age has been assessed and productive forest area of even-aged forests. The stratification of forest area by growth classes (tree size) was based on tree sizes and total productive forest area, excluding the areas with trees below 1.3 m height-that cover at least 65 % of the plot.

In total 94 tree species occur in Croatian forests, while only 5 main tree species have share larger than 5 %. The predominant tree species is cursiv (European beech) with a share of almost one third of productive forest area (29.8 %), followed by common hornbeam which covers one tenth of productive forest area (10.0 %). Besides beech and hornbeam, three other less common tree species are highly valuable: pedunculate oak (7.5 %), sessile oak (7.1 %) and silver fir (5.4 %). The remaining 89 tree species together cover 36.6 % of the forest area. The productive forest area and the coverage by the tree species is given in Table 15.4.

The age-classes are assessed in intervals of 10 and 20 years, however, the area covered by the individual 20-year age classes is given in Table 15.5. The highest age class includes all tree ages above 140 years. Considering the total even-aged

Table 15.4 Stocked forest area by species (first NFI, 2006–2009)

Tree species	Area (1000 ha)	Area (%)
European beech (*Fagus sylvatica* L.)	708	29.8
Pedunculate oak (*Quercus robur* L.)	189	7.9
Sessile oak (*Quercus petraea* Liebl.)	170	7.1
Other oaks (*Quercus* spp.)	140	5.9
Common hornbeam (*Carpinus betulus* L.)	238	10.0
Narrow-leaved ash (*Fraxinus angustifolia* Vahl.)	61	2.6
Other broadleaved hardwood	341	14.3
Other broadleaved softwood	118	5.0
Silver fir (*Abies alba* Mill.)	129	5.4
Norway spruce (*Picea abies* (L.) Karsten)	49	2.1
Black pine (*Pinus nigra* J.F. Arnold)	41	1.7
Aleppo pine (*Pinus halepensis* Mill.)	37	1.6
Scots pine (*Pinus sylvestris* L.)	14	0.6
Other conifers	28	1.2
Young even-aged stands	115	4.8
Total productive forest land	2378	100.0

Table 15.5 Stocked forest area by age-classes (first NFI, 2006–2009)

Age class (years)	Area (1000 ha)	Area (%)
1–20	253	10.6
21–40	547	23.0
41–60	343	14.4
61–80	250	10.5
81–100	227	9.5
101–120	119	5.0
121–140	40	1.7
>140	5	0.2
Selection and uneven-aged forests	594	25.0
Total productive forest land	2378	100.0

forests in Croatia, the second and third age classes have the largest coverage while the two last have smallest coverage among all age classes. This is related to the presence of forest types of short rotation and the fact that high rotation forest types compose part of total even-aged forest area. Selection and uneven-aged forests cover almost 600 thousand ha. Small trees (dbh 10–30 cm) have highest coverage of the area (40 %) followed by medium large trees (dbh 30–50 cm) with coverage of 30 %, while large trees (dbh ≥ 50 cm) and young trees (< 10 cm dbh) cover 22 % and only 8 %, respectively.

Table 15.6 Stocked forest area according to the national definition by growth classes (first NFI, 2006–2009)

Growth-class	Area (1000 ha)	Area (%)
Regeneration I	59	2.5
Regeneration II	210	8.8
Pole stage	501	21.1
Timber I	709	29.8
Timber II	512	21.5
Large timber	387	16.3
Total productive forest land	2378	100.0

Based on the diameter structure of sampled trees, growth classes are defined by the tree size:

- Regeneration I: height below 1.30 m
- Regeneration II: minimum height of 1.30 m and a maximum dbh of 10 cm
- Pole stage: dbh from 10 to 20 cm
- Timber I: dbh from 20 to 35 cm
- Timber II: dbh from 35 to 50 cm
- Large timber: dbh ≥ 50 cm.

The area covered by the growth classes is given in Table 15.6. Regeneration classes cover smallest forest area, particularly Regeneration I. On the other side, Timber I has the largest coverage, followed by the growth classes Timber II and Pole stage with equal amount of 500 thousand ha, while Large Timber cover a little less than 400 thousand ha.

15.2.2 Wood Resources and Their Use

15.2.2.1 Standing Stock, Increment and Drain

Standing stock estimation is based on the sample plot tree measurements (i.e. tree diameters and heights) and available volume tables for several tree species. The tables define tree volume as the volume of the stemwood over bark, which includes all stem parts above the ground, i.e. the bole with bark and stem top excluding parts of branches smaller than 3 cm or 7 cm top diameter (Špiranec 1975, 1976). The commonly used minimum dbh is 10 cm measured over bark, while in all uneven-aged forests, Mediterranean forests and young even-aged stands the minimum dbh is 5 cm. The volume of these small trees (dbh 5–10 cm) is estimated as product of dbh, height and tree form factor (Table 15.7). The Croatian NFI estimates the volume of standing stock which can be divided into the volume of growing stock and volume of standing dead wood. Due to the fact that there are no two consecutive measurements, nor were increment cores sampled in the first NFI, estimation of increment is not available from the NFI. A rough estimate of increment given in Table 15.8 is based on the estimated volume of growing stock and

Table 15.7 Definitions for volume of standing stock, increment and drain in Croatian NFI

Quantity	Definition
Standing stock	Volume of standing trees (alive and dead) with dbh ≥ 10 cm over bark, including the bole (wood and bark), and stem top, and including the above-ground part of the stump. In uneven-aged forests, Mediterranean forests and young even-aged stands volume of trees with dbh 5–10 cm can also be provided
Increment	Volume increment of surviving trees with dbh ≥ 10 cm over bark as average estimation of growth period Final definition and proper approach, considering method of concentric plots sample (nongrowth trees), will be defined after completion of second NFI
Drain	Volume of trees with dbh ≥ 10 cm over bark as average estimation of tree volumes felled over a given period After completion of second NFI: volume of trees with dbh ≥ 10 cm over bark at the first measurement that were found to be harvested in the subsequent NFI

Table 15.8 The volume of standing stock, growing stock, increment, and drain on productive forest land by tree species for the first NFI (2006–2009)

Tree species	Standing stock (1000 m^3)	Growing stock (1000 m^3)	Increment 1000 m^3/year	Drain 1000 m^3/year
European beech (*Fagus sylvatica*)	196,135	192,283	4360	3543
Pedunculate oak (*Quercus robur*)	73,019	71,830	1477	1118
Sessile oak (*Quercus petraea*)	51,881	50,597	1127	537
Downy oak (*Quercus pubescens*)	7014	6634	153	29
Turkey oak (*Quercus cerris*)	11,460	11,318	246	114
Holm oak (*Quercus ilex*)	2235	2140	51	5
Narrow-leaved ash (*Fraxinus angustifolia*)	17,761	17,619	496	243
European hornbeam (*Carpinus betulus*)	50,930	50,526	1365	675
Hop hornbeam (*Ostrya carpinifolia*)	3733	3567	88	10
Black locust (*Robinia pseudoaccacia*)	13,648	13,172	400	342
Sycamore maple (*Acer pseudoplatanus*)	8417	8298	204	48
Other maple (*Acer* spp.)	8845	8583	211	38
Sweet chestnut (*Castanea sativa*)	6990	5849	171	48

(continued)

Table 15.8 (continued)

Tree species	Standing stock (1000 m^3)	Growing stock (1000 m^3)	Increment 1000 m^3/year	Drain 1000 m^3/year
Common alder (*Alnus glutinosa*)	10,248	9915	332	119
Linden (*Tilia* spp.)	7086	7014	230	71
Poplar (*Populus* spp.)	5255	4946	167	29
Willow (*Salix* spp.)	3828	3519	163	57
Other broadl. hardwood	14,148	13,672	392	53
Other broadl. softwood	1878	1759	57	10
Silver fir (*Abies alba*)	35,951	34,191	559	918
Norway spruce (*Picea abies*)	13,719	13,244	337	233
Black pine (*Pinus nigra*)	7371	7204	213	52
Aleppo pine (*Pinus halepensis*)	5683	5492	162	19
Scots pine (*Pinus sylvestris*)	3376	3162	93	62
Eastern white pine (*Pinus strobus*)	2877	2758	81	19
Other conifers	2948	2853	128	29
Total	566,437	552,146	13,263	8418

annual rates of volume increment for several tree species provided from a stand-wise inventory (GFMP 2006). Estimation of drain is based on measurements of stump diameters of felled trees during last 5 years and stump diameters of standing trees, on sample plots. The dbh/stump diameter data, tree height/dbh and tree volume/dbh-height models were used to estimate volume of felled trees. Natural losses and types of harvesting have not been assessed.

The estimated growing stock was the basis of calculating carbon sequestration in above-ground and below-ground tree biomass in the first Croatian NFI (Čavlović 2010). While there are no nationally valid biomass expansion factors (BEFs) in Croatia yet, global BEFs for main tree species or group of species were used (Whittaker and Woodwell 1971; Zavitkovski and Stevens 1972; Ruark and Bockheim 1988; Brown 1997; Brown and Schroeder 1999; ECE/FAO TBFRA 2000; Isaev et al. 2005). Research to provide nationally valid BEFs is expected in future activities.

The total standing volume of 566.4 million m^3 on the productive forest land in Croatia is composed of 552.1 million m^3 of growing stock and 14.3 million m^3 (2.5 %) of standing dead wood. The productive forest area produces about 13 million m^3 of volume increment each year, of which 8.4 million m^3 are harvested annually. During the last two decades the drain represented two-thirds of the increment. The need for a higher intensity of stand thinning and regeneration, an increased demand of fuel wood, storm damage events (Čavlović et al. 2012), are facts that should lead to more intensive utilisation of wood resources in the future.

European beech contributes to the standing stock/growing stock volume with largest share (34.8 %). The second third of the growing stock is composed of the following four tree species: pedunculate oak (13.0 %), sessile oak (9.2 %), common hornbeam (9.2 %) and silver fir (6.2 %). The remaining 89 tree species altogether account for the remaining 27.6 % of the standing volume. For all tree species the harvest are lesser than increment, except silver fir, which is characterised by greater harvest (164 % of increment) as a result of the diameter structure (high share of large trees) and the intention of encouraging more intensive silver fir regeneration. Over three quarter (75–85 %) of pedunculate oak, beech and black locust (*Robinia pseudoaccacia* L.) increment has been harvested, while sessile oak, hornbeam and narrow-leaved ash are characterised by harvesting of only half of volume increment. Low drain/increment ratio, below one third or even one fifth is characteristic for other tree species (conifer plantations, plantations of broadleaved softwood tree species, Mediterranean tree species). The estimates of standing stock, growing stock, increment, and drain on productive forest land by tree species are shown in Table 15.8.

15.2.2.2 Tree Species and Their Commercial Use

Considering the quantity and increment share, pedunculate oak, sessile oak, European beech and silver fir are the most economically important tree species in Croatia and are mainly used for the production of sawlog, veneer and other industrial roundwood. According to the Croatian bureau of statistics (SY RC 2013), of the total harvested wood in Croatian forests, 52 % is used as sawlog and veneer, 21 % as pulpwood and other industrial roundwood, and 27 % is fuel wood including wood for charcoal. The share of coniferous wood amounts only to 18 %, which is structured as: sawlog and veneer (85 %), industrial wood (11 %) and energy production (4 %). Nearly half of the broadleaved wood is used for sawlog and veneer (45 %), energy production (32 %) and pulpwood and other industrial wood (23 %). Broadleaved wood includes species with high wood quality and unique properties (e.g. sycamore maple, sweet cherry, black walnut). There is an increasing trend towards the use of wood for energy production in recent years in Croatia. Wood harvested for energy in 2008 was 0.76 million m^3, which increased to 1.56 million m^3 in 2012.

15.3 Assessment of Wood Resources

15.3.1 Forest Available for Wood Supply

15.3.1.1 Assessment of Restrictions

The existence of legal restrictions is assessed in the field for each sample plot. Three categories were assessed considering wood supply;

1. without any restrictions (existence of management plan, economic function, accessible);
2. cuttings partly limited (due to protective, aesthetic, recreational, social forest functions);
3. cuttings are not allowed or are unfeasible (strict nature protection, unaccessible sites).

The assessment is based on the observation of the relevant variables in the field, such as slope, rockiness, altitude, distance to the skidding and forest road, harvesting and logging technologies, as well as the collection of relevant information from sources such as the forestry administration of local forestry, national parks and nature parks, and local authorities. Relevant field variables and specific GIS data are combined to post-stratify the various degrees of restrictions for wood supply.

15.3.1.2 Estimation

Based on the field assessments on sample plots of the three categories of availability for wood supply the productive forest area was classified and estimated as following: without any restrictions (90 %), cuttings are partly limited (8 %) and forests where cuttings are not allowed (2 %). This estimation generally corresponds to the data presented in Table 15.2 where forest area is classified according the forest functions, which are relevant with regard to availability of wood resources. Further refinement of these field estimations, is possible through the use of more detailed and spatially defined estimations. Through the integration of available spatial layers using GIS spatial analysis the following areas can be taken into consideration: nature protection and conservation area, and priority areas of different restrictions regard to the wood availability, as well as terrain, site-specific and stand-specific data which indicate economic conditions of harvesting.

15.3.2 Wood Quality

15.3.2.1 Stem Quality and Assortments

The classification of timber in Croatia is formally defined by the Croatian/EU timber standards. Timber is classified according to species, diameter at breast height, length and quality of the log. The dbh classification comprises the nine classes:

- 1a (10–14 cm)
- 1b (15–19 cm)
- 2a (20–24 cm)
- 2b (25–29 cm)
- 3a (30–34 cm)
- 3b (35–39 cm)
- 4 (40–49 cm)
- 5 (50–59 cm)
- 6 (60 cm and more).

The quality classes of sawn timber contain the grades A (best quality), B, C and D (lowest quality). These classes are assigned depending on the stems physical properties, such as straightness, knots, and other defects. Apart from these categories assortments are specified according to standards regarding particular purposes: veneer, sawnwood, industrial roundwood, pulpwood, fuelwood, etc. Veneer logs are of very good quality and require a minimum length of 2 m and a minimum diameter of 30 or 40 cm. Sawn logs are classified into three classes, first being the best quality. Requirements for minimum diameter/length and maximum allowed wood defects are specified for each purpose category. The specifications of the purpose grades are different for broadleaved and for coniferous logs.

15.3.2.2 Assessment and Measurement

Stem quality is assessed for all standing sample trees with a dbh ≥ 30 cm on field plots. Since the classification of logs according to the EN has limited applicability in the field, tree quality is assessed according to dimensions and preferred purpose of logs. Trees are graded into one of five classes according to the quality of the first two segments of the stem. The length of each segment equals to one third of bole length for conifers and one quarter of bole length for broadleaves. The same quality classes are used for conifers and broadleaves. The stem quality classes are described in Table 15.9.

Stem damage is assessed based on the size of mechanical damage, regardless of cause and is classified into three classes (Table 15.10).

Bark thickness at breast height is measured on each sample tree in order to calculate volume share of bark. In addition, several other parameters related to stem

Table 15.9 Stem quality classes as assessed by Croatian NFI

Stem quality class	Description
1. Excellent	First segment consists of veneer logs, first class sawn logs; second segment has logs at least second class sawnwood
2. Very good	First and second segment at least second class sawn logs (or first segment better and second segment worse than second class)
3. Good	First segment consists of second class sawn logs; second segment third class sawn logs or cordwood
4. Sufficient	First and second segment consist of third class sawn logs or cordwood (or first segment better and second segment worse than that)
5. Poor	First segment consists of third class sawn logs or cordwood; second segment fuelwood

Table 15.10 Stem damage classes as assessed by the Croatian NFI

Stem damage class	Description
1. Undamaged	Stem with no mechanical damage, or small damages total size less than 3 dm^2
2. Slightly damaged	Stem with mechanical damage on bark, size 3–10 dm^2
3. Severely damaged	Stem with mechanical damage on bark, total size more than 10 dm^2

quality are assessed on sample trees: the tree status (dead or alive), competition status (dominant or suppressed). Stand quality according to quality of dominant trees (stem length, straightness, taper, knots) is assessed on plot level and classified into four categories (very good, good, medium, and poor).

15.3.2.3 Estimation and Models

Stem quality data are available only for trees dbh > 30 cm, which is less than 10 % of total sampled trees but includes about 65 % of the estimated standing volume. According to stem quality classes 14.2 % of sampled trees are of excellent quality, very good are 23.7 %, good 39.7 %, 1.43 % are sufficient, and 7.8 % are trees of poor quality. The estimated volume share by stem quality classes is as following: 25.6 % of excellent quality, very good is 27.2 %, good 31.4 %, 10.7 % is sufficient, and 5.1 % is poor quality.

More detailed availability of timber by stem quality and assortment classes could be estimated in future inventories by implementing more detailed assessment procedure. Present estimates of timber assortments are based on harvested and sawn wood data from Croatian bureau of statistics.

15.3.3 Assessment of Change

15.3.3.1 Assessment and Measurement

To date one NFI has been completed in Croatia. There is an intention to base future estimates of increment and drain on the field measurements on permanent plots at two consecutive points in time. By completing second NFI, comparison of sample trees on permanent sample plots will provide estimates of increment and drain. The method of increment estimation using the concentric sample plot design (non-growth and on-growth trees) has still to be decided. In the first NFI only two variables relevant for increment estimation were measured on all sample trees with dbh ≥ 10 cm (for uneven-aged forests, Mediterranean forests and young even-aged stands sample trees dbh ≥ 5 cm): the diameter at breast height (dbh) and tree height (h). Estimation of drain in the first NFI was based on measurements and assessment of stump diameters, tree species and "age" of stump (1–2 and 3–5 years) of felled trees on circle plots of 13 m in radius, and measurements of stump diameters of all standing (living) sample trees. Data models: dbh/stump diameter, tree height/dbh and tree volume/dbh-height were applied to estimate volume of felled trees.

15.3.3.2 Estimation of Increment

The final definition of volume increment and the method of its estimation has still to be decided. There are several approaches which could be considered:

(a) volume increment of sample trees at first measurement predicted with model,

$$iv_1 = f(dbh_1, id, v) \tag{15.1}$$

(b) volume increment of sample trees at second measurement predicted with model,

$$iv_2 = f(dbh_2, id, v) \tag{15.2}$$

(c) average value of iv_1 and iv_2
(d) volume increment of survivor trees between two field assessment periods (volume differences of survivor sample trees between two occasions).

where dbh is the diameter at breast height, *id* is the annual diameter increment (direct or modelled), *v* is stem volume function (v = f(a, b, c, dbh, h)). The coefficients a, b, c of the volume functions for several tree species were estimated by Špiranec (1975).

The approaches a–d (above) do not include the increment of trees that die between cycles, are felled and fall over naturally. However, increment of these trees can be estimated separately using modelled data. In case (d) and concentric circle plots sample method, volume of non-growth trees that grow into the sample should

be excluded from the increment estimation. Gross increment is estimated as the volume increment with including the volume of ingrown trees that exceed the dbh-threshold of 10 cm between the two points in time. The increment or volume of trees on land areas under land use change (conversion to forest, changing from forest to other land uses) should be included in increment estimates, regarding the reporting obligations of the Kyoto Protocol and LULUCF sector. The assessed volume increment of sample tree, volume increment per ha represented by the sample tree, productive forest area, sample plot location, will be the basis for increment estimates on national level and classification by counties, Forest Administrations, forest types, tree species and ownership categories. Using the volume increment estimates and appropriate biomass expansion factors, gross increment in units of biomass could be calculated, until nationally valid BEFs are available.

15.3.3.3 Estimation of Drain

The drain estimated by the first Croatian NFI as the average annual volume of trees felled during last 5 years. For several tree species the same volume functions as for living trees were used. Diameters at breast height and heights of felled trees were assessed by data models of standing trees. According to Table 15.7 the volume estimates of trees with a dbh ≥ 10 cm over bark contain all stem parts above ground (bole, stem top and stump). The drain estimates of the Croatian NFI are average annual volumes of drain for the 5-year time period before field assessments. Drain is defined as the volume of trees with a dbh ≥ 10 cm over bark at the first measurement that were found to be harvested in the subsequent NFI, will be applied after completion of second and following NFIs. An assessment of the type of felling as well as volume of sample trees on plots within land-use changes (forest conversion to other land-uses) should be included in the drain estimates. The assessed volume of felled trees, volume per ha represented by the felled sample tree (first occasion), productive forest area, sample plot location, will be the basis for drain estimates on national level and classification by counties, Forest Administrations, forest types, tree species, types of fellings and ownership categories. The estimation of drain could be calculated in units of biomass, similar to increment.

The drain estimates in Table 15.8 can be compared with data of annual statistics on the amount of wood harvested in Croatian forests (SY RC 2013). The data based on stand-wise inventory and management data provided by "Hrvatske šume" Ltd. and Public service for private forests have shown lower estimates compared to the NFI. This difference can be explained with facts that the statistic data reports commercial volume under bark, the existence of unregistered felling especially in private forests and differences in inventory methodology.

15.3.4 Other Wooded Land and Trees Outside Forests

15.3.4.1 Assessment and Measurement

Other wooded land mainly includes shrub land, lands on upper limit of forest vegetation, and *copse* and *garrigue* land. In the Croatian NFI, field assessment included only the assessment of an area (share) of the other wooded land within sample cluster squares. Plots located within other wooded land have been excluded from sample and assessments. Other land with tree cover has been excluded from any assessments. Shrub and *macchia* lands composed of trees which reach height above 5 m in situ and crown coverage higher than 10 %, have been determined as forest land and included in sample plot assessments with dbh threshold of 5 cm, relatively 0 cm (smallest sample plot, $r = 2$ m). Introduction of other wooded land and other land with tree cover as separate categories for remote sensing or/and field assessments of site-, stand- and tree-specific variables will be considered for the next NFI cycle.

15.3.4.2 Estimation

The area of other wooded land or permanently and temporarily unstocked parts of the forest was estimated by classification on satellite images and is available as presented in Table 15.2. Also, the area of other wooded land, from field assessments on sample cluster squares, is estimated to be 180,000 ha which more or less corresponds to the satellite image estimation. Volume and biomass estimates of the other wooded land are not available as these attributes were not assessed in the field. Moreover, there are no alternative data available from other sources or projects. Inclusion of this land category, as well as other land with tree cover, in sample plot assessment and remote sensing will be considered for the next NFI. This information would provide sound data for area, volume and biomass estimates of those land categories.

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