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Editors

National Forest Inventories

Assessment of Wood Availability and Use

ENFIN

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If you want to go fast go alone, if you want to go far go together

Old African proverb

This book is dedicated to ENFIN, the European National Forest inventory Network created in 2003. This network provides its members with a good framework and a confident working atmosphere to deliver ambitious projects. This book is one of them.

Foreword

The question of availability of wood in Europe on a sustainable basis is highly relevant to define global change mitigation strategies and targets for biomass energy as adopted at national and European level, and to support the proposal of an increased use of wood as a post-Kyoto decision. During the 21st annual Conference of Parties of the UN Framework Convention on Climate Change in Paris 2015 the role of global forests was again strengthened for future climate change policy.

Information is required to allow forest managers to manage forest resources sustainably and to ensure sustainable wood supply at national and international levels. However, it is essential that the information is based on a robust, statistically sound, and regularly updated long-term information system. National forest inventories (NFIs) comprehensively contribute to these information needs, both at national and international level. In many countries NFIs have been carried out for many decades and are increasingly participating in major international reporting mechanisms. Due to different historical backgrounds and varying environmental conditions, NFIs apply different basic definitions and methodologies leading to inconsistencies and lacking comparability between countries for international reporting. Recent results from European countries on the balance between wood supply and demand show significant differences among countries depending on data availability and approaches of data collection. Information on the potential wood supply in Europe is not readily available, and information on the precision of estimates is lacking. Therefore, transparent, comprehensive, comparable and consistent information on wood resources is necessary as a basis for future-oriented decision-making.

To harmonise global forest information, the Food and Agricultural Organization of the United Nations (FAO) has been developing commonly agreed key definitions. Nevertheless, for practical application within international reporting, those definitions were not widely adopted by national agencies responsible for reporting. Therefore, the European NFIs decided to collaborate on the harmonisation of forest information and founded the European National Forest Inventory Network (ENFIN). Under the umbrella of this Network several harmonisation projects have been carried out during the last ten years. Based on the results of COST Action E43, "Harmonisation of National Forest Inventories in Europe: Techniques for Common Reporting" of the European program, Cooperation in Science and Technology (COST), the subsequent COST Action Usewood aimed at improving information and methodologies on the potential sustainable wood supply based on the NFIs to reduce the given uncertainties. Such harmonised information is urgently needed to improve the information available to decision makers in the forest, environment, and in the wood and energy sectors. Extensive parts of this work were dedicated to harmonising the assessment and estimation of the state and change in wood resources based on NFIs and are now presented in this book.

The book provides a comprehensive and informative overview as well as in depth description and analyses on the need for harmonised estimates of wood supply and their application within the NFIs including practical tests with raw data. Recommendations on the applicability and feasibility of different definitions and methodologies offer a valuable basis for future applications in both NFI assessment methods and international reporting requirements. I congratulate the editors and authors to this outstanding work on global future monitoring of wood resources and wood supply.

Vienna, Austria
April 2016

Klemens Schadauer
ENFIN Chair

Preface

The origins of forest inventories are linked to national needs for information about forest resources and to inform forestry policies formulation. In Europe, some information was produced in countries such as Belgium, France and United Kingdom in the 19th Century in line with these national objectives. The first statistical National Forest Inventories (NFIs) were designed in countries such as Norway, Sweden and Finland more than one century ago in order to obtain a precise evaluation of national forest timber resources. Most western European countries adopted various methodologies for their NFIs between the 1960s and 1990s in line with their national definition of forest and the economic interest of their wood resource. Finally, other countries set up NFIs in the years from 2000 to answer international agreements and commitments following the Rio Earth Summit in 1992.

National forest monitoring processes have been formed over time and are influenced by the historical, cultural, political and economic context in which they were developed. Forest is defined by law for some countries; others use productivity criteria and most of them utilise tree crown coverage, sometimes with different thresholds as a defining feature. Sampling techniques are now used across Europe, and inventory cycles are commonly employed even if the methodologies and the length of cycles are not the same. The total number of sampling plots visited in one inventory cycle in Europe is more than half a million plots (excluding the Russia Federation). Therefore, NFIs constitute the main source of forest information in terms of exhaustiveness and precision. Nevertheless, due to different national needs, definitions and methodologies, important harmonisation work is needed to facilitate using this full set of plot information and to obtain comparable data that can be aggregated at European level.

The role of forests is continuously growing and diversifying. Starting with the production of wood, forests are nowadays recognised as important reservoirs of carbon and biodiversity. Forest soils are also increasingly recognised as an important component of the ecosystem. Over time NFIs broadened their scope, and new variables were collected step by step. The utilisation of NFI information for national purposes remains an important function, but international reporting is increasing in importance, particularly after the Rio Earth Summit in 1992. The challenge for NFIs to answer all these reporting exercises is greater than in the past.

New political needs have also arisen, such as intensive use of energy wood to fulfil renewable energy targets (EU 2030 objective of 27 % of renewable energy). The evolution of technologies such as utilisation of wood chips, pellets and briquettes have obliged those responsible for designing and implementing NFIs to reconsider their way of thinking in terms of "wood resources". It is no longer sufficient to estimate growing stock as "stem volume" because now more compartments of a tree are utilised by the wood industry for producing these new kinds of energy wood. On the other hand, NFIs are obliged to look outside of the traditional sources of wood within forest areas, to those areas outside the forest, as a possible source of additional wood resources. If we would like to increase the use of wood for energy purposes, NFI teams will have to investigate new domains to estimate wood resources outside of the forest with sufficient accuracy.

People responsible for NFIs across Europe gathered in Vienna in 2003 in order to find a way to face these new challenges together and to increase the visibility of NFIs as key actors for both production of information and the knowledge and expertise on how to deal with this information. They created a network of NFIs called "European National Forest Inventory Network" (ENFIN). The ENFIN members submitted a joint proposal for developing research work on the harmonisation of NFIs to the COST office—European Cooperation in Science and Technology—to receive funding for meetings and collaborative activities. A total of 27 European countries joined the COST Action E43: "Harmonisation of National Forest Inventories in Europe: Techniques for Common Reporting". In addition, the Joint Research Centre Institute for Environment and Sustainability as EU institution, the FIA program of the U.S. Forest Service and Scion from New Zealand as non-COST countries joined this COST Action E43. NFI representatives from several other countries such as the US participated in the meetings, highlighting the importance of this subject for production of information and international reporting.

The main objective of this COST Action E43 was to improve and harmonise the concepts and definitions of the existing national forest inventories in Europe in such a way that the inventories will provide comparable forest resource information. The other objectives were (i) to support new inventories in such a way that inventories will meet national, European and global level requirements in supplying up-to-date, harmonised and transparent forest resource information; and (ii) to promote the use of scientifically sound and validated methods in forest inventory designs, data collection and data analysis. The main outputs were a SPRINGER book "National Forest Inventories: Pathways for common reporting" and a Special issue of Forest Science (Vol 58, 2012).

Thanks to this success and the cohesion of the NFI group, ENFIN presented a new COST Action in 2010 called COST Action Usewood focusing on the question of comparable data in terms of availability of wood in Europe on a sustainable basis. This question is highly relevant to define global change mitigation strategies and targets for biomass energy as adopted at national and European level, and to support the proposal of an increased use of wood as a post-Kyoto decision. Future scenarios at EU-level highlight a deficit of wood supply compared to wood consumption. Major issues to be clarified by this Action were the potential supply of tree biomass, trees outside forest, and the economic, social and ecological conditions that will determine the wood supply. This COST Action aims at improving the information and methodologies based on the NFIs, in order to reduce the given uncertainties on the potential sustainable wood supply. Such harmonised information is urgently needed to improve the calculation basis for decision makers in the forest, environment, and in the wood and energy sectors.

COST Action "Usewood" involved 27 European countries plus the United States of America as a non-COST member country. NFIs worked closely together with international organisations and institutions such as United Nations and the European Commission. The substantive work was carried out in meetings, workshops and a number of scientific missions involving early stage researchers trained and supervised by senior scientists. Each country actively participated in the work of collectively building questionnaires, filling in these questionnaires and writing the country reports contained in this book. The active participation of forest inventory experts directly involved in practical and scientific work stimulated discussion and promoted successful outcomes. The official duration of the Action was from end of July 2010 to October 2014, but the publishing work through scientific articles and books continued into 2015 and 2016.

The members of COST Action Usewood collected a large amount of information from the NFIs of the participating countries and agreed to compile national methods to estimate wood resources in a single book. In addition to the member countries participating in the COST Action "Usewood", country reports were also submitted by some of the most significant forestry countries around the world. As a result, this volume includes NFI reports from 28 COST member countries plus Argentina, Brazil, Canada, Chile, China, Ecuador, Japan, New Zealand, Republic of Korea, Peru, the Russian federation, and the United States of America. The forests of these countries comprise seventy percent of the total global forest surface. Most of the reports follow the same structure. The first part of each country report comprises a brief history of the NFI, sampling methods and periodicity, data collection, processing, reporting and use of results on wood resources. A second part contains a description of the land classification, the variables used to estimate wood resources, assessment of wood resources defining forest available for wood supply, wood quality, assessment of changes and other wooded land and trees outside forests.

This information was collated into this book, thanks to the active participation of NFI experts. The authors and editors hope that forest researchers and all those in the community interested in wood resources worldwide will find this information interesting and useful. Furthermore, one of the main aims of this book is to be an essential source of information for people planning a new forest inventory or thinking about modifying the existing one.

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Abbreviations

C	Carbon
CBD	Convention on Biological Diversity
CLC	CORINE Land Cover
CO_2	Carbon dioxide
CORINE	Coordinated Information on the European Environment
COST	European Cooperation in Science and Technology
CPF	Collaborative Partnership on Forests
EC	European Commission
EEA	European Environment Agency
EFDAC	European Forest Data Centre
EFFIS	European Forest Fire Information System
EFI	European Forest Institute
EFICP	European Forest Information and Communication Platform
E-Forest	Consortium of NFIs providing data and services to European Forest Data Centre
EFS	European Forest Strategy
EFSOS	European Forest Sector Outlook Study
EU	European Union
EUFORGEN	European Forest Genetic Resources Programme
EUROSTAT	Statistical Office of the European Communities
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization of the United Nations, Statistical database
FAP	Forest Action Plan
FAWS	Forest available for wood supply
FRA	Forest Resource Assessment (FAO)
GHG	Greenhouse Gas
GIS	Geographic Information System
H2020	Horizon 2020. EU Research and Innovation programme with funding available over 7 years (2014–2020)

ha	Hectare
ICP Forests	International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
INSPIRE	Infrastructure for Spatial Information in Europe
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
JRC	European Commission – Joint Research Centre
LULUCF	Land Use, Land Use Change and Forestry
MCPFE	Ministerial Conference on the Protection of Forests in Europe (now known as FOREST EUROPE)
NAI	Net annual increment
NFI	National Forest Inventory
NFMA	National Forest Monitoring and Assessment
NUTS	Nomenclature des unités territoriales statistiques (The Nomenclature of Territorial Units for Statistics)
NWFP	Non-wood forest product
NWGS	Non-wood goods and services
OLwTC	Other Land with Tree Cover
OWL	Other Wooded Lands
REDD	Reducing Emissions from Deforestation and Forest Degradation
SFM	Sustainable Forest Management
TBFRA	Temperate and Boreal Forest Resources Assessment
TOF	Trees Outside Forests
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
Yr	Year

COST Information

The European Cooperation in Science and Technology (COST) is the longest-running European framework supporting trans-national cooperation among researchers, engineers and scholars across Europe.

Based on a European intergovernmental framework for cooperation in science and technology, COST has been contributing, since its creation in 1971, to closing the gap between science, policy makers and society throughout Europe and beyond. As a precursor of advanced multidisciplinary research, COST plays a very important role in building a European Research Area (ERA).

The COST organisation features the Ministerial Conferences, the COST Association, the COST National Coordinators and the Scientific Committee. COST convenes, every 5–6 years, a Ministerial Conference with the aim to reaffirm the Member Countries support for COST as a unique framework for pan-European cooperation in research and innovation. The COST Association was established in September 2013 by the COST Member Countries as an international not-for-profit association under Belgian law. The COST Association integrates governance, management and implementation functions into a single structure, thus ensuring the intergovernmental nature of COST and its pan-European dimension. The 36 COST Member Countries are full members of the COST Association; Israel is a Cooperating State.

COST funds pan-European, bottom-up networks of scientists and researchers across all science and technology fields. These networks, called ‘COST Actions’, promote international coordination of nationally funded research. It anticipates and complements the activities of the EU Framework Programmes, constituting a “bridge” towards the scientific communities of COST Inclusiveness Target Countries. It also increases the mobility of researchers across Europe and fosters the establishment of scientific excellence.

Since 2011, COST has been shaping its future and preparing for the new challenges to be taken up under Horizon 2020. This means a renewed evaluation and selection procedure aiming at identifying breakthrough ideas and favouring interdisciplinary and multidisciplinary projects. Web: http://www.cost.eu/.

COST is supported by the EU Framework Programme Horizon 2020

Chapter 1
Introduction

Claude Vidal, Ola Sallnäs, John Redmond, Iciar Alberdi, Susana Barreiro, Laura Hernández and Klemens Schadauer

1.1 History of Use and Assessment of Wood Resources

Wood resources have been an essential component of life for human beings over the millennia and remain critically important today. Beginning with the first human habitations and fire to more industrial energy needs, wood was always essential for mankind. Access to sufficient supplies of wood was a vital part of a countries competitive advantage. Uses included fuel, industry, housing, shipping and temporary applications such as supporting trenches in the First World War. Some purposes required wood with specific characteristics, notably in ship building, which demanded softwood for masts and hardwood for keels. Such specialised requirements stimulated transnational exchanges and exports between countries.

European forests are the result of centuries of human activities (Spiecker 2003). Forest resources have been overused over the course of history, particularly during times of emergency such as, to supply timber for military ships and energy for armies or displaced populations. During and immediately after both world wars,

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European forests were systematically overcut and principles of sustainable yield disregarded. In a few extreme cases, war has helped forests by allowing ecosystems to recover free of human pressure. For example, in the Hundred Years' War between England and France in the fourteenth century, the destruction and subsequent abandonment of many villages had a positive effect on forests. Wars are rarely fought over timber, but in Cambodia for example insurgent groups prolonged their struggles in part to engage in illegal logging operations (Le Billon 2000; Global Witness 2003). However, in more recent decades, increasing social demands required a wider scope of forest management based on sustainable forest management (Spiecker 2003).

Overtime wood resource evaluation and availability became a growing political concern. The first local investigation to evaluate the wood resources in Europe goes back to the Middle-Ages when the nobility required an assessment of wood availability on their territory. At that time intensive use of forest resources led, firstly to wood shortages which, in turn, forced forest owners to establish forest planning particularly in the vicinity of cities and mines (Loetsch and Haller 1964; Gabler and Schadauer 2007; Tomppo et al. 2010). Loetsch and Haller (1964) summarised: "the characteristics of the methods of forest inventory in Central Europe during the nineteenth century are very accurate area information from terrestrial surveying and area-related information on relatively small stands as units of assessment. The results of the stand inventories are compiled for groups of stands and finally for the whole independent management unit…" Thus, the first inventories were often local with the aim of assessing the available timber resources for some specific use. But it became obvious that such inventories could not be easily used to compile national level forest information.

However, it was not until the early twentieth century, in the late 1910s and early 1920s, when due to importance of forest and wood resources for their economy, the European Nordic countries initiated the first sample-based National Forest

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Inventories (NFIs). However, such tools were not introduced in other European countries until after World War II (Tomppo et al. 2010). During the reconstruction phase that followed World War II, the political importance of forest and forest resources were then recognised by the implementation of a NFI in 1958 in France, in the 1960s in Austria, Spain, Portugal and Greece; and in the 1980s in Switzerland, Italy, Poland and the reunified Germany. Today, statistical sample-based inventories are conducted in almost all European countries not only to investigate forest resources and elaborate National Strategies but also to answer international information requirements which are relevant for political decision making.

1.2 International Requirements for Information on Wood Resources

The main international requirements for forest information are the Food and Agriculture Organization of the United Nations (FAO) Forest Resources Assessment (FRA), and the obligations following from the commitments towards sustainable forest management and United Nations Framework Convention on Climate Change (UNFCCC). NFIs are the main data source for all these processes.

1.2.1 Food and Agriculture Organization of the United Nations (FAO)

The FAO Forest Resource Assessments has been monitoring the world's Forest at 5 to 10 year intervals since 1948: from FAO (1948) to FAO (2015). There has been a long standing scientific and technical consultation process between countries and the FAO in order to improve the definitions and enhance the comparability of data. From 1987 onwards, an expert level meeting organised in Kotka (Finland), with a periodicity of approximately 6 years, has had an important role in proposing common definitions in connection with the global forest resource assessments conducted by the organisation. These assessments have been carried out in collaboration with countries from all parts of the world and they have become an important driver towards global harmonisation of forest statistics. However, as shown in the 2005 report (FAO 2004) a lot remains to be done before forest statistics from different countries are really comparable.

At United Nations (UN) regional level, the joint UNECE/FAO Forestry and Timber Section, has served as an important source of information, data and analysis. This information has described the forest sector in the UNECE region for more than 50 years. A cornerstone of the harmonisation process was the Temperate and Boreal Forest Resources Assessment (TBFRA). In collaboration with the FAO, the Section plays a pivotal role in the regular assessment of the state of forests in the pan-European region and contributes to the periodic global Forest Resources Assessment (FRA). Moreover, the scope of the FRA has changed regularly since the first assessment was published in 1948. The changing scope required the introduction of new attribute definitions.

1.2.2 United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Conference on Environment and Development (UNCED), better known as the Rio Earth Summit, was a key United Nations conference focusing on the global environmental challenges. Held in Rio de Janeiro in June 1992, the Earth Summit resulted in the following documents*: Rio Declaration on Environment and Development, Agenda* 21 *and Forest Principles*. Moreover, important legally binding agreements were opened for signature: Convention on Biological Diversity (CBD 2009), Framework Convention on Climate Change (UNFCCC 2009) and United Nations Convention to Combat Desertification (UNCCD 2012).

The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty with the objective to "stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The convention provides a framework for negotiating specific international treaties (called "protocols") that may set binding limits on greenhouse gases. As a follow up the Kyoto Protocol was signed in 1997, establishing legally binding obligations for developed countries to reduce their greenhouse gas emissions. One of the first tasks set by the UNFCCC was for signatory nations to establish national inventories of greenhouse gas (GHG) emissions and removals, which were used to create the 1990 benchmark levels for member countries to the Kyoto Protocol. According to the agreements, information should be provided annually from many different sectors; one of them being the land use, land-use change, and forestry (LULUCF) sector. A report by Cienciala et al. (2008) highlights the important role of NFIs in providing data for the LULUCF sector. The report also describes the processes towards harmonisation ongoing in Europe and identifies several remaining harmonisation needs.

1.2.3 Sustainable Forest Management

The Forest Principles is the informal name given to the Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all types of forests. It makes several recommendations for the conservation and sustainable development of forests.

From the conclusions of the Earth Summit in 1992 and the new reporting obligations that followed, the workload at national level increased due to the many new international information needs. These new requirements placed an emphasis on the data provision mechanisms required to provide robust, statistically sound, current and long term information. As main source of forest resource information, NFI's are contributing to reach this goal. In particular, world regional processes such as the Montreal Process (2005) or Forest Europe (MCPFE 2007) define a set of Criteria and Indicators (C&I) for assessing the sustainability of forest management. This reporting exercise is quite demanding, in terms of individual countries capacity to report on the definition.

At pan-European level, from 1990 onwards, Ministerial Conferences on Protection of Forest in Europe (MCPFE) were regularly set up. The first Strasbourg Conference was a major step to initiate the incorporation of scientific data into political action to protect Europe's forests. At the Second Ministerial Conference, held in Helsinki in June 1993 agreement was reached the promotion of sustainable forest management, the conservation of biological diversity, strategies regarding the consequences of possible climate change for the forest sector, and increasing co-operation with countries in transition to market economies. At the Lisbon Conference in 1998 the Ministers decided to adopt a set of criteria and indicators (C&I) as a basis for international reporting on the sustainability of forest management in Europe. The set of quantitative and qualitative (descriptive) indicators was discussed and definitively adopted at the Ministerial Conference in Vienna in 2003 (the improved pan-European indicators for sustainable forest management, 35 quantitative and 17 qualitative indicators). A report titled State of Europe's Forest (SoEF) was produced in 2003, 2007, 2011 and 2015. In 2011, at the Ministerial Conference in Oslo (the process is now called "FOREST EUROPE"), countries committed to take a clear mission to advance the realisation of the shared vision, goals and 2020 targets to secure and promote Sustainable Forest Management (SFM) with the aim of maintaining the multiple functions of forests crucial to society (Oslo Ministerial Decision: European Forests 2020—Ministerial conference —Oslo 2011-Final declaration). Due to the 2012 convergence process at international level initiated by FAO, the most recent SoEF report was produced in 2015, close to the FRA 2015 report both using national data coming from the NFIs (Fig. 1.1). The majority of data was collected using a joint questionnaire called Collaborative Forest Resources Questionnaire (CFRQ), where only part of data concerns the pan-European process.

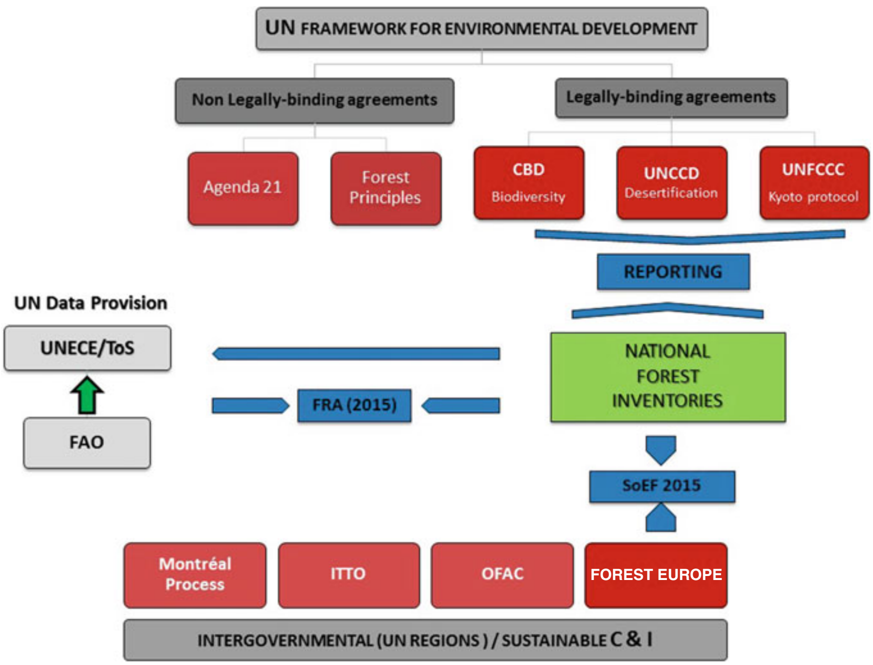

Fig. 1.1 International reporting in the forestry sector with a focus on Europe. Where the International Tropical Timber Organization is called ITTO and the Observatoire des Forêts d'Afrique Centrale, OFAC, the United Nations Framework Convention on Climate Change is called UNFCCC, the United Nations Convention to Combat Desertification, UNCCD, and the Convention on Biological Diversity, CBD

1.3 EU Forest Policy Framework

The need for the European economy to be more productive, innovative and competitive whilst using fewer resources and reducing its environmental impact has been widely acknowledged (EC 2014a). It is evident that Europe's forest sector, as part of the European green infrastructure (EC 2014b), can play an important role here and can contribute to tackling significant future social, ecological and economic challenges, such as unemployment, climate change and globalisation (WHO 2012). Yet, these challenges will also increase the demands on forests, which besides wood and energy production, include carbon sequestration, biodiversity conservation, water protection, landscape management, soil and nutrient regulation, tourism and recreation. Moreover, the competition for land use between traditional agriculture, biomass production, and forestry is expected to increase in the future (EC 2014c).

Forests represent the 33 % of the total land in Europe, excluding Russia (FOREST EUROPE, UNECE and FAO 2015). These forest areas are crucial component of the European landscape, with regard to biodiversity and management of natural resources, mitigation and adaptation to climate change and a main contribution to ecosystem goods and services, among other roles (FAO 2010a, b). While European forest policy is cross-sectorial (Winkel et al. 2013), there is no mandate for working with forest issues directly and no coherent forest policy at EU level. Forests are indirectly part of several main EU environmental policies and legislations as highlighted in the new EU forest strategy for forests and the forest-based sector (COM 2013/659). Forests are also an integral component of the EU Habitats and Birds Directives, as about 46 % of the Natura 2000 Network of protected sites is covered by forest ecosystems (EEA 2012), and the EU Biodiversity Strategy 2020 has several targets where forests are particularly mentioned.

The EU supports SFM and the multifunctional role of forests as expressed in the EU Forest Action Plan and the Forest Strategy. Forests also play an important role in other existing EU policies, such as energy policy and Reducing Emissions from Deforestation and forest Degradation (REDD+) and rural development legislation. There is a continued need for forest assessment and indicators at EU level to support the development and implementation of a number of European environmental policies, where forests play a major role.

The formulation of forest policy demands relevant, harmonised, comprehensive and reliable data in order to achieve balanced and robust policies necessary for directing forest management. In addition, reporting obligations associated with EU forest-related policies and international agreements call for comparable data and information on Europe's forest ecosystems e.g. Millennium Development Goals on preventing deforestation and activities under the Kyoto Protocol, the CBD and UNFCCC.

NFIs are reliable sources of forest-related information. Nevertheless, due to the increasing demands by the forest and other related sectors there is a clear need to make data collection and analysis more efficient and harmonised, enhance interoperability, provide information for the main parameters on complete coverage maps and deliver the information up-to-date. Better knowledge on forest resources and their sustainable future supply can help predict the development of forest ecosystem goods and services. Thus forests can serve a broad range of affected stakeholders and create new opportunities for an innovative, sustainable and inclusive bio-economy in Europe.

Results from recent European NFIs show an increased forest area and growing stock in most surveyed European countries as detailed in the SoEF 2010 (FOREST EUROPE, UNECE and FAO 2011) and SoEF 2015 (FOREST EUROPE, UNECE and FAO 2015) reports. However, due to environmental, economic and social restrictions, only parts of the resources are available for timber supply. Moreover, the development of new techniques to use wood as fuel (e.g. wood chips and pellets) has enlarged the demand for wood (EC 2009). Parts of the trees that traditionally remained in the forest can now be harvested e.g. tree-top, branches and stumps, but these parts of trees are rarely estimated. Short rotation coppice is also planted specifically to rapidly produce biomass for fuel. In areas with a low forest cover trees outside forests (TOF) and hedgerows have become a possible source of energy. But few countries are assessing wood resources on these areas and if any are, it is not at all in a harmonised way as shown in Chap. 2 of this book. Finally, a large part of the energy wood resource is composed of industrial residues and wood waste. Since many NFIs collect more information both on trees inside and outside forests, it could be possible to create harmonised methodologies necessary to estimate the total EU available wood resources from both within and outside forests in a near future.

Running from 2014 to 2020 with a budget of just over €70 billion, Horizon 2020 is the EU's new programme for research and innovation and is part of the drive to create new growth and jobs in Europe. Horizon 2020 is a core part of Europe 2020 the Innovation Union and the European Research Area and is responding to the economic crisis to invest in future jobs and growth, addressing people's concerns about their livelihoods, safety and environment and strengthening the EU's global position in research, innovation and technology (COM (2010) 2020). As a response to the new EU Forest Strategy (COM 2013/659) a Horizon 2020 funded project Distributed, Integrated and Harmonised forest information for bio-economy outlooks (DIABOLO) aims at: (i) strengthening the methodological framework for more accurate, harmonised and timely information derived from forest inventories and monitoring systems, that can be fed into the EU information systems; (ii) to support the development of EU policies and international processes relying on consistent forest information and (iii) to make innovative use of field-collected data and EC space-based applications of Earth observation and satellite positioning systems.

1.4 The Role of NFIs in Estimating the Potential Wood Supply

NFIs are the main source of information for characterising the state and change of wood resources overtime, making NFI data an essential component for generating projections on wood supply over varying climatic and management scenarios. In this section the policy needs and the role of NFIs for estimating potential wood resource availability at national and international scales will be described.

With the EU Renewable Energy Directive put forward, the climate change discussions and the post-Kyoto negotiations ongoing wood supply is an important issue in the light of rapidly growing demand for wood for all aspects including; carbon storage in forests, energy from forests and harvested wood products (EC 2014c). Woody biomass is an important renewable energy source and will play a decisive role in mitigating climate change. Hence in a future "low-carbon" society, wood fuel has a high potential to displace fossil fuels. The political questions NFIs have to answer at pan-European and at EU level are the following:

– How is the forest resource in Europe developing when different policy goals related to forests are implemented?

- Is it possible to ensure a sustainable provision of ecosystem services from forests even though climate change and social pressures increase?
- What are the consequences for forest management when implementing one or more forest related policy?
- What are the trade-offs in forest development and in the provision of the various services of forests when favouring one forest related policy goal over another (e.g. more biodiversity vs. more resources for energy)?

To address these questions, intensive monitoring on the status of forests is required, which goes beyond the borders of countries. Harmonising national level data and developing information systems to collect and analyse the results at European level are fundamental steps to the production of a sound European forest information system and the provision of future woody biomass availability scenario projections.

There are basically two different kinds of questions; "is it possible to …?" and "what are the consequences of (new policies)…?" Estimating the potential wood supply would help in answering some questions of the first type, while the second type is more about illustrating a probable development. To answer both types of questions, some scenario projection tools are needed.

In order to make a scenario projection describing the evolution of forests, two fundamental components are required: a description of the starting state of the forest and a model that describes what will happen with the forest over time. This development of the forest is driven by the bio-physical settings, the climate and interventions in the form of management and catastrophes. This in turn implies that the level and intensity of interventions must be formulated. If a potential is sought, it is necessary to find the intensity and structure that would yield the highest potential. One standard application is to try to find the highest possible, non-declining, harvest level under the restriction that the standing volume over time should not decrease. Often this harvest level is interpreted as the "potential wood supply", where the non-declining character and the preserved standing volume are used as sustainability criteria. Of course different restrictions can be imposed in the assessment, for example by taking into account accessibility issues.

If the aim is to investigate the consequences of a certain policy intervention, analyses of the most probable development following the intervention is required. In many cases the relevant question is: what forest management practices (in terms of silviculture and harvest) would be the result of the policy intervention? Often NFI data is not sufficient for this kind of analyses. In addition, socio-economic information from other sources is required.

1.4.1 ENFIN Harmonisation Methodology

In many countries, information systems have been developed at the national level for national policy needs and are now increasingly being integrated into major international reporting mechanisms. Due to the different historical backgrounds, varying environmental conditions and NFI objectives, NFIs have adopted different basic definitions and methodologies, leading to inconsistencies and lack of comparability in international reporting (Gabler et al. 2012).

A distinction is often made between harmonisation and standardisation (Köhl et al. 2000). Standardisation implies that all parties need to apply the same definitions, and possibly even field protocols, whereas harmonisation only prescribes that a final conversion from the local to the reference definition be made. Thus, harmonisation leaves a certain freedom to parties to use existing time series of data and definitions rather than establishing new or parallel data acquisition systems. This is important in times of expanding international information requirements, since standardised protocols to every new agreement would be very costly. This flexibility is also important to adapt data collection to information requirements that tend to change slightly over time such as the Good Practice Guidance (GPG) of Intergovernmental Panel on Climate Change (IPCC). On the other hand, standardisation is the most accurate way to have comparable data over time and between countries.

In 2003, the European NFIs decided to collaborate in order to enhance comparability of forest information by founding the European National Forest Inventory Network (ENFIN). Being aware of activities related to assessments, reporting and analysis by international institutes and organisations focused on Europe is essential. These results in the ENFIN group, collaborating with organisations such as FAO, UNECE, FOREST EUROPE and European Commission, which can benefit of and be complementary to ENFIN's efforts is essential. The overall objective of ENFIN is to promote NFI's as comprehensive monitoring systems by collecting harmonised information on forest ecosystems, forest resources and land cover/land use/landscape changes. The ENFIN group decided therefore to work on a sound and clear harmonisation process with two objectives. The first one is to allow each country for keeping its data collection system in line with its national needs and specificities and to adapt it in line with new policy requirements both at national and international levels. The second objective is to move forward towards harmonisation, being aware that a lot of data are not comparable despite a lot of harmonisation processes from decades at international level such as the FAO driven one.

1.4.1.1 COST Action E43

In order to respond to the need for harmonised information at the European level, ENFIN members initiated an EU COST Action project, to work towards the goal that NFIs would be able to provide comparable forest resource information (COST Action E43 2010, 2010). COST Action E43 was launched in June 2004 and 27 European countries joined the action. The COST Action was titled "Harmonisation of National Forest Inventories in Europe: Techniques for Common Reporting". The Working Groups of the Action collected, analysed and distributed information in currently applied definitions, measurement practices and methods to improve the dialogue between NFIs on one hand and between NFIs and NFI data users on the other. The main objective of COST Action E43 was to harmonise the European NFIs in such a way that inventory results were comparable (Tomppo et al. 2010). A common set of precise and unique reference definitions were the basis for this harmonisation.

Existing definitions at national and international level often refer to and rely on terms that leave room for interpretation. For example, the definitions of forest, other wooded land (OWL), growing stock, and numerous other definitions for biomass according to FAO (1998), UNECE/FAO (2000), IPCC (2003), FAO (2004) and FAO (2012) frequently use terms that are either not precisely defined or not defined at all. In particular, these definitions often refer to trees or shrubs. Although the FAO (1998, 2004, 2012) and UNECE/FAO (2000) specify trees and shrubs in their terms and definitions, these definitions may fail when distinguishing trees from shrubs as often required in NFIs. However, it is important to emphasise that, due to variations in nature, the distinction between trees and shrubs can be difficult. Moreover, existing definitions often employ terms that are not defined for the purpose of reporting, primarily at the international level. This is particularly true for the distinction of tree elements, i.e. roots, stump, stem, branches, bark, foliage, but also for variables such as height, crown cover and for the characteristics of living and dead, standing and lying, and unusually shaped trees which are essential for estimating the resource of wood. Since the individual tree is the basic element of any forest resource assessment, the clarification of tree-related terms was an important achievement of COST Action E43 to harmonise common reporting of NFIs. Based on a review of existing definitions and on the identification of the requirements for harmonised reporting, common tree-related definitions have been established (Gschwantner et al. 2009).

The secondary objective of COST Action E43 was to support new inventories in such a way that inventories meet national, European and global level requirements in supplying up-to-date, harmonised and transparent forest resource information, and to promote the use of scientifically sound and validated methods in forest inventory designs, data collection and data analysis. More than 30 countries and institutions, mainly from Europe, and multiple international institutions joined the Action, initiated in 2004 (McRoberts et al. 2012).

The published methodologies of establishing reference definitions and bridges to enhance harmonisation opened up the possibility to produce harmonised data at European level.

1.4.1.2 Harmonisation Steps

The methodology developed within COST Action E43 considered four steps for harmonisation (Vidal et al. 2008). The first step was to establish a screening exercise to assess the situation nationally. To be able to speak about improving the comparability of data it is necessary first to have a clear "**state of the art**". For that purpose, the way of working of COST Action E43 was to design a questionnaire by working groups (WG) on variables of interest. This questionnaire was discussed, amended and validated by all countries participating in the action. This process was an iterative process with bilateral exchanges, in order to have a clear common understanding of national situations and concepts and definitions used.

The second step was to make an **analytical decomposition** of each definition to be harmonised. By analytical decomposition it must be understood to individualise and describe the main criteria necessary to define the concept. Let’s take the example of definition of a forest. The main criteria used are minimum area, crown coverage and land use. To these criteria are associated thresholds. With the example of forest, the thresholds associated to minimum area could be 0.1 ha or 0.5 ha or also 1 ha and thresholds associated to minimum crown coverage could be 5, 10 % or even 30 % depending on the countries.

The third one is to build what was called a **reference definition**. In light of the questionnaire results and the analytical decomposition, the COST Action E43 members discussed and agreed upon a common definition which is possible to be accepted by everybody and the closest possible to the way of working of each. This is also an iterative process to reach a consensus.

The fourth step of the harmonisation process is to build **bridges** (Ståhl et al. 2012) between national definitions and the agreed reference definition. The analytical decomposition of the criteria and thresholds during the process formed the basis of this work. Information on the criteria and thresholds assists in the identification of where the differences are and how to build a bridge to transform national data into comparable data.

This way of working is diverse and challenging depending on the context and differences between the definitions. However, this step-wise methodology provides a framework towards harmonisation.

1.4.1.3 Requirements for Successful Harmonisation

For harmonisation to be successful, several factors need to be considered. Firstly, the definitions involved (both the reference and the local definition) must be concise and sharp so that it is clearly understood what are the differences between them. One “side-effect” of this first step is also to have a clear picture of the non-comparability of data contained in international reporting from producer of information but also from data user sides. This awareness is an essential clarification step in order to enhance the willingness to harmonise data. Secondly, local data or information with adequate accuracy must be available. Thirdly, methods to convert from the local to the reference definition must be developed and then applied depending specifically on the context. Finally, bridges can be seen as means to cross over from “islands” of local definitions to a reference definition “mainland”. The objective is to propose a structured approach to develop bridging functions from different sorts in line with different situations.

1.4.2 European Framework Contract

The above mentioned methodology was applied in helping the EC Joint Research Centre (JRC) to set up a harmonised forest database as requested by the EU forest strategy document (COM 2013/659). In this respect, in 2007 the JRC launched a four-year Framework Contract (FC) for provision of forest data and services. A consortium of ENFIN members was successful in securing this contract. The main outputs of this first FC were: (i) the provision of harmonised tree species distribution data from European NFIs with the joint JRC-ENFIN publication of a European tree species atlas as an output (San Miguel et al. 2016) (ii) the validation of the JRC European forest map with more than 2 million NFI forest/non forest plots and (iii) a harmonised basal area statistical estimation based on the 50 × 50 km Infrastructure for Spatial Information in the European Community (INSPIRE) grid with a satisfactory confidence interval. After this four-year FC recognised by the European Commission (EC) as a demonstration project, a second FC was signed in 2011 in order to continue to provide data and services to the JRC on a voluntary basis. Initial results from this second FC include (i) a harmonised method for calculation of biomass with a common methodology accepted by mainly all European countries (ii) an open source model on estimation of volume and growing stock applicable under different climatic and forest management conditions all over Europe. This model is called European Forest Dynamic Model (EFDM) and is under development.

1.4.3 Projection Tools at National Level

Nordic countries were not only the first to initiate sample-based NFIs in the twentieth century but also in trying to assess the potential availability of wood as an industrial raw-material. This information was required to provide a sound basis for the establishment of forest industries. With the increasing interest in the forest and the forest resources, not least as a biomass source for energy use, a growing interest in assessing the potentials and the possible development of the forests is being observed. Over the last decades computerised systems have been developed to predict wood supply across Europe. In many cases these projection systems are based on NFI data and are applicable at both local and regional level. However, in Eastern countries the implementation of sampling based NFI designs has begun in recent decades, with official projections frequently based on forest management plans. As the demand for projection systems arose within countries, these are normally developed with a national scope being subject to the differences in NFI layouts and designs. As a result, the application of a specific system across countries is difficult and even projections obtained using different tools are not easily comparable.

In Europe many different forest management systems coexist, yielding differently structured forests. The two main groups of forest structures are even-aged forest and uneven-aged forests. Even-aged forests are the result of tract harvesting system with regeneration, followed by thinning and clear felling as the basic management cycle. It could also be the follow up management action after a natural disaster such as a forest fire. The uneven-aged forests, result from management systems that are based on continuous-cover silvicultural principles or from no management at all. Adding to this, species mixtures also contribute to increasing the complexity of forests systems. Countries which had a major interest in the forest sector and long experience in the use of NFI data, became forerunners in the development work. Sweden and Finland, characterised by even-aged homogeneous forests under active management, became leading countries, while for countries such as France, Italy and Spain where the diversity in soils, climate and forest conditions prevail, the development of projection systems has proven difficult. In Spain, such efforts resulted in the development of many forest projection tools intended to be used on a local scale (Bravo et al. 2011).

Many projection systems are based on a stand-wise description of the forest, examples of which are found in Czech Republic, Bulgaria, Hungary, Ireland and Lithuania. Irrespective of the description of the forest, some kind of a growth model must be applied in order to express the development of the forest under a pre-defined management. These growth models can be developed using NFI plot data, experimental plots or a combination thereof. Permanent as well as temporary plots can be used to develop growth models as demonstrated by examples from Finland, Sweden and Portugal. Fundamentally, the use of a model to project the future development of a forest means that we are extrapolating historical patterns, as estimated from historical data, into the future.

Individual NFI plots are the basic calculation unit in many modern projection tools, currently applied or applicable to even-aged forests. The initial state of the forests is described by a set of plots, each one characterised by a number of attributes as tree species, tree diameter and height or basal area and tree dominant height. The models used for illustrating the dynamics of the forests are applied directly to the plots representing the forest. A multitude of growth models are at hand, some of them are area based whereas others express the development of individual trees. Examples of this type of systems are the Swedish Heureka-system (with its predecessor HUGIN) (Wikstrom et al. 2011) and the Finnish MELA (Redsven et al. 2012).

In turn, uneven-aged forests are often described by using the distribution of stems by diameter-classes. Most projection tools developed for these types of forests are not intended for national application, but for stand level analysis. However, there are a few projection tools based on regional aggregates of plots either by age, diameter or tree classes, e.g. in Austria or France. Regional aggregates by diameter classes could contain trees with the same diameter, but from very different stands, implying that the development over time could be significantly different, due to varying competition from other trees and lack of observed variation in natural conditions. Long-term simulations using this kind of models always require careful analysis.

Many national studies were recently conducted to address the question of wood available for energy in European countries and in other parts of the world (FAO 2008). Fewer studies characterise the total available wood split into the different usage categories: saw timber, other industrial wood and energy wood. One difficulty for the comparability of the results at international level is the variety of definitions describing wood assortments, which frequently depend on the species, the industry and the market. A recent report by the UNECE/FAO Timber Section showed that there is a potential to supply more wood from the European forests (Hetsch 2009). However, the authors highlight that the results used in the report suffer from diversity of sources and definitions, which limits the comparability of the results between countries. For example, the “potential supply” is not a clear concept. It could mean that the wood is technically harvestable, but also that it is environmentally, economically and socially acceptable. NFIs can provide information on the technical availability, sometimes taking into account environmental factors, but these parameters differ from one country to another, which makes it difficult to compare or sum the results.

1.4.4 Projection Systems at International Level

Over the years, some efforts have been put into trying to establish European level forest dynamics analyses based on a more or less harmonised data structure. One of the first attempts was the so called IIASA-model developed in late 1980s, and used to make forest analyses at European level including the European part of the former Soviet Union (Nilsson et al. 1992). This projection tool was an area based matrix type model that was calibrated using differing wood quality and stand structure data sets. For some countries available NFI data and in other cases official statistics and yield tables were used. The basic concept was later moved into the European Forest Information SCENario Model (EFISCEN) model (Nabuurs et al. 2007; Sallnäs 1990; Schelhaas et al. 2007; Verkerk et al. 2011) developed at the European Forest Institute (EFI) which kept being improved and has been applied in a number of studies, many of them at European level. To carry out these studies, in many cases supported by national NFIs, the EFI built up a European data base from which the model can be calibrated and run. The EFISCEN projection system has served as the “forest part” of some of the most recent forest sector outlook studies, for example EFSOS-II. The original model concept was designed to be applied on even-aged forests, and it is still of limited application to uneven-aged forests. More recently, the JRC project EFDM (European Forestry Dynamics Model) (Packalen et al. 2014) aimed to further develop the model concept of the IIASA and EFISCEN models. The project is carried out in close collaboration with the national NFIs under the coordination of ENFIN so that the model can be based on NFI plots. The approach is based on the premise that information from NFI plots measured or assessed in two consecutive points in time are aggregated into the matrices that constitute the core of the model. However, opinions among countries vary regarding the provision of detailed NFI-based data for European wide analyses. While some countries publish detailed data on the Internet, others are more restrictive due to national confidentially agreements. Therefore, detailed work with NFI data is carried out at a national level, while the aggregated information contained in the matrices can be used on a pan-European level. Making pan-European analyses also demands "national" information about management and other parameters reflecting the socio-economic conditions in the country. A successful pan-European analysis, especially in the domain of policy impact analyses thus presupposes a close cooperation between the analytical body and national experts. That is one of the goals of the future European Commission's European Forest Bureau Network (COM 2013/659), a joint NFI experts and stakeholder network developing harmonised criteria for NFI data.

Since around half of the EU forests, mainly in the South of Europe, can be regarded as uneven-aged the Joint Research Centre also decided to invest in developing a European projection tool, able to make projections for these forests, based on an alternative concept. The approach is to model the development of areas, represented by NFI-plots, instead of trees, with the areas (plots) characterised by volume and stem-number (Sallnäs et al. 2015).

1.5 COST Action Usewood

In 2010, the ENFIN group proposed a new COST Action focused on wood resources estimation and called: "Improving Data and Information on the Potential Supply of Wood Resources. A European Approach from Multisource National Forest Inventories". The Memorandum of Understanding of this action focused on the following: "The question of availability of wood in Europe on a sustainable basis is highly relevant to define global change mitigation strategies and targets for biomass energy as adopted at national and European level, and to support the proposal of an increased use of wood as a post-Kyoto decision. Future scenarios at EU-level highlight a deficit of wood supply compared to wood consumption. Major issues to be clarified are the potential supply of tree biomass, trees outside the forest, and the economic, social and ecological conditions, which will determine the wood supply. The COST Action aimed at improving information and methodologies on the potential sustainable wood supply using NFI data to reduce the given uncertainties. Such harmonised information is urgent to improve the calculation basis for decision makers in the forest, environment, and in the wood and energy sectors" (Cost Action Usewood 2014).

The objectives of this COST Action were:

- to improve and harmonise data and information on the potential supply of wood resources at European level as well as to compare and disseminate the methodologies including remote sensing techniques, definitions and results of wood resource studies in European countries
- to develop best practices and harmonised guidelines in this field
- to exchange information on difficulties and challenges and find harmonised solutions in e.g. modelling taper curves and assortments of trees or in assessing trees outside forests, to help countries to improve their expertise in special modelling or remote sensing techniques in capacity building of these technical areas, to contribute to build a comprehensive and reliable picture of potential wood supply as an input to energy, environment, forest policy making, and wood industry decision making.

The objectives of the Action were to achieve the following three basic mechanisms. Firstly, the scientific program including its work plan, time table and deliverables were elaborated with specific consideration to the production of results. Secondly the large body of ongoing work on assessing and using wood supply both at national and international level would ensure that the Action is based on substantial scientific activities. Thirdly the collected expertise involved in the Action would guarantee both linkages to the data providers and the research communities working within the topic and the use, and dissemination channels of the action.

1.5.1 COST Action Usewood Working Groups

The focus of Working Group 1 (WG1) was on available field data and information from the NFIs, as well as information on sampling design and estimation techniques for wood resources. The work further developed the methodology for the harmonisation of NFIs performed under the COST Action E43. New variables are discussed, such as Forest Available for Wood Supply (FAWS), quality of wood, increment, fellings, and mortality, Other Wooded Land (OWL) and Trees outside Forest (TOF) were investigated and harmonised definitions developed. The major question to investigate was, how much wood is available at present (taking age classes and diameter thresholds into account), and in collaboration with WG3 how much will be available in the next decades. Although the question is not entirely addressed, recommendations for statistically sound data assessment and estimation techniques are given. The effects of different approaches on the results are also presented.

Working Group 2 (WG2) investigated methods for improving estimates of wood resources by integrating remotely sensed and NFI field data. The overall aim was to develop scientifically sound practices for assessing tree biomass and other forest resources, inside and outside forests, in support of periodic and rapid updates of estimates at NUTS3 and regional levels. WG2 provided an overview of the extent to which NFIs use remote sensing data, tools, and methods (e.g. satellite and airborne imagery, optical area, LiDAR and radar data). The role of remote sensing in improving the efficiency of sampling designs and the precision of estimates was considered. Methods to estimate forest attributes, such as biomass and volume, for small areas and to map their spatial distribution was discussed and evaluated. Special attention was devoted to error estimation, detection of clear-cuts and other changes in forest resources for the purpose of estimating change in biomass.

Working Group 3 (WG3) worked on guidelines for harmonised forest information for better exchange of information between inventory data of standing volume and consumption statistics which follow market needs and developments. The WG3 identified availability of production and trade statistics and the potential to improve information for a better transfer from NFI -data to consumption data.

1.5.2 Working Group 1

This book is a product of WG1 work. One of the main actions of WG1 pursued to harmonise data and information on the potential sustainable wood supply around Europe. Within this framework, the main goal of WG1 was to increase the knowledge about different national definitions to promote the harmonisation of the assessments and estimation techniques of current and changing wood resources based on NFI data.

To achieve the aforementioned goal more efficiently the WG1 was organised to four subgroups that focused on four thematic areas: (1) Forest available for wood supply (FAWS); (2) Stem quality assortments; (3) Change estimation; and (4) Other Wooded Land (OWL) and Trees Outside Forest (TOF) (Fig. 1.2).

The way of working within the WG1 was elaborated in four steps:

1. An analyse of existing international definitions for each variable of interest was conducted by sub-group and the weaknesses of international definitions identified
2. A questionnaire was built in order to have a clear picture of how definitions were applied nationally
3. Reference definitions were firstly discussed and proposed by each SG. The definitions were then amended and validated in plenary by all COST member countries
4. A country report (CR) was foreseen and the structure and template of such a CR was discussed and approved by the full WG1.

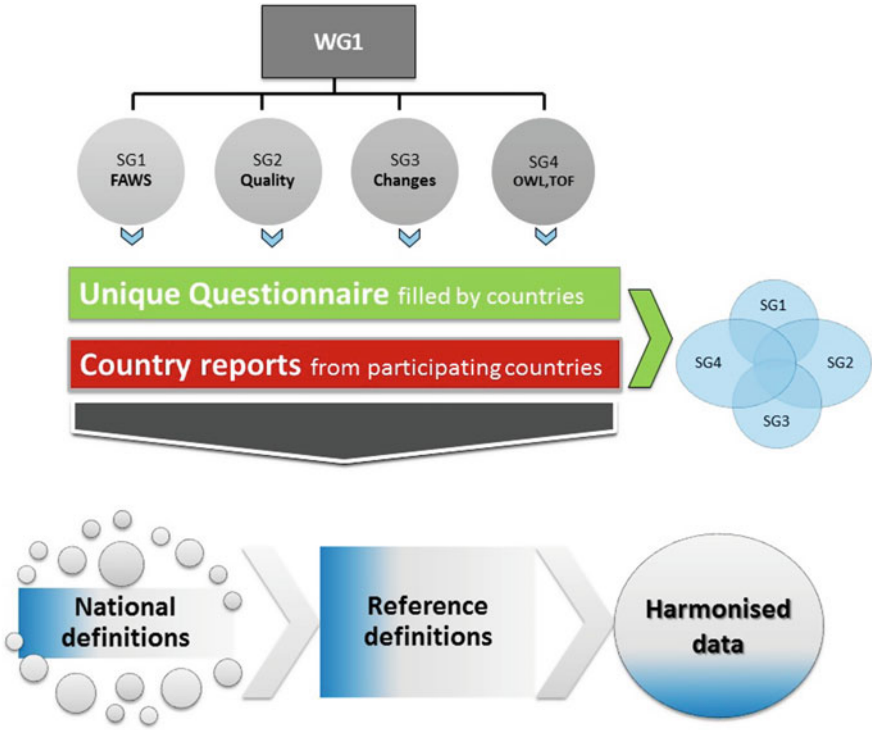

Fig. 1.2 Structure of COST Action Usewood WG1 and the working sub-groups (SG)

After four years of work and cooperation, these four subgroups have compiled a huge amount of information about wood resources assessments, estimations and national definitions at European level through country reports (CRs) and questionnaires. The analysis of all this information based on the collaboration between international research groups provide interesting results to further understand the diversity of wood resources and estimations in Europe. This volume contains (i) a general overview of the main findings (ii) obtained common reference definitions established and (iii) the contents of the CRs on the assessment, availability and use of wood resources sent by the participating countries. Thirteen non-COST countries joined our initiative and provided a CR as far as possible in line with European questions and specifications.

Taking into consideration the broad-scale goal of the book it was important to collect as large a number of CRs as possible. In total 40 country reports were completed, 28 of which were from COST member countries plus the USA and due to the international focus of this book a further 11 non-COST member countries also submitted country reports (Fig. 1.3).

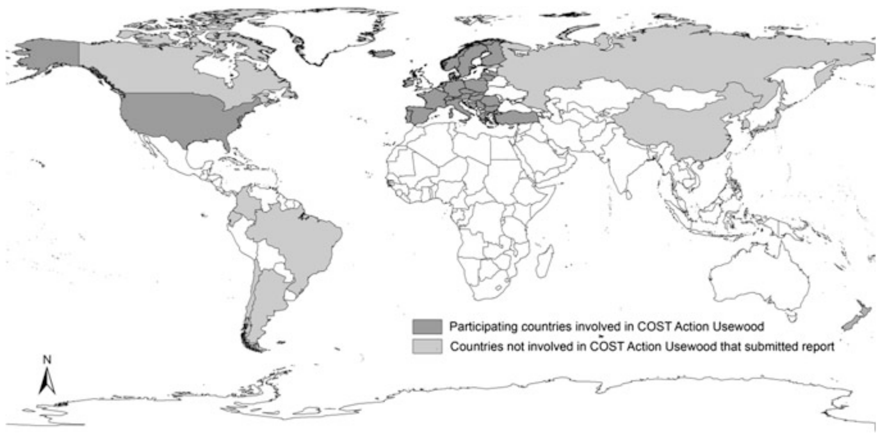

Fig. 1.3 Countries submitting a report for this book

1.6 Structure of the Book

This introductory chapter one of the book provides an overview of the motivation of COST Action Usewood and outlines the necessity of the international provision of wood resources information in a harmonised context. After briefly describing the history of wood resource assessment in Europe, this chapter illustrates the function of NFIs as forest data providers to estimate wood resources at national and international level. Finally, the objectives and structure of COST Action Usewood are described. Chapter 2 summarises the synergies found regarding wood resource definitions, assessments and estimation focus in the four main subjects of WG1: (i) forest available for wood supply (ii) stem quality assessment (iii) change estimation and (iv) other wooded land and tree outside forests estimation. This information is based on the material from country reports and questionnaires supplied by the participating countries during the COST Action.

Chapters 3 and 4 present an overview of the harmonisation progress regarding wood resource assessment. Chapter 3 focuses on the construction of reference definitions, presenting the agreed definitions by WG1 for the four main subjects. Chapter 4 concentrates on the bridge building concept, showing some applications and examples accomplished during the COST Action that facilitate the estimation of wood resources consistent with the reference definitions.

Finally, focused on the information from non-COST member countries, Chap. 5 presents an overview of the wood resource assessment beyond Europe and the feasibility of these countries to adopt the COST Action Usewood reference definitions proposed.

After Chap. 5, 40 individual reports are presented. These reports were submitted voluntarily by countries and describe national wood resources, methods and estimation techniques together with related reference definitions. Most of the reports follow the same structure. This includes a first part comprising a brief history of the NFIs, sampling methods, data collection as well as processing, reporting and use of results on wood resources. A second part contains a description of the land classification, the variables used to estimate wood resources and the particular assessment of wood resources. The third part describes the different methods to assess and estimate the forest available for wood supply, wood quality assortments, changes (increment and drain) and other Wooded Land and Trees outside Forests from national forest surveys.

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Chapter 2
Comparison of Wood Resource Assessment in National Forest Inventories

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2.1 Introduction

The main objective of COST Action Usewood was to improve and harmonise data and information on the potential sustainable supply of wood resources at European level based on NFIs. The question of availability of wood in Europe on a sustainable basis is highly relevant to define global change mitigation strategies and targets for biomass energy as adopted at national and European level, and to support the proposal of an increased use of wood as a post-Kyoto decision. NFIs were

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primarily developed to address national level policy needs, while also being widely used as source of information for international reporting processes. However due to the different historical backgrounds, national ecological processes, environmental conditions and objectives, NFIs adopted different basic definitions and methodologies, leading to inconsistencies and lack of comparability in international reporting (Gabler et al. 2012; Tomppo et al. 2010).

To satisfy the objectives of the COST Action it was necessary to first ascertain the current status of wood resources assessment in European NFI's, which would provide the basic information required for harmonisation. WG1 initially focused its efforts on the sampling designs and estimation techniques used to assess the status and changes in wood resources. The NFI harmonisation work achieved during COST Action E43 (2010) was built-on and further extended to focus more on the assessment of wood resources. Case studies were conducted to demonstrate harmonisation options and elaborate recommendations for remote sensing and field data collection. To address the specific objectives of COST Action Usewood, the activities of WG1 were organised into four sub-groups that would comprehensively address the assessment of wood resources. The four sub-groups dealt with the topics of; *Forest Available for Wood Supply*, *Stem Quality*, *Change Estimation* and *Other Wooded Land and Trees outside Forest.*

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2.2 Development of Wood Resource Assessment

Forest surveys were first commenced to address concerns surrounding the sustainable supply of wood resources within a defined area. The primary interest concerned the availability of wood for local needs e.g. mining. When wood resources became a limiting factor for societal needs, the need for long-term sustainability of forest management was highlighted. Forest owners or policy makers required detailed information on the status of forest areas to inform future management decisions at a more strategic level.

Many European countries firstly used Forest Management Planning (FMP) techniques to assess wood resources within forests. Forest Management Planning techniques involve the sub-division of forest areas into homogenous units on a map. The areas identified on the map are further described in associated tables, which provide attribute information such as tree species composition, stand age, growing stock volume per hectare, etc. The aggregation of this stand-level information facilitated the production of regional and national estimates. An important advantage of these inventories is that forest managers and owners have local level information to manage their forest areas. In many European countries the requirement to undertake a FMP is enshrined in national legislation. FMP techniques by their nature are extremely labour intensive and as such carry a significant burden in terms of time and financial resources. They cannot provide precise national data at a specified date due to the wide assessment timeframe of the management units.

Statistical based NFIs were first introduced in Nordic countries as a means of assessing the wood resources at a regional and national level. The sampling design applied in NFIs provide a very robust basis for the assessment of the national forest estate. Due to the lower resolution of forest sampling used in NFIs compared to FMP, the statistics generated are generally not suitable for local forest management. NFI's provide robust data to generate statistics at a national and regional level where the sampling intensity is high enough for the objectives at hand. However it is worth noting, that given the extent of forest resources, remote sensing techniques have been successfully incorporated into inventory and monitoring processes (Tomppo et al. 2008; McRoberts et al. 2006).

The main international requirements for forest information, are the Food and Agriculture Organization of the United Nations (FAO) Forest Resources Assessment (FRA), and the obligations following from the commitments towards sustainable forest management (FOREST EUROPE) and United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. NFIs are one of the main data sources for all these reporting processes.

The existing gap in harmonisation concerning data being reported to international processes has been highlighted in Chap. 1. To understand the reasons behind this lack of harmonisation the measurement and estimation techniques to assess the status and changes in wood resources were evaluated at a more strategic level in the this chapter.

2.3 Materials Used to Compare Wood Resource Assessment Techniques

Two separate mechanisms were used to collect information on the current status of wood resources assessment and change estimations in European NFIs during the COST Action Usewood: questionnaires and country reports. This combined approach of collecting information from NFIs was successfully applied during COST Action E43 (2010) and integrates the advantages of both survey techniques. While the questionnaire requested information using concisely formulated questions that can mostly be answered by “yes” or “no” or by giving values, the country reports offered an opportunity to describe the country-level assessment systems more freely and to bring in aspects that are of particular importance under the respective conditions in the individual countries.

2.3.1 Questionnaires

The questionnaire was conducted in order to ascertain the differences between the definitions and components that make up the definitions that are applied nationally by the various NFIs.

There were four questionnaires, each one covering the topics of the sub-groups. The questionnaire included two steps of information collection. In the first step, the essential questions were elaborated, delivered to the NFI experts as an online survey, their responses collected in a database, and the provided information analysed. In the second step the questionnaire was reviewed, refined and again sent to the NFI experts. This two-step approach was established as a robust method to collect good quality information during COST E43 (Vidal et al. 2008). Supporting information was also provided to avoid any misunderstanding. Plausibility checks were made at the first and second step of the enquiry which included cross-checks between corresponding questions and comparisons with additionally drafted country reports. The reliability of questionnaire results under the given survey conditions was discussed by Cienciala et al. (2008). The aims, contents and supporting information of the four thematic parts of the questionnaire are described in the following sections.

2.3.1.1 Sub-working Group 1: Forest Available for Wood Supply

The aim of the questionnaire was to assess whether NFIs in Europe evaluate forests available for wood supply (FAWS) and whether it is comparable to international definitions of FAWS. The objective was to build a common definition of FAWS for

European NFIs which allows for harmonised information on available wood resources. The questionnaire requested information on:

- The definition of FAWS
- Harvesting techniques and costs
- Estimation and assessment of FAWS
- Relevance of legal restrictions
- Relevance of physiographic restrictions
- Relevance of restrictions due to environmental conditions and biodiversity conservation (without legal restrictions)
- Use of International Union for Conservation of Nature (IUCN) categories
- Relevance of restrictions due to management, harvesting and silvicultural conditions.

Supporting information was provided on:

- The existing definition of FAWS
- Harvesting techniques and costs.

2.3.1.2 Sub-working Group 2: Stem Quality and Assortments

The questionnaire focused on the stem quality assessment of living trees in NFIs. The methods of stem quality assessment were of primary interest. Implementation of existing European standards on stem quality grading into national specifications was also of interest. The objective of the questionnaire was to identify how European NFIs assess and estimate stem quality and wood assortments. The questionnaire requested information on:

- Field assessment of stem quality
- Quality classification in field
- Product assortments.

Supporting information was provided in the form of a template presenting the application of stem quality assessment in Slovakia.

2.3.1.3 Sub-working Group 3: Change Estimation

This questionnaire focussed on the approaches of NFIs in Europe to estimate changes in forest resources. Particular attention was paid to the sampling design, sample tree assessments, the use of models, the change components included tree parts, and the produced estimates. The enquiry built on the work and information collected during COST Action E43 which included country-level descriptions of increment and drain estimation from 37 countries (Tomppo et al. 2010). The information already available was complemented by an analysis of literature and by expert opinions of the members of WG1 of COST Action Usewood (2014) to reflect the current situation of change estimation in the questionnaire. The information was collected with a view to exploring the change components considered relevant by NFIs, and to facilitate the formulation of reference definitions in order to allow for the harmonisation and common reporting of increment and drain estimates. The questionnaire consisted of three sections:

- General questions with regard to change estimation
- Increment
- Fellings and natural losses.

Supporting information was provided on:

- International definitions, including UNECE/FAO (2000), FAO (2004, 2010, 2012), FOREST EUROPE, UNECE and FAO (2011), and IPCC (2006)
- Graphical representation of change components
- Relevant information from scientific literature.

2.3.1.4 Sub-working Group 4: Other Wooded Land and Trees Outside Forest

The aim of the questionnaire was to find out how NFIs in Europe define, measure and estimate tree resources outside forest as defined by the Food and Agriculture Organization of the United Nations (FAO), i.e. the Forest Resources Assessment (FRA) categories other wooded land (OWL) and other land with tree cover (OLwTC), as well as other (single) tree resources outside forest (TOF).

The objective was to review and to define reference definitions for such tree resources outside forest which allows for the harmonisation of information and common reporting on such tree resources from European NFIs. The way of working was to partition of the TOF category in order to discuss the possibility of creating a harmonised methodology of estimating tree resources in each class. The questionnaire requested information on:

- Other wooded land
- Trees outside forest
- Other land with tree cover.

Supporting information was provided on:

- International definitions
- Differences between trees and shrubs definitions in FRA and COST E 43
- Differences between OWL in FRA and E43.

2.3.2 Country Reports

In addition to the questionnaires, the second approach used to ascertain information about resource availability took the form of country reports. The country reports aimed to collate detailed information on NFI methods from countries in a descriptive manner and complemented the information collected through questionnaires. This turned out to be particularly useful in countries where methods had changed since the COST Action E43 (2010) and in countries where change estimation procedures are under development. Through consultation within WG1, a standardised Country Report (CR) template was created to act as a guide on the content that countries should include in their national report. As such the country reports include thematic sections on the history and objectives of NFIs, sampling methods, data collection, data processing, reporting and the use of results, the classification of land and forests, wood resources and their use, and the assessment of wood resources which focussed on the topics of the four sub-groups: forest available for wood supply, wood quality, assessment of change, and other wooded land and trees outside forest.

The valuable collection of CR information for 40 countries form a significant part of this publication. Non-COST member countries were also invited to submit country reports for publication. For European countries it was possible to follow the standardised layout. However, for countries outside of Europe certain concepts, such as FAWS, may not have been adopted. Thus, the country reports for the non-European countries deviate slightly from the above layout.

2.4 COST Action Framework

2.4.1 Working Group Meetings

The work of COST Actions is organised through Working Groups (WG), that aim to perform the necessary tasks required for the Action to fulfil its objectives as defined in the Memorandum of Understanding. The Management Committee (MC) appointed WG Leaders and Vice Leaders for each WG who were responsible for coordinating and managing the activities and tasks associated with the Action objectives relevant to the specific WG.

WG members are selected from amongst MC Members, or MC Observers from Near Neighbour Countries (NNC), International Partners Countries (IPC), Specific Organisations, as well as any researchers from participating COST Member Countries.

The WG meetings provided an important opportunity for the members to meet and discuss the activities and progress towards addressing the tasks associated with the Action objectives. During COST Action Usewood four WG meetings were held, the details of which are outlined in Table 2.1.

Table 2.1 COST Action Usewood WG meetings

WG meeting	Location	Host	Date
1	Vienna, Austria	Austrian Research Centre for Forests (BFW)	10–11 March 2011
2	Copenhagen, Denmark	European Environment Agency	12–13 June 2012
3	Riga, Latvia	Latvian State Forest Research Institute	12–14 March 2013
4	Dublin, Ireland	Department of Agriculture, Food and the Marine	28–29 April 2014

2.4.2 *Short Term Scientific Missions*

Short Term Scientific Missions (STSM) are COST instruments for supporting individual mobility, with the aim of strengthening new or existing networks and fostering collaborations by allowing scientists to visit research institutions in other Participating COST Countries. A STSM should contribute to the scientific objectives of the COST Action, while at the same time allowing applicants to learn new techniques or gain access to specific instruments and/or methods not available in their own institutions. During the course of the COST Action Usewood, 32 individuals partook in STSM.

STSMs proved to be very useful mechanism in terms of analysing the results of the questionnaires and allowing participants to learn new techniques and to broaden their knowledge. The activities of the STSM were ultimately aimed at completing tasks associated with the Action objectives relevant to the specific WG. Within WG1 eight STSM were undertaken, the details of which are outlined in Table 2.2.

2.5 Diversity and Similarities in the Assessment of Wood Resources

The information provided through questionnaires and country reports provided the raw materials required to understand the differences between the definitions and components that make up the definitions that are applied nationally by the various NFIs. Results from the four sub-groups are presented outlining the diversity and similarities among the assessment of wood resources between countries.

Table 2.2 Overview of WG1 STSM's

STSM details	Objectives of STSM
Change estimation Birmensdorf, Switzerland 7–21 Nov 2012	The purpose of this STSM was to carry out a comparitive analysis of the change estimation techniques implemented in the Bulgarian NFI compared to those in the Swiss NFI using Bulgarian data. The STSM included the following activities: (i) A study of the methodology of the Swiss NFI and the experience of its third application (ii) Compare the estimates from the Bulgarian software to those generated using the Swiss software (iii) Undertake field work for the calculation and evaluation of dead wood, and regeneration in forest
Change estimation Birmensdorf, Switzerland 12–21 Nov 2012	The purpose of this STSM was to: (i) Assess the different methods to estimate changes in forest resources like net increment, gross increment, fellings and losses, drain etc. (ii) Assess the different definitions and/or the understanding of these change estimate components
Change estimation Birmensdorf, Switzerland 12–16 Dec 2012	The purpose of this STSM was to: (i) Review the situation of current data availability (ii) Develop a questionnaire to evaluate the practices applied by NFIs, assess the means of distribution and analysis methods for the questionnaire results (iii) Prepare the structure of a template for country reports (iv) Collate and review the relevant definitions existing at the international level
OWL & TOF Nancy France 19–30 Nov 2012	The purpose of this STSM was to: (i) Analyse the responses of the WG1 questionnaires on Other Wooded Land (OWL), Other Land with Tree Cover (OLwTC) and Trees Outside Forest (TOF) (ii) Identify the main differences and discuss ways of definitions harmonisation
OWL & TOF Nancy, France 14–25 Oct 2013	The purpose of this STSM was to: (i) complete the model of partition of the territory and to name each category (ii) formulate reference definitions for each category (iii) prepare and discuss scientific paper structure
Stem quality Wexford, Ireland 11–17 Nov 2012	The purpose of this STSM was to: (i) Overview of assessed quality parameters on stem in NFIs using questionnaires and country reports (ii) Overview of European standards relevant to the assessment of stem quality (iii) Identify relevant parameters for stem quality assessment on standing Trees
FAWS Madrid, Spain 19–29 Nov 2012	The purpose of this STSM was to: (i) Evaluate the results from the questionnaires (ii) Further, the possibility to draft the outline of a scientific publication concerning harvesting COST calculations
FAWS Madrid, Spain 21 Oct –1 Nov 2013	The purpose of this STSM was to: (i) Evaluate the new results from the questionnaires (ii) To analyse restrictions relevance in case studies
WG1 Book edition Birmensdorf, Switzerland 15–30 Aug 2014	The purpose of this STSM was the following: (i) the revision, edition and homogenization of the different CRs information for the last chapter of the book (ii) to perform a partial analysis contrasting the diversity of FAWS assessment and estimation around Europe, and (iii) participation in the Editorial Board meeting held during the last week of the STSM (from 26th to 28th August)

2.5.1 FAWS Assessment

2.5.1.1 Differences in National Definitions

The main information source for estimating the FAWS as well as its growing stock and its change at national level are NFIs. FAWS is one of the basic characteristics collected through international forest reporting. The COST Action Usewood questionnaire regarding FAWS was answered by NFI delegates from 29 European countries.

Some countries have adopted the international definition from SoEF (FOREST EUROPE, UNECE and FAO 2011) while others have developed national definitions (Table 2.3). The SoEF international definition is the following: "*Forest where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood. Includes: areas where, although there are no such restrictions, harvesting is not taking place, for example areas included in long-term utilisation plans or intentions*".

Following the analysis of the questionnaire, it became apparent that the term "availability" (for wood supply) of FAWS was not equally interpreted by all countries. Some considered it as potential availability (future availability), current availability or even as a period of time (such as the rotation period). Table 2.4 shows that some countries even consider both the potential and current availability in their assessments.

The national definitions of FAWS differ considerably from country to country as summarised in Table 2.5, extracted from Alberdi et al. (2016). Generally, different restrictions and thresholds are considered by the countries to determine "forest not available for wood supply" (FNAWS) (such as protected areas or slope) and therefore FAWS is estimated by exclusion. The most prevalent restrictions are legal, environmental, and economic restrictions. A specified forest area can be subject to more than one and up to a combination of all three restrictions. However, economic restrictions are only considered within a few countries.

Table 2.3 Percentage of European countries according to the adopted FAWS definition (N = 29)

Definition adopted	Percentage of countries
SoEF 2011 definition	24.2
National definition	65.5
No definition adopted (but reported in SoEF 2011)	10.3

Table 2.4 Number of European NFIs according to the time frame of FAWS definition (N = 29)

FAWS time frame	Percentage of countries
Current	69.0
Potential	48.3
Time period	6.9

Table 2.5 National definitions of FAWS (Alberdi et al. 2016)

Country	National definition
Belgium	National forest area with the exception of the forest with slope above 15 %, non-productive forest land and additionally roads, mud, moors, pools and rivers which are part of the forest
Bosnia and Herzegovina	Forests with productive character
Czech Republic	Categorisation of forest according to forest law considering its prevalent function
Estonia	All forests not strictly protected
Finland	Very similar to SoEF definition. For each specific land use category, a protection programme is defined with the 3 categories (a) fully AWS, (b) semi-AWS (c) non-AWS
France	Forest where tree felling is physically and legally possible, even if it is difficult and not economically profitable. No condition on site productivity
Germany	Restrictions on use exist if the potential uses of the timber cannot be realised. This includes restrictions on the use of timber due to legal regulations or other external reasons. The reason for such restrictions is indicated: Restrictions on use: no restriction on the use of timber; restricted forest utilisation; use of timber not authorised or not expected; approx. 1/3 of the usual harvest to be expected; approx. 2/3 of the usual harvest to be expected External reasons for the restriction on use: no external restrictions on use; nature conservation; protection forest; recreational forest; other external reasons In the case of several external reasons, the most important reason is specified Internal reasons for the restrictions on use: no internal restrictions on use; split ownership of uneconomic size (e.g. if the system of land tenure provided for the equal division of land among all qualified heirs); stand-alone location insufficient accessibility; site characteristics, wet location; low yield expectation (mean total increment <1 m^3/year/ha); areas protected at owners discretion (e.g. natural forest reserves); and other internal reasons In the case of several internal reasons, the most important reason is indicated
Greece	Productive or Industrial forests
Ireland	Describes the likely availability of the forest area in terms of wood supply in three classes: 1. Available: Forest where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood. Includes: Areas where, although there are no such restrictions, harvesting is not taking place, for example areas included in long-term utilisation plans or intentions 2. Unlikely: Forest where physical productivity or wood quality is too low or harvesting and transport costs are too high to warrant wood harvesting, apart from occasional cuttings for autoconsumption. Areas include: (i) Forest Type is scrub; (ii) Height growth status is stagnating; (iii) Severe water logging; (iv) Excessive slope (>30°) 3. Not available: Forest with legal restrictions or restrictions resulting from other political decisions, which totally exclude or severely limit wood supply, inter alia for reasons of environmental or biological diversity conservation, e.g. protection forest and other protected areas, such as those of special environmental, scientific, historical, cultural or spiritual interest. Areas classified as National Parks and Nature Reserves are included in this class To date no consideration has been given to economic aspects

(continued)

Table 2.5 (continued)

Country	National definition
Latvia	Forests where forest management as such or specific measures are not limited by regulations, including environmental restrictions (like buffer zones), nature conservation restrictions or regional planning (like cultural heritage) related restrictions
Lithuania	Exploitable forest with usual environmental restrictions. Includes protective forest (protective forests, forests for soil, water, human living surroundings and infrastructure protection) and commercial forest (all forests excluding strict reserves, protected and protective forests). It excludes forests with natural features, key habitats, zones surrounding nests of rare birds, other valuable cultural, historical objects and forest stands of very low productivity
Netherlands	The classifications even-aged and uneven-aged standing forest, standing forest in transition (plantation appearance to more natural forest) and clearcuts are considered as productive and are for this reason considered as FAWS If actual harvesting takes place, it does not have any consequences for the allocation to FAWS
Portugal	It comprises all the forest area, with the exception of cork and holm oak areas, in which wood harvest has strict restrictions and the "Laurisilva" forest, and conservation areas where harvesting is strictly prohibited. Additionally burnt areas and harvested areas are excluded
Romania	Forest with production functions, situated at a distance smaller than 1.2 km from a (forest) road
Serbia	The FAWS category consists of all forests which are not in first regime of protection (rare species of flora and fauna, cultural and heritage areas) and also forests which are accessible for forest mechanisation
Slovenia	Forests are divided into multipurpose forests, special purpose forests with legal restrictions which exclude or limit wood production, forests with protective functions
Spain	Forest land where legal restrictions, site conditions and specific environmental restrictions have a significant impact on the supply of wood. Legal restrictions comprise specific protected areas (National parks, nature parks, reserves and others)
Switzerland	Forest where tree felling is physically and legally possible, even if it is difficult and not economically profitable. No condition on site productivity
Turkey	Very similar to SoEF definition

2.5.1.2 Differences in Methods

FAWS area assessment is done using two main sources of information: NFI sample plots and national maps. Sometimes other sources are employed as for example forest management plans. However, the source of information depends on the restriction that is being considered (Table 2.6). Accessibility, age or diameter classes, slope and expected wood quantity are mostly estimated using NFI plot information while protected areas and ownership are mainly estimated using map information.

Table 2.6 Percentage of European NFIs according to the main sources of information by restriction attribute considered for FAWS assessment (N = 29). Derived from Alberdi et al. (2016)

Restriction attribute	NFI plot (%)	GIS/Map (%)	Others (%)
Protected areas	48.3	55.2	6.9
Protected species	37.9	31.0	3.4
Ownership	24.1	31.0	0.0
Cultural	24.1	27.6	3.4
Slope	41.4	27.6	6.9
Accessibility	41.4	24.1	0.0
Erosion	27.6	24.1	3.4
Historical	24.1	24.1	13.8
Spiritual interest	20.7	24.1	0.0
Altitude	20.7	20.7	0.0
Flooded areas	27.6	17.2	0.0
Riverbank	17.2	17.2	3.4
Age or diameter classes	31.0	13.8	3.4
Harvesting technology	13.8	10.3	3.4
Expected silvicultural treatment	13.8	3.4	0.0
Expected wood quantity	20.7	0.0	3.4
Harvest cost	0.0	0.0	0.0

It is also noteworthy that Iceland and Italy include the FAWS assessment in the field plot survey. In Germany the information about FAWS is assessed as a preliminary detail generally, but if restrictions on the use are only detected during the field assessment they must be indicated too. All other countries conduct the FAWS assignation a posteriori (e.g. through the intersection of sample plot location with thematic maps of restricted areas to identify areas that should be excluded from FAWS).

2.5.1.3 Summary of the Main Findings

The objective of reporting on the availability for wood supply is to distinguish between areas where wood could be harvested from those where it cannot (UNECE/FAO 2000). However, European NFIs have different national definitions and different ways to apply the international definitions provided by FRA 2000 (FAO 2001) and SoEF (FOREST EUROPE, UNECE and FAO 2011). Therefore, the national estimations reported cannot be easily compared and European FAWS estimates cannot be obtained as an aggregation of national estimates. The differing interpretations are a result of the lack of clarity created by the reporting bodies requesting this indicator for reporting on the sustainability of wood production without specifying the timeframe, i.e. current or potential availability of timber. Two primary divergent interpretations of FAWS were identified by analysing the NFI definitions:

- Productive forest (e.g. Bosnia Herzegovina)
- All forest with the exception of those where harvesting is strictly forbidden (e.g. Estonia).

There are other national definitions that can be considered as intermediate variation between the two primary divergent interpretations. Although in general, national definitions of FAWS are close to the international ones, the available data, estimation methods and interpretation varies between countries. However, the majority of the countries in Europe classify forest land based on legal restrictions and forest functions. This is a positive finding, as these classifications set the necessary basis for the potential harmonisation of FAWS estimation. However, as Fischer et al. (2016) suggests that the thresholds of components describing these restrictions should be flexible to represent the particularities of the forest and management systems around Europe.

2.5.2 Stem Quality Assessment

The potential of the European NFIs for harmonised reporting of stem quality and assortment structure of the European forests, including national definitions, was comprehensively described in a recent study by Bosela et al. (2015). This study was supported and is the main result of the COST Action Usewood. In the following sections, the main results of this study are briefly presented.

2.5.2.1 Differences in National Definitions

National definitions regarding stem quality assessment can be split into two main groups: (i) definition of stem quality related parameters (such as diameter threshold, the part of stem to be assessed, damage type, etc.); and (ii) definition of stem quality classes (classification system including a number of classes used and definition of thresholds for each category). While the harmonisation of definitions of common tree parameters has been a matter of recent international activities, the harmonisation of parameters related to stem quality assessment has not yet been considered. In particular, the direct assessment of stem quality or assortment classification has been poorly addressed. This is due to the fact that only several European NFIs consider stem quality assessment. From 28 countries responding to the questionnaire released during the COST Action Usewood as many as 18 (64.2 %) directly classify or assess stem quality in their NFIs but as few as 8 countries use quality classes that are assessed in the field for subsequent quantification of timber assortments (Table 2.7).

Concerning the sampling strategy, 39.3 % of countries measure and record a set of stem quality parameters for all trees registered in the sample plots, while 53.6 % of countries use only a sub-sample of trees. The Austrian NFI assesses stem quality

Table 2.7 Stem quality and assortment assessment in European NFIs (N = 28)

Level of wood quality assessment	Percentage of countries
Assessment of some parameters related to stem quality	100
Stem quality assessment	64.2
Estimation of assortments	39.3
Visually assessed quality classes used to generate assortments	28.6

on sample trees with a dbh over 20.4 cm, while Bosnia and Herzegovina uses a minimum dbh of 5 cm. Czech Republic assesses quality parameters for all trees with dbh over 7 cm on the plot with a radius of 5 m and trees with dbh over 27 cm on the plot with a radius of 12.62 m (these thresholds are at the same time the registration thresholds for tree recording). The same strategy is applied in the Slovakian NFI, but the thresholds are different (trees with dbh in the range of 7–12 cm are sampled in the plot with the radius of 3 m while trees with dbh over 12 cm are recorded on the plot with a radius of 12.62 m). The Danish NFI applies random selection proportional to size, while Estonia generally selects every 3rd tree for this purpose.

Differences between European NFIs were also found in the portion of the tree that is used to assess stem quality (Table 2.8). As few as 6 NFIs (31.6 %), from the total of 18 that apply some stem quality assessment in their NFI, assess the stem quality on the whole stem of the tree (from the base to the tree top). Other NFIs do the assessment using a portion of the tree stem specified by height, top diameter or relative height.

2.5.2.2 Differences in Methods

Methods involve the application of different stem quality and assortment classification systems in European NFIs. Interestingly, eighteen countries distributed over Europe apply some kind of stem quality classification. However, a different number of classes are used among the countries (Table 2.9). In addition, six NFIs assess potential stem quality regardless the current tree size (Table 2.10).

Table 2.8 Number of European NFIs applying stem quality assessment for different portions of the tree stem (N = 18)

Portion of the stem to be assessed	Percentage of countries
Whole tree	33.3
Specific height	33.3
Specific top diameter	22.2
lower 1/3 of stem	11.1
Not specified	5.5

Table 2.9 Number of European NFIs using different number of stem quality classes (N = 18)

Number of stem quality classes	Percentage of countries
2	5.6
3	27.8
4	44.4
5	5.6
6	5.6
9	5.6
n.a.	5.6

Table 2.10 Number of European NFIs using different assessment time-frame (N = 18)

Reference point	Percentage of countries
Current	100
Potential	33.3

The largest number of classes, nine, is used in Finland, while only two quality classes are used in Lithuania. Moreover, differences are also in the classes definitions. A special case is the Swedish NFI, where estimates for timber quality or assortments are not directly from NFI data, but these data are used as an input to the "RegWise" forecasting system, in which projections for distributions of assortments are made for timber and pulp wood (Wikström et al. 2011). According to personal communication with Sweedish NFI staff, the question of stem quality and assortment assessment has been discussed since the first NFI (1923), but no system has fulfilled national requirements. Far fewer NFIs use some kind of assortment generation and quantification.

Concerning land use type, knowledge on stem quality or assortment structure is mostly important for the forest domain. However, as the importance of the timber resources located outside the forest domain has been increasing, the NFIs were also asked to specify on which land use types they collect data for stem quality assessment. Less than 40 % of NFIs record parameters for other wooded land, and very few countries have some information for other domains such as trees outside forest, other land with tree cover.

2.5.2.3 Summary of the Main Findings

The questionnaire on stem quality assessment shows that very few NFIs assess a number of timber quality parameters that could be used for developing harmonised timber quality classification (Table 2.11). Less than 50 % of NFIs assess parameters such as stem cavity, curvature, straightness, branching, branch angle or upper diameter. On the other hand, almost 80 % of NFIs assess occurrence of stem damage and more than 60 % even recognise sources of damage (abiotic, biotic, forking, etc.), which is a very promising base for future harmonisation. Usually,

Table 2.11 Proportion of European NFIs assessing individual stem quality related parameters

Stem quality parameter	Recorded in the field (N = 28) (%)	Used to stem quality assessment (N = 18) (%)	Used to assortments generation (N = 11) (%)
Tree status (dead, alive)	100	94	91
Tree dbh	100	100	100
Tree height	100	78	91
Stem damage source	64	72	45
Abiotic damage	64	72	36
Biotic damage	61	72	36
Stem damage	79	89	73
Forking	64	72	64
Tree break	75	83	73
Curvature	43	67	73
Splitting due to frost	61	67	64
Splitting due to lightening	50	67	64
Rottening	57	72	73
Stem cavity	46	61	55
Presence of fruiting body	36	56	55
Staining of discolouration on bark	11	33	18
Branching	36	56	45
Size of branches	29	50	45
Branching density	25	61	45
Branch angle	7	11	9
Base of crown	64	50	45
Base of living crown	68	56	45
Base of dead crown	11	17	18
Straightness	43	67	73
Crown projection or diameter	14	11	27
Artificial removal of branches	29	22	9
Upper diameter	25	22	55
Bark thickness	18	22	36
Stem taper	11	33	36
Other	21	33	36

stem quality-related parameters are assessed on all sample trees registered in the plot using different national thresholds for dbh ranging from 0 to 12 cm (Tomter et al. 2012). The NFIs that apply direct stem quality assessment in the field often apply different dbh thresholds (larger dbh) than that used for sample trees selection. For example, Austria uses a dbh threshold of 20.5 cm for stem quality assessment, but 5 cm for sample tree selection to assess common tree parameters such as height, dbh and other.

Only a few NFIs estimate the type of assortments present and the approaches employed differ considerably in the methodology.

The study showed large differences in stem quality assessment among European NFIs. Furthermore, very few countries go beyond the stem quality assessment to estimate timber assortments either by direct assessment in the field or by further application of a model developed in the country.

The inquiry showed that the current systems are not capable of reporting the stem quality of European forests in a harmonised manner at this stage. However, the quantity of wood resources alone will not be sufficient to satisfy policy needs and progressively steps should be taken to harmonise stem quality estimations. Considerable efforts will be required before the harmonised stem quality assessment or assortments estimation can be prepared.

2.5.3 Change Estimation

2.5.3.1 Differences in National Definitions

In terms of NFIs the estimation of change basically includes estimates of net changes, gains and losses. Changes in forest area, increment and drain are the main change estimates reported by NFIs. A change in growing stock is not necessarily identical to the balance of increment and drain as the first is a result of successional application of the growing stock definition while the latter are normally defined based on individual change components like survivor, ingrowth, cut and mortality trees. Estimates of change always refer to a specified time span between consecutive surveys at the time of t1 and t2.

Forest Area Change

The estimation of forest area changes usually involves the determination of afforestation and deforestation areas between the previous and present survey. The net forest area change can be obtained either as difference between the afforestation area and the deforestation area, or by subtraction of the forest areas at t1 and t2. Definitional differences between countries regarding forest area change are due to the applied forest definitions and the associated criteria and related quantitative thresholds and specifications (Vidal et al. 2008; Tomppo et al. 2010). Usually the differently defined criteria in forest definitions are crown cover, minimum area, minimum width, and land use.

Increment and Drain

The change components are taken into account differently in the definitions of NFIs to estimate the increment and drain between the field plot assessments at t1 and t2.

Permanent plot sampling

The estimation of increment and drain relies on the distinction of sample trees into change components. Beers (1962) generally distinguishes between survivor growth, mortality, cut and ingrowth for fixed area plots. For horizontal point sampling (Angle Count Sampling, ACS) the additional components of ongrowth and nongrowth trees (e.g. Martin 1982; Van Deusen et al. 1986; Roesch et al. 1989; Eriksson 1995) have to be taken into consideration. Similarly, this is also the case for concentric circular plots (CCS). The components are defined by three criteria at the time points t1 and t2, the status of the tree (living or dead, present or cut), whether the minimum dbh is reached or not, and whether a tree is in the sample or out of the sample. Lying trees are handled like standing trees, while virtually the axis of the stem is repositioned vertical. Table 2.12 shows these groups of trees according to Martin (1982).

On permanent plots the sample trees are measured with calipers, diameter tapes and hypsometer for t1 and t2. The increment can thus be obtained as difference between the two measurements. Felled trees and mortality trees can be identified by comparing the sample trees present on the plots at t1 and t2.

Table 2.12 Components of growth as defined by Martin (1982) permanent plot sampling

Growth component	Definition	Relevant for
Survivor trees	Trees which are above the minimum dbh and in the sample at both measurements t_1 and t_2	All sampling schemes
Ingrowth trees	Trees which are below the minimum dbh and in the sample at the first measurement t_1 but exceed the minimum dbh at the second measurement t_2	All sampling schemes
Ongrowth trees	Trees which are below the minimum dbh and out of the sample at the first measurement t_1 but are above the minimum dbh and in the sample at the second measurement t_2	ACS, CCS
Nongrowth trees	Trees which are above the minimum dbh but out of the sample at the first measurement t_1 but are in the sample at the second measurement t_2	ACS, CCS
Cut trees	Trees which are above the minimum dbh and in the sample at the first measurement t_1 but are cut prior to the second measurement t_2	All sampling schemes
Mortality trees	Trees which are above the minimum dbh and in the sample at the first measurement t_1 but die prior to the second measurement t_2	All sampling schemes

Temporary plot sampling

Fixed area plot sampling, CCS and ACS can be applied in temporary plot sampling too. Therefore, the above given growth components play some role also in temporary plot assessments but their status is known for t2 only. The status at t1 needs to be reconstructed to allow for a classification into the change components. For increment estimation on temporary plots an increment borer and a device for year ring measurement is commonly applied to determine the dbh 5 or 10 years before. In some NFIs also the height increment is assessed visually to obtain the tree height at t1. The assessment of dead and cut trees on temporary plots is afflicted with large uncertainties, because of the difficulties in identifying the time of felling and mortality. For removed trees models based on stump measurements can be applied to derive estimates for t1.

2.5.3.2 Differences in Methods

As the estimation of change involves many methodological aspects also the differences in applied approaches are manifold.

Forest Area Change

There is an increasing trend to develop multisource European NFIs through the integration of data from additional digital sources like remote sensing material, land-use maps, and other cartographically mapped information. The estimation of afforestation and deforestation areas is either accomplished by terrestrial sampling alone or supported by remote sensing. Usually a first-phase land cover/land use classification is conducted to identify plots that are clearly forest and non-forest, but also check that may be forest. Forest and check plots are visited and verified in the field. Aerial photos are predominately used for the first-phase land classification of plots.

Increment and Drain

Three main forest inventory methods can be distinguished for increment and drain estimation, permanent plot designs, temporary plot designs, and the aggregation of data from stand-wise inventories. The use of permanent and/or temporary sample plots is a basic difference as it determines the feasibility of NFIs regarding change estimation (Kuliešis et al. 2016) and furthermore also the applicable measurement instruments, assessment methods and estimation procedures.

Apart from the differences between permanent and temporary plot designs, the distinguishable change components depend on the sample tree selection methods which are either angle-count sampling, concentric circles, or fixed-area plots in European NFIs (Table 2.13).

Table 2.13 Sampling methods applied by European NFIs (N = 17)

Sample tree selection	Permanency of sample grid (percentage of countries)		
	Permanent plots	Temporary plots	Combination
Angle count sampling	12	0	6
Concentric circles	82	12	35
Fixed area plots	6	6	12

Several of the NFIs using permanent plots have actually recently established a permanent sampling system having up to now completed only one sample-based NFI. These NFIs also rely on increment cores and height increments assessed on whorls as long as only one field assessment at t_1 is completed on the permanently established plots. Alternatively, in these countries increment estimates can be obtained by applying increment models, and calculations based on forest parameters such as species composition, growing stock, age, site productivity, or assumptions on increment percentages (default values). Many of the countries having recently established sample-based NFIs permanent sampling system run also stand-wise inventories at regular time intervals and offer an additional information source on country-level increments and drain. However, data obtained from stand-level inventories, especially those based on ocular estimates, are characterised by frequent systematic deviations (Kuliešis et al. 2016). Gross increment, including its components, can only be estimated in an indirect way and is of low reliability.

Apart from the basic difference between permanent and temporary plot designs, several other aspects related to methods are relevant for increment and drain estimation and their harmonisation. These include; sampling grid, sample tree selection methods and sub-sampling, dbh thresholds, the kind of used volume models and tree parts included in estimates. All of these may to some extent influence the national increment estimates.

2.5.3.3 Summary of the Main Findings

The enquiry on the sampling systems of European NFIs revealed temporary or permanent plots as basic difference regarding change estimation, because it determines identification of change components, the assessment methods, measurement instruments and estimation procedures. Definitions of increment and drain are formulated on the basis of change components as given by Martin (1982) which was further enhanced by Eriksson (1995). Changes in forest area involve the respective forest definition applied at national level, but are harder to assess from NFIs with only permanent plots. Ancillary information from Remote Sensing (RS) is required in a first phase for distinguishing between those areas which are clearly forest, non-forest and check plots. Forest and check plots are visited in second phase in the field for verification purposes. NFIs that do not conduct a first

RS phase assessment have to visit all plots to fully capture afforestation and deforestation over time.

NFIs based on temporary plots are capable of supplying reliable data with known accuracy on growing stock and gross annual increment as well. Nevertheless, data on the various increment components, fellings and dead trees, derived from temporary plots normally have lower accuracy. This lower accuracy is caused by a lack of feasibility to assess the time of felling or death of trees, using one single measurement of the sample plot only.

A combined use of permanent and temporary plots was introduced by the NFIs of Sweden and Norway in the eighties and later on followed by Finland and the Baltic countries. Also NFIs that are actually based on permanent plots sometimes include a sub-grid of temporary plots as part of their quality assurance purposes. If increment estimation is based on permanent and temporary plot data in order to take advantage of the totl number of plots, estimators that combine increments from re-measurements and increment cores are required to obtain overall increment estimates which is challenging. Initiated by Sweden in 1983, a new NFI method combining the use of both permanent and temporary plots in the same sampling design was introduced, with a view to estimating area change dynamics (particularly for area increase) as well as estimation of volume change at tree level. This system capitalises on the advantages of the permanent and temporary plots. Nevertheless, finding estimators to take advantage of the total number of plots in adding permanent and temporary ones is challenging and complicated. Countries using NFIs with permanent plots, can be divided into 3 groups: (1) countries that have at least two and more completed re-measurements; (2) countries having at least one repeated measurement; and (3) countries with ongoing establishment of a sample-based NFI or ongoing first re-measurement of permanent plots. Countries of the third group will have considerably improved information following re-measurement of the first cycle plots. On permanent plots the definition of increment and drain relies on the distinction and grouping of sample trees into change components like survivor, ingrowth, cut and mortality trees. Depending on the applied sample tree selection method the distinguishable change components vary.

Stand-level inventories are still in place in several countries but complemented or replaced by sample-based NFIs. The compilation of national inventory results by aggregating stand level data for all forests has survived under conditions of centrally planned economy (Brukas et al. 2002). Under other circumstances of forest ownership, it is problematic to ascertain the regularity and coverage of such inventories.

The increment and drain definitions of European NFIs reveal two basic strategies, either to produce conservative estimates on the “safe side”, or to cover all possible growth components. About 40 % of the NFIs apply definitions that yield conservative estimates and usually include only survivors and ingrowth trees in the estimation, whereas 60 % of NFIs estimate according to definitions that are more encompassing and take the increment of other components like cut and mortality trees, ongrowth trees, non-growth trees into account. The number of ingrowth, cut and mortality trees and their proportion related to the survivor trees increases as the time span between t1 and t2 increases, thus also the need for their inclusion in increment estimation becomes more relevant. A crucial criterion in definitions is the dbh-threshold since it specifies the part of the population that is included in the estimation of increment and drain. In European NFIs the minimum dbh ranges from 0 cm up to 12.0 cm. Based on the distinguished change components NFIs produce estimates for gross increment, net increment, and drain which comprises fellings and natural losses. While the understanding of gross increment is comparable, the definition of natural losses varies among NFIs and is in the range of international definitions with “trees dying naturally from competition” IPCC (2006) to “mortality from causes other than cutting by man” UNECE/FAO (2000).

The recent expansion of NFIs based on sampling methods opens new opportunities for European forestry and forest monitoring by facilitating efficient control of wood flow from forests, silviculture measures, the attained level of forest productivity and biodiversity, carbon storage in forest ecosystems, and the sustainability of forest management in general.

2.5.4 Other Wooded Land and Trees Outside Forest

2.5.4.1 Differences in National Definitions

NFIs are mainly focused on estimation of tree resources in forests. Nevertheless, due to recent political commitments at international and European level, it is more and more important to have an insight into tree resources coming from areas other than forests.

The first important area to investigate is “other wooded land” (OWL), when combined with forest is what the FAO refer to as “wooded lands”. The rest of this wooded land category is called “Other Land” (OL). A further step of investigation was completed by the FAO and national correspondents to evaluate the land uses with tree cover (De Foresta et al. 2013). The FAO study focused first on “Other land with Tree Cover” (OLwTC) which has the same definition as forest except for the land use, because OLwTC contains a lot of tree resources where the main purpose of these areas is not the harvest of this tree resource. To go a step further FAO proposed the concept of “Trees outside Forest” (TOF) in order to classify OL in 2 parts (De Foresta et al. 2013). The FAO specified the following definitions:

Other land with TOF: “Land classified as Other Land—i.e. not classified as Forest nor Other Wooded Land-, spanning more than 0.05 ha with trees higher than 5 m and a canopy cover above 5 %, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 %. It includes land that is predominantly under agricultural or urban use. It also includes some land that is not predominantly under agricultural or urban use”.

And **Other land with no TOF**: "Land classified as Other Land, with no tree and/or no shrub cover or with trees or shrubs but with an area is <0.05 ha, canopy cover <5 % if trees are present, or <10 % if combined trees, bushes and shrubs, or for linear structures a width <3 m or length <25 m".

This classification is a necessary step to investigate tree resources outside the forest. OLwTC is a subset of OLwTOF. Nevertheless, it apparent that the term TOF includes trees outside the wooded land instead of outside the forest and that the classification contains some imperfections because OL with no TOF includes large areas with scattered trees or shrubs and so could contain trees.

Concerning OWL, the situation is diverse from one country to another one concerning the attributes that describe OWL (Vidal et al. 2016). Despite the use of different definitions, they generally have the same structure, whereby a list of quantitative variables (Fig. 2.1) and associated threshold values are applied. Table 2.14 gives an overview of OWL definitions applied among the 21 countries that answered the questionnaire.

As described above the FAO defined "trees outside forest" (but this concept should in fact be called trees outside wooded land) to characterise the 2 subsets of OL. Within the OLwTOF category the FAO gives a priority to OLwTC which fulfils the same definition as forest, except with reference to the land use. In line with these FAO definitions our questionnaire focused on these 3 definitions OWL, OLwTC and TOF to assess how close the national definitions are to the international ones (Table 2.15).

Among the 24 responding countries to this part of the questionnaire, 83.3 % have a definition of OWL. Over half (54.2 %) of the countries adopted the definition of FRA or COST Action E43 (Tomppo et al. 2010). It is interesting to notice that 62.5 % of countries are reporting OWL according to FRA definition even if two of them don't have a definition in line with the FRA definition. Similarly for

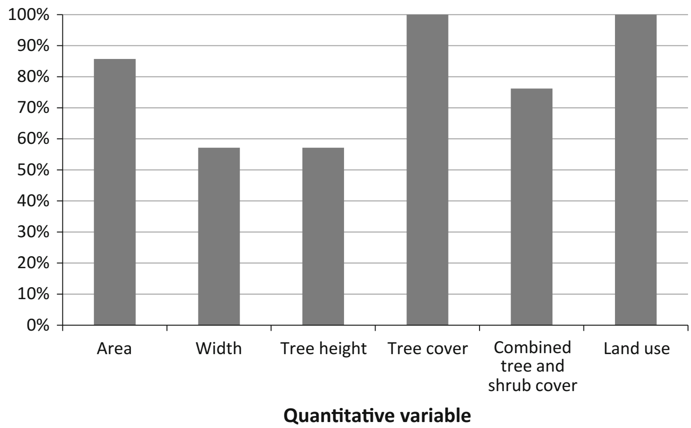

Fig. 2.1 Proportion of NFIs using quantitative variables to define OWL (N = 21)

Table 2.14 National OWL thresholds applied (N = 21)

Country	Minimum Area (>ha)[a]	Minimum width (>m)	Land use[b]	Minimum tree cover (%)	Minimum combined tree and shrub cover (>%)	Tree height (≥m)
Austria	0.05	10	1	0–9	30	0
Bosnia and Herzegovina		–	1	–	20	–
Belgium	0.1	10	1	5–10	–	–
Switzerland	0.5	25	1	20	20	3
Check Republic	0.5	20	1	5–10	10	5
Estonia	0.5	0	1	5–10	10	–
Greece	–	–	1	5–10	10	–
Spain	0.5	–	1	10	–	–
Finland	0.5	20	1	5–10	10	5
France	0.5	20	1	–	25	0
Hungary	0.5	20	1	5–10	10	5
Ireland	0.1	–	1	20	–	–
Iceland	0.5	20	1	–	10	0
Italy	0.5	20	1	5–10	10	5
Lithuania	0.1	10	1	n.r.	30	n.r.
Latvia	0.1	20	1	20	–	5
Norway	0.1	4	1	5–10	10	5
Portugal	0.5	20	1	5–10	–	5
Romania	0.5	20	1	5–10	10	5
Sweden	0.5	0	1	5–10	10	5
Slovenia	0.1	–	1	75	75	5

[a]The character "–" means variable not considered in the country definition
[b]The number "1" in the Land Use column means that the country has the land use criteria "predominantly not agricultural or urban land use"

TOF only 54.2 % countries have a definition and 66 % are collecting information on TOF and reporting TOF data to FRA.

Since TOF is defined for categories that are neither forest nor OWL, it can be assumed that countries with a forest and OWL definition have an implicit definition for the remaining category OL which contains all the TOF. Therefore 54.2 % of countries have a TOF definition in line with the FRA or COST E-43 definition. In total, 54.2 % countries apply some kind of definition for TOF and 66.6 % are at least partly assessing TOF. Seven countries (30 %) apply the FRA definitions of forest and OWL and also perform TOF assessment. Apart from Iceland, all land with TOF inventories (including OLwTC) are completed using the regular NFI sampling scheme.

Table 2.15 Summary of results from COST Action Usewood questionnaires about OWL, OLwTC and TOF (N = 24)

Wood Resources	Conclusions from questionnaires	Percentage of countries
OWL	NFIs with OWL definitions	83.3
	Of which according to FRA or COST E43 definitions	54.2
	NFIs reporting on OWL according to FRA definitions	62.5
OLwTC	NFIs applying a definition of OLwTC	45.8
	Of which according to FRA	33.3
	NFIs reporting on OLwTC according to FRA definitions	41.7
TOF	NFI's applying a definition for TOF	54.2
	Of which only for OLwTC	12.5
	NFI's collecting information on TOF	66.7
	Of which on TOF but not on OLwTC	16.7
	Of which only for OLwTC	8.3

2.5.4.2 Differences in Methods

OWL is normally assessed using the NFI forest sampling design, which generally uses 2 phase sampling, the first one using remote sensing and the second ones by field survey. The sampling effort is generally less onerous for OWL particularly for field survey due to reduced number of measurements required and the lower precision levels required for these areas and resources. Regarding the methodology for OWL assessment, it was concluded that 90 % of the countries are assessing OWL using field measurements while 65 % use remote sensing techniques. The use of aerial photos is the most common method followed by satellite imagery. Only a few countries (5 %) are using airborne LIDAR at the moment.

The techniques used for assessing TOF are less harmonised. Table 2.16 shows the methodologies used for collecting information on TOF by different countries that have some form of TOF assessment and in which the information is available. Nearly one-third (31.25 %) of the countries rely solely on remote sensing and 37.5 % solely on terrestrial methods, while 31.25 % use a combination of both. All countries making use of remote sensing techniques used aerial photo interpretation.

Table 2.16 Methods to assess TOF in European countries (N = 16)

Countries	Assessment method	Percentage of countries
Austria, Czech Republic, Ireland, Italy, Switzerland	Remote sensing	31.25
Bulgaria, Estonia, Finland, Latvia, Lithuania, Sweden	Terrestrial	37.50
France, Iceland, Norway, Romania, Slovenia	Combined	31.25

2.5.4.3 Summary of the Main Findings

The aim of the sub-working group was to build a reference definition for OWL and TOF categories. The analysis of the criteria and thresholds described above provided a framework to decide which criteria should be included in a common reference definition.

The main variables commonly used from the questionnaire for further analyses were: (i) size threshold (ii) crown cover threshold (iii) land use.

An area size threshold is applied by 85.7 % of the countries participating. Two thirds employ a 0.5 ha threshold value equivalent to the FRA 2015 (2012) definition. The exceptions to area size 0.5 ha are all smaller areas. Since a majority has adopted 0.5 ha threshold, it would be unwise to propose a change.

An area width threshold is applied by 57.1 % of the countries that responded, of which 75 % apply the minimum width of 20 m to distinguish between Other Wooded Land and Other Land categories. Since three quarters of the countries apply this threshold, it will be retained.

Tree height is adopted by 57.1 % countries, which is low considering the importance of this variable in defining forests. This is problematic since tree height is an essential variable not just classifying OWL but also forest. Eleven countries have the 5 m threshold and Switzerland has a minimum tree height of 3 m. The results demonstrated that harmonisation is essential but will be difficult to achieve.

The tree crown cover thresholds used are between 5 and 10 %. Seventeen countries (81 %) apply a "tree crown cover threshold" of which 12 are as defined by FAO, the others having slightly different thresholds (Table 2.15).

Combined tree and/or shrub crown cover is used by over three-quarters (76.2 %) of countries. The threshold "more than 10 %" used in international definitions (COST Action E43 and FAO) is adopted by over half (56.3 %) of the 16 countries.

Land use is the social and economic purpose for which land is managed (e.g. grazing, timber extraction, conservation) (IPCC 2006). Land use is widely recognised by all of the 21 countries as a main criterion to distinguish between the different categories including OWL.

2.6 Conclusion

In COST Action Usewood, the way of working established during COST E43 (Vidal et al. 2008; Gschwantner et al. 2009) proved to be a successful framework for the collection of information on the current status of wood resource assessment in European NFIs. The information provided by the questionnaires and country reports provided the raw materials required to understand the differences between the definitions and components that make up the definitions that are applied nationally by the various NFIs. This level of information is essential to inform discussions on the choice of core variables and associated thresholds necessary to build robust reference definitions. It is also essential to highlight the lack of comparability between data in international reporting.

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Chapter 3
Harmonisation of Data and Information on the Potential Supply of Wood Resources

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3.1 Introduction

The number of international agreements and commitments has increased over time and thus also the reporting requirements have increased both in terms of frequency and content (Tomppo and Schadauer 2012). NFIs are the major information source operationally implemented in most European countries to provide information on forest resources at country and sub-country levels. The estimates produced by

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different countries frequently lack comparability because of differences in applied definitions, sampling designs, plot configurations, measured variables, and measurement protocols (McRoberts et al. 2012a, b).

COST Action E43, "Harmonisation of National Forest Inventories in Europe: Techniques for Common Reporting" of the European program, Cooperation in Science and Technology (COST), focused on developing methods for producing harmonised and thus comparable NFI estimates. The harmonisation approach developed by COST Action E43 (2010) features two basic components, reference definitions and bridges (McRoberts et al. 2012a, b), e.g. defining reference definitions (by analysing both, national and international definitions) and establishing bridges (case studies). The subsequent COST Action Usewood (2014) used the same methodology as the one employed in COST Action E43 (2010) but applied it to other topics of forest resource reporting: forest available for wood supply, change estimation, stem quality, other wooded land and trees outside forest. Many studies have been carried out to date using this methodology for variables such as forest area (Vidal et al. 2008), growing stock (Vidal et al. 2008; Tomter et al. 2012), stem quality (Bosela et al. 2015), biodiversity indicators (Chirici et al. 2011, 2012) and specifically for variables such as deadwood (Woodall et al. 2009; Rondeux et al. 2012), naturalness (McRoberts et al. 2012b) or ground vegetation (Alberdi et al. 2010). Therefore, both COST Actions shared the same objective: to develop

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concepts, definitions and methods to be used for harmonising NFIs in such a way that the information from different countries would be made comparable (Tomppo and Schadauer 2012).

The main objective of COST Action Usewood (2014) was to improve and harmonise data and information on the potential supply of wood resources at European level considering the actual extent due to the scarce or imprecise information available (Hetsch 2009). This will enable an improved overview of the available data and information on wood resources and possible wood uses. As a consequence of the development of reference definitions related to the supply of wood resources, sound basic data and information could be built on using a comprehensive approach that clearly distinguishes between the maximum potential and the quantity of wood that is likely to be available. Additionally, future wood supply is expected to come from all types of wood from forests, other wooded land, trees outside forest and residues. This high quality information could be used for future scenario modelling and help political decision making for the renewable energy sector (COST 4137/10 2010).

Reference definitions related with wood supply are discussed and described in this chapter: forest available for wood supply, change estimation, stem quality, other wooded land and trees outside forest. These definitions will enable data comparison between countries and consequently, this will imply a transparent, comprehensive and robust information for decision-making.

3.2 Developing Reference Definitions

The variables used in international reporting may have several definitions and furthermore national definitions also differ, leading to incomparable results. Therefore, transboundary and comparable forest information cannot be obtained by simple data aggregation due to the varying definitions employed.

In-depth analyses of national definitions, their similarities and differences are shown in Chap. 2 as a result of responses to specific questionnaires related to wood supply. The review of national definitions is based on specific questionnaires to the NFI experts participating in the COST Action Usewood. These questionnaires address multiple aspects of national definitions including variables and threshold values, application of these definitions, and the flexibility of NFIs to provide results according to different definitions (Tomppo and Schadauer 2012). Common definitions are crucial for achieving comparability of the estimates among countries (Tomppo and Schadauer 2012).

To establish reference definitions, a review of existing international and national definitions is necessary as a first step (Vidal et al. 2008). The analysis of international definitions is crucial because they imply previous harmonisation efforts and indicate the reporting needs at international level (Tomppo et al. 2010). National definitions together with an analysis of data availability are essential to study the consistency of the concept and to establish the frame of a feasible reference definition. With this information, the list of variables and associated thresholds needed to characterise the object (of which the reference definition will be established) can be determined. Then, the reference definition proposal is established considering the following nine criteria: acceptability, objectivity, clearness, sufficiency, usefulness, sustainability, neutrality, practicability, measurement device independency (Vidal et al. 2008). Reference definitions are precise definitions which can be used as common international NFI definitions or to compare and integrate national definitions. For successful harmonisation, several conditions have to be fulfilled, (i) the national and reference definition must be concise to clearly point out the differences, (ii) data and or information must be available with adequate accuracy, and (iii) methods to convert estimates from the national definitions to the reference definition must be available or be established (Ståhl et al. 2012). Reference definition proposals have to be analysed and validated by NFI experts in an iterative verification process before being adopted. ENFIN (European National Forest Inventories Network) represents the platform for the exchange between NFIs. This harmonisation process is illustrated by Fig. 3.1. Although reference definitions are used for harmonisation, they sometimes present a first step toward standardisation.

Up to now, the reference definitions for European NFIs established by NFI experts cover a broad range of topics and include tree related definitions, forest, other wooded land, other land with tree cover, volumes, land use categories, afforestation, reforestation and deforestation, carbon pools, forest management and managed forest, biodiversity and biodiversity features (Lanz et al. 2010). The development of reference definitions is frequently accomplished with numerous

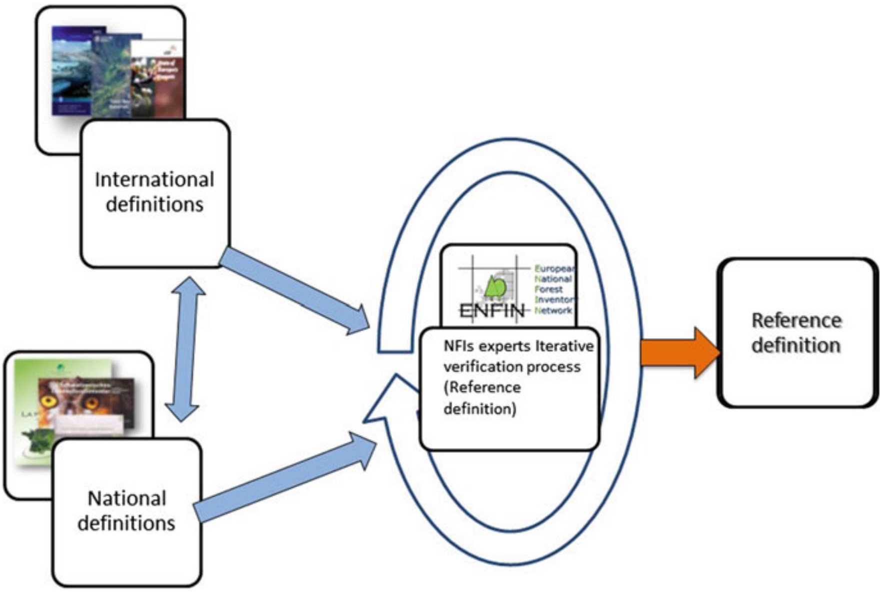

Fig. 3.1 Reference definition establishment process in the frame of the European National Forest Inventory Network (ENFIN)

studies that analyse the circumstances and pre-conditions for establishing the definitions:

– Forest and growing stock (Vidal et al. 2008). After an analysis of the existing forest definitions, the criteria minimum area, minimum tree crown cover and minimum width were proposed to characterise forest land and the associated thresholds were specified. The analysis of the term growing stock concluded that a common definition should contain statements for the following variables: type of woody plants (trees/shrubs), life status (living/dead), statement (standing/lying), size expressed as minimum diameter at breast height (dbh) and a list of tree elements.
– Tree definitions (Gschwantner et al. 2009). The study established common definitions for NFIs for the distinction of trees from shrubs, provides a hierarchical partitioning approach by which the whole tree is stepwise divided into disjoint and defined tree parts, and specifies variables like tree height, stem length, dbh, crown and crown projection area, and tree characteristics regarding life status, standing status and tree shape.
– Greenhouse Gas Reporting from European Forests (Dunger et al. 2012). This study is based on case studies of Finland, Germany, Norway, Portugal, Slovenia, and Sweden. It concludes that common reference definitions and country-specific bridges are a means to harmonise the estimates and make greenhouse gas reporting from forests comparable across countries.
– Biodiversity indicators (Chirici et al. 2011, 2012). Biodiversity core variables were selected, their reference definitions were determined and related indicators were identified. Main core variables identified were: forest types, stand structure, regeneration, forest age, forest naturalness, ground vegetation and dead wood. Different studies were carried out for each one such as forest types (Ståhl et al. 2012), forest structure (McRoberts et al. 2008), deadwood (Rondeux and Sanchez 2010; Rondeux et al. 2012; Woodall et al. 2009), forest age (Alberdi et al. 2013), naturalness (McRoberts et al. 2012b) and ground vegetation (Alberdi et al. 2010).

3.3 Reference Definitions on Wood Supply Variables

In this section the background and the agreed reference definitions on forest available for wood supply, stem quality, variables related to the change in forest resources and the area classification considering wood resources outside the forest are presented. The existing international definitions of these and related variables are included in the following documents: Global Forest Resources Assessment FRA 2000 (FAO 2001), FRA 2010 (FAO 2010), FRA 2015 (FAO 2015), State of Europe's Forests (SoEF) 2003 (MCPFE, UNECE and FAO 2003), SoEF 2007 (MCPFE, UNECE and FAO 2007), SoEF 2011 (FOREST EUROPE, UNECE and FAO 2011) and SoEF 2015 (FOREST EUROPE 2015).

3.3.1 Forest Available for Wood Supply

Forest available for wood supply (FAWS) is a key definition for forest management and one of the basic characteristics requested through international forest reporting. The current terms and definitions of FAWS were established by the expert consultative and advisory group for the Global Forest Resources Assessment 2000 (FAO 2001). The established definition of FAWS is the following: "Forest where any legal, economic or specific environmental restrictions do not have a significant impact on the supply of wood". Additionally, this definition was complemented by specifying that FAWS includes "areas where, although there are no such restrictions, harvesting is not taking place, for example in areas included in long-term utilisation plans or intentions". Other international processes such as FOREST EUROPE also request information on FAWS adopting the established international definition of (FAO 2001) in the State of Europe's Forests. However, countries have interpreted the international definitions in different ways, as it is shown in Chap. 2. This fact reinforces the need for a reference definition which clarifies the terms and concepts involved, and additionally specifies the restrictions that should be taken into account for the assessment of FAWS. Thresholds of the different restrictions were also analysed in COST Action Usewood but due to the different countries characteristics (forest policy, forest acts, social role of forests topography, climate etc.) it is not possible at the moment to unify them according to the evaluation of national correspondents (Fischer et al. 2016). Thus in addition to the reference definition, recommended reporting notes were added with the aim of facilitating comparisons between national definitions.

With regard to the international definitions and the results obtained through this screening exercise of national definitions in the European context, the following reference definition of FAWS was proposed (Alberdi et al. 2016):

> Forests where there are no environmental, social or economic restrictions that could have a significant impact on the current or potential supply of wood. These restrictions could be based on legal acts, managerial/owners' decisions or other reasons.
>
> – Environmental restrictions should consider: protected areas, protected habitats or species, and also those protective forests meeting the above requirements. Age or diameter class restrictions should not be taken into account (except in the case of protected ancient forest).
> – Social restrictions include restrictions to protect aesthetic, historical, cultural, spiritual, or recreational values as well as areas where the owner has taken the decision to cease wood harvesting in order to focus on other goods and services (e.g. leisure, landscape, aesthetic value).
> – The economic restrictions are considered as those affecting the economic value of wood utilisation (profitability). These include: accessibility, slope and soil condition. Short-term market fluctuations should not be considered.

A significant impact on the supply of wood occurs when harvesting is totally prohibited or when restrictions severely limit the feasibility of cuttings for commercial purposes. When restrictions do not severely limit commercial utilisation of wood in a forest area, it should be considered as available for wood supply even if currently only harvest for auto-consumption or no harvest at all is taking place. Conversely, when restrictions limit the feasibility of commercial wood utilisation, even if there are occasional cuttings for auto-consumption or other small-scale interventions of a non-commercial nature, the forest should be considered as forest not available for wood supply (FNAWS).

Regarding the assessment of availability for wood supply, the following recommendations are proposed for improving reporting (if the information can be disaggregated): (i) the three different categories of restrictions should be accounted for separately (environmental, social, and economic); (ii) the kind of restrictions considered for each category should be detailed (e.g. protected areas, protected species).

3.3.2 Stem Quality

Wood availability is the key to defining global mitigation strategies and goals for the use of biomass energy (European Parliament and Council of the European Union 2009) and other wood products. However, information on the available wood quantity is by far not enough as the wood quality and assortment structure of trees in the forests play an important role in the wood market chain.

Stem quality and assortment structure are among the rarest tree attributes assessed or quantified in European NFIs (Bosela et al. 2015). This fact thus limits the potential for the quantification of assortment structure of European forests using NFIs at present. On the other hand, the absence of this information, provides the opportunity to elaborate a common internationally accepted definition which may serve to European NFIs to introduce stem quality assessment in the future. This is because the current NFIs are not limited by already existing national definitions and are thus able to adopt a common reference definition. However, there are still some tree attributes already used by NFIs that are important in stem quality and assortment assessment (Bosela et al. 2015) and their definition varies greatly among the NFIs (Vidal et al. 2008; Gschwantner et al. 2009; McRoberts et al. 2009, 2010; Ståhl et al. 2012; Tomppo and Schadauer 2012; Tomter et al. 2012).

The first step in harmonising stem quality and assortment assessments is to elaborate a common terminology. As mentioned by Bosela et al. (2015), there is a different and not comprehensively harmonised terminology of "wood quality", "wood properties" and "stem quality" (MacDonald and Hubert 2002; Nuutinen et al. 2009; van Leeuwen et al. 2011; Rais et al. 2014; Schneider et al. 2008).

For preparing a common definition, European standards may serve as the base. These standards have been developed by the European Committee for Standardisation (CEN), which is the only recognised European organisation according to Directive 98/34/EC for the planning, drafting and adopting of European Standards in relation to roundwood quality (Bosela et al. 2015).

A harmonised terminology (reference definitions) for the purpose of stem quality assessment in European NFIs was comprehensively elaborated in the recent work by Bosela et al. (2015). For the purpose of NFIs, assessing timber (wood) quality or inherent quality on standing trees is practically impossible. Therefore, a visual assessment of "stem quality" can be used by external quality features instead to make an inference on wood quality. For the purpose of European NFIs the following definition of "stem quality" can be used:

> Stem quality is the visual quality of a standing tree assessed in the field. Physical properties such as straightness, knots, visible forms of decay, rotting, and other parameters that affect the utilisation of logs can be used to visually assess stem quality.

Then the timber assortments can be defined as (Bosela et al. 2015):

> Potential end product determined by market need. They are defined combining timber quality parameters and tree dimensions (e.g. length and diameter).

Assortments represent the size, quality, and quantity available for potential manufacture of end products (lumber, veneer, shingles, etc.). Partitioning of the stem into assortments on standing trees is, again, difficult and models are therefore necessary to translate visually assessed timber quality-related attributes into assortments (Bosela et al. 2015). An example of such a model developed for Slovakia is shown in Chap. 4 of this book.

Concerning stem quality assessment on standing trees within the NFIs, a set of quality-related parameters can be identified and the priority level can be assigned to each (Table 3.1). This set of parameters was elaborated from international standards and already published by Bosela et al. (2015). Certain parameters can be directly measured or assessed in the field while the others can only be derived from models. This list can serve as the base for adopting stem quality assessment in European NFIs in the future.

3.3.3 Change Estimation

The estimation of changes in forest resources over time relates to the topics of sustainable use and development of forests, the efficiency of forest management operations, the change of environmental conditions, the natural damages and damage risks to forests, and carbon sequestration in forest ecosystems. As the demand for information on the changes within forest ecosystems has evolved during the last century, the reporting of changes in international reporting programs commenced around the end of the last century. FAO (2001) compiled increment information from countries in the temperate and boreal regions and provided a basic set of definitions. The maintenance and encouragement of productive functions of forests is a criterion of pan-European quantitative indicators for sustainable forest

Table 3.1 List of standing tree quality parameters measured in the field or derived from a model, which influence the timber properties and can thus be potentially used for timber assortment classification (the list was prepared from the review of European and national standards for timber grading)

Type	Parameters	Field	Derived	Priority
Quantitative	dbh	X		1
	Height	X		1
	Upper diameter	X	X	2
	Bark thickness	X	X	2
	Height to fork	X		2
	Live crown height	X		2
	Dead crown height	X		2
	Roundwood height	X		2
	Continual bole height	X		2
	Stem break height	X		2
	Branch number (living)	X		3
	Branch angle (living)	X		3
	Branch diameter (living)	X		3
	Branch number (dead)	X		3
	Branch angle (dead)	X		3
	Branch diameter (dead)	X		3
	Ovality or elipticity	X		2
	Sweep	X		3
	Taper		X	2
	Rate of growth (mm)		X	1
Qualitative	Species	X		1
	Tree status (dead/alive)	X		1
	Biotic stem damage	X		1
	Abiotic stem damage	X		1
	Frost/Lightening stem damage	X		1
	Straightness	X		1
	Forking	X		2
	Break (stem, crown, top)	X		1
	Fluting	X		2
	Ovality	X		2
	Rottening	X		1
	Branch status (dead/alive)	X		2
	Branch size (low, med, high)	X	X	2
	Artificial pruning	X		3
	Formative shaping	X		3
	Insect in timber (beetle, larvae holes)	X		1-2
	Spiral grain	X		1
	Reaction wood	X		2

After Bosela et al. (2015)

management (FOREST EUROPE, UNECE and FAO 2011) and accordingly, the balance between increment and fellings is considered decisive for the availability of wood at present and in the future. The fellings should not exceed increment in the long run for shaping a stable and sustainable growing stock. The recent FRA 2015 integrated net annual increment for the first time in the global assessments (FAO 2012). The main achievement during COST Action Usewood (2014) was a comprehensive categorisation of the components of change independent of the sampling method. The overall change in wood resources was considered by compartments, i.e. the compartment of standing living stems, the compartment of standing dead stems, and the compartment of lying coarse woody debris. The compartments are defined by relying on the respective definitions of living and dead trees as well as standing and lying trees elaborated during COST Action E43 (Lanz et al. 2010). Over time the individual trees either remain in a compartment, or, as part of the components of gains and losses newly enter a compartment from outside or change between the first time point t1 and the second time point t2 from one to another compartment due to mortality, fall over etc. Gains and losses can be further differentiated into sub-categories (recruitment, forest area gain, tree loss etc.) as defined in Table 3.2.

In addition to the main compartments and change components given in Table 3.2, others of minor importance also exist like for example recruitment trees that die after entering the compartment of living trees, as well as tree loss, mortality and downed wood on forest area gains. The losses in the compartments of living stems and standing dead stems can be further diverted into the two categories of fellings and natural losses. Both categories are detailed in Table 3.3.

Fellings and natural losses from the compartments of living stems and standing dead stems further divert into the categories of removals, residues and losses as defined in Table 3.4. Residues that are taken out from the forest at a later time point (after t2) fall under the separate category of removal of residues. Residues and losses remaining in the forest constitute the compartments of coarse woody debris, fine woody debris and litter depending on size criteria.

During the time span between t1 and t2 in the compartment of living stems wood is accumulated due to growth. Apart from the tree individuals that are gained or lost between t1 and t2 a usually large proportion of individuals remains in the compartment of living stems. All trees, gained, lost or remaining in the compartment of living stems contribute to the increment, either during the whole period between t1 and t2, or only for parts of the time period. Under the sampling schemes of NFIs (mainly angle-count sampling and concentric circular plots) the trees contributing to the increment are distinguished into defined growth components. Beers (1962), Martin (1982), Van Deusen et al. (1986), Roesch et al. (1989), and Eriksson (1995) distinguish between survivor trees, in-, on-, non-growth, mortality and cut trees (Chap. 2). These growth components refer to forest areas that remain forest between t1 and t2. Additionally, also the trees on forest area gains and losses contribute to

Table 3.2 Reference definitions for gains and losses of individuals in the compartments of living stems, standing dead stems and lying coarse woody debris between the time points t1 and t2

Compartment	Change components		Definition
Living stems	Gains	Tree recruitment	New wood due to the recruitment of young trees into growing stock between t1 and t2
		Forest area gain	New wood in growing stock due to non-forest land being transformed into forest land between t1 and t2
	Losses	Tree loss	Lost wood due to stems leaving the compartment of living stems (growing stock) between t1 and t2
		Forest area loss	Lost wood due to forest land being transformed into non-forest land between t1 and t2
Standing dead stems	Gains	Tree mortality	New wood due to trees died off in the compartment of living stems between t1 and t2
		Forest area gain	New wood in standing dead stems due to non-forest land being transformed into forest land between t1 and t2
	Losses	Tree loss	Lost wood due to stems leaving the compartment (stock) of standing dead stems between t1 and t2
		Forest area loss	Lost wood in standing dead stems due to forest land being transformed into non-forest land between t1 and t2
Lying coarse woody debris	Gains	Downed wood	New wood due to downed wood from the compartments of living and standing dead stems between t1 and t2
		Forest area gain	New wood in lying coarse woody debris due to non-forest land being transformed into forest land between t1 and t2
	Losses	Loss in coarse woody debris	Lost wood due to pieces of coarse woody debris leaving the compartment (stock) between t1 and t2 (decay)
		Forest area loss	Lost wood in lying coarse woody debris due to forest land being transformed into non-forest land between t1 and t2

the increment. The time period over which the individual growth components contribute increment for is described in Table 3.5, as well as the compartments they are assigned to at t1 and t2.

These components constitute the basis for increment estimation by NFIs and their distinction depends on the sampling method in place. Because the distinguishable growth components depend on the sample tree selection method, common reference definitions for increment have to be formulated independent of these components. Tomter et al. (2016) showed that the increment is equal to the sum of volume change, volume of cut trees, and volume of mortality trees during the assessment period between t1 and t2, and including the increment of cut and

Table 3.3 Reference definitions for fellings and natural losses as two categories in the compartments of living stems and standing dead stems

Compartment	Change component		Definition
Living stems	Tree loss	Fellings	Lost wood from growing stock between t1 and t2 due to human intervention, such as harvesting and silvicultural operations
		Natural losses	Lost wood from growing stock between t1 and t2 due to natural causes, such as mortality, storms, forest fires, sanitary cuts, insects or wood decay
Standing dead stems	Tree loss	Fellings	Lost wood from dead standing stems between t1 and t2 due to human intervention, such as harvesting and silvicultural operations
		Natural losses	Lost wood from standing dead stems between t1 and t2 due to natural causes, such as storms, forest fires, sanitary cuts, insects or wood decay

Table 3.4 Reference definitions for removals, residues and losses as three categories in the fellings and natural losses

Change component		Category	Definition
Tree loss	Fellings and natural losses	Removals	Wood lost from growing stock or standing dead trees due to fellings or natural losses between t1 and t2 which has been immediately transported out of forest
		Residues	Wood lost from growing stock or standing dead trees due to fellings or natural losses between t1 and t2 which remains in forest and may be recoverable for future wood use
		Losses	Wood lost from growing stock or standing dead trees due to fellings or natural losses between t1 and t2 which remains in forest but is not recoverable for future wood use

mortality trees before they died or have been felled. In order to integrate former harmonisation efforts, the reference definitions formulated by COST Action Usewood (2014) take into account the achievements of FAO (2000) and integrate also the features of the COST Action E43 (2010) growing stock definition (Lanz et al. 2010) to ensure consistency between increment and growing stock estimates. Thus, the reference definitions for gross and net increment are formulated using a dbh-threshold of >0 cm, specify the bole (wood and bark) and stem top as included tree parts, and specifies to include all growth components by comprising all trees (Table 3.6). The land area to which the increment shall refer, the reference period and the types of natural losses remain to be specified depending on the target of application.

Table 3.5 Growth components, their compartments at the time points t1 and t2, and the time period when they contribute to the increment within the collective of sample trees

Growth component	Compartment		Time period when increment is contributed within the sample	
	t1	t2		
Survivor trees	Living stems	Living stems	Inventory at t1	Inventory at t2
Ingrowth trees	–	Living stems	t1 + xi when tree reaches the minimum dbh	Inventory at t2
Ongrowth trees	–	Living stems	t1 + xo when tree reaches the minimum dbh	Inventory at t2
Nongrowth trees	–	Living stems	t1 + xn when tree enters the sample	Inventory at t2
Cut trees	Living stems	–	Inventory at t1	t1 + xc when tree is cut
Mortality trees	Living stems	Standing dead trees or lying coarse woody debris	Inventory at t1	t1 + xm when tree dies
Trees on forest area gains	–	Living stems	t1 + xfag when plot becomes forest	Inventory at t2
Trees on forest area losses	Living stems	–	Inventory at t1	t1 + xfag when plot becomes non-forest

Table 3.6 The reference definitions for gross annual increment and net annual increment as adopted by COST Action Usewood (2014)

Term	Definition
Gross annual increment	Gross annual increment is the average annual stem volume increment of living trees over a specified area during the reference period. The stem volume increment includes the over-bark increment from the stump height to and including the stem top of trees with a diameter at breast height of more than 0 cm (height of more than 1.30 m). Branches are excluded. Included is the stem volume increment of trees which have been felled or die during the reference period
Net annual increment	Net annual increment is the average annual stem volume increment of living trees over a specified area during the given reference period denoted as gross annual increment minus the stem volume of annual natural losses. The stem volume of natural losses includes the over-bark stem volumes from stump height to and including the stem top of trees subject to natural losses with a diameter at breast height of more than 0 cm (height of more than 1.30 m). Branches are excluded

3.3.4 Wood Resources Outside of the Forest

Wood resources outside the forest are composed of two distinct parts. The first part was investigated by FAO from the end of the twentieth century. It concerns Other Wooded Land (OWL) which together with Forest constitutes an aggregate called wooded lands by FAO (2012). The second part contains the trees outside this wooded land and is known at FAO level as Trees outside Forests (TOF). These two categories have gained political importance over time due to the significance of amenities and wood resources they provide to specify in rural but also urban communities. For more than fifteen years, the FAO together with NFI experts has been working on a common approach and definition of these two concepts (FAO 2001, 2010, 2012). However, due to the diversity between different eco-zones and climatic conditions it is very difficult to have a clear common understanding of these concepts. Moreover, the political interest may change over time with the focus shifting more towards some areas than others. A step by step classification of forest, OWL and TOF in terms of areas and wood resources was proposed by FAO. These concepts were discussed with countries in expert level meetings for refinement (De Foresta et al. 2013), but as a consensuses had to be reached the result is not exactly a classification (i.e. covering everything without any overlap). Wood resources in these areas are growing in political and social importance and the FAO attempted to improve the estimation of these resources. Nevertheless, the tools to evaluate OWL and TOF areas as well as wood resources contained in them are not in place and often too costly compared to the expected results, so the quality of this data is still questionable.

Forest area in Europe currently accounts for 33 % of the total land area, whereas OWL represents 5.5 % of the total land area. On the other hand, data about TOF resources is rare, and available information is typically fragmented across the different institutions and stakeholders. However, an analysis made by Schnell et al. (2015) with data from 11 countries across three continents showed that for six countries, more than 10 % of the national above-ground tree biomass was actually accumulated outside forests. As OWL and TOF are an important source of wood resources in the context of new policy needs such as renewable energy, the COST Action Usewood investigated how these areas are defined and how their wood resources are estimated at national level. The results from the COST Action Usewood questionnaire highlighted important differences in how countries comprehended the concepts and thus the estimates of areas and wood resources (Chap. 2). A review of the definitions of these categories was done and reference definitions were proposed.

The OWL reference definition proposed is very close to the FAO one (Vidal et al. 2016). Nevertheless, the goal was to enforce a more rigorous interpretation of terms contained in this definition. The first aspect to focus on was the percent of crown coverage by trees and by a combination of trees and shrubs. As a consequence, it is very important to have a clear definition of what a tree is and what a shrub is (Gschwantner et al. 2009). A reference definition of shrub cover was proposed by COST Action Usewood members in order to precisely understand the shrub crown coverage for estimating the percent of cover. The reference definition of a shrub and shrub cover is expressed as:

> A shrub is a woody perennial species typically not forming a single main stem and not having a definite crown. For NFI purpose shrub crown cover is defined as the horizontal projection of the outermost crown limits of a shrub or a group of shrubs.

The distinction between forests and OWL is highly demanding in field assessment. Some case studies on the estimation of OWL and its wood resources were conducted in order to highlight the difficulties that NFI projects face in Northern and Central Europe, as well as in Mediterranean and North Atlantic conditions. Therefore, the proposed clarifications provide a clear definition for tree, shrub and shrub crown cover. This is essential to avoid misinterpretation of the OWL category.

A first definition of Trees outside forest (TOF) was provided by FAO in 2000 stating that TOF is defined "*as all trees excluded from the definition of forest and other wooded lands*" (FAO 2001). This FAO definition also includes a further elaboration about the exact meaning: "*Trees outside forest are located on other lands, mostly on farmlands and built-up areas, both in rural and urban areas. A large number of TOF consist of planted or domesticated trees. TOF include trees in agroforestry systems, orchards and small woodlots. They may grow in meadows, pastoral areas and on farms, or along rivers, canals and roadsides, or in towns, gardens and parks. Some of the land use systems include alley cropping and shifting cultivation, permanent tree cover crops (e.g. coffee, cocoa), windbreaks, hedgerows, home gardens and fruit-tree plantations.*" The diversity of cases mentioned in the definition above and the mosaic of different patches of land it represents drew us to propose a land classification by wood resource contained in each class). The main idea behind this classification is to allow countries to focus on categories that are primarily important in terms of wood resources and biomass. Then countries can propose a methodology to estimate these wood resources depending on the importance of the category and neglect the remaining categories.

The criteria and thresholds used for this classification are in accordance with the FAO forest and OWL reference definitions. Two important new categories similar to Forest and OWL except for the land use were defined by COST Action Usewood (Fig. 3.2). They are called *Agricultural or Urban land similar to Forest* and *Agricultural or Urban land similar to other Wooded Land* and defined as:

> Agricultural or Urban land similar to Forest (AUF):
>
> Land area spanning more than 0.5 ha and more than 20 m width with trees higher than 5 m or trees able to reach these thresholds in situ, of a crown cover more than 10 % and land predominantly under agricultural or urban use.

Note: This AUF concept is similar to what FAO called OLwTC.

> Agricultural or Urban land similar to other Wooded Land (AUWL):
>
> Land area spanning more than 0.5 ha and more than 20 m width with trees higher than 5 m or trees able to reach these thresholds in situ, of a crown cover between 5 % and 10 %, or a

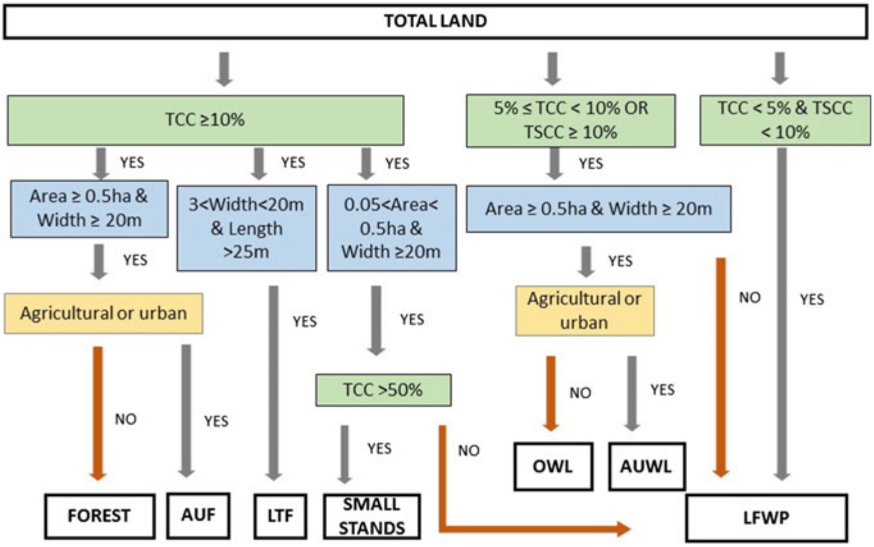

Fig. 3.2 Partition of the land in order to facilitate estimation of wood resources in each category, according to COST Action Usewood. Criteria to define the classification: (a) tree crown cover (TCC) and tree and shrub crown cover (TSCC) in *green colour*; (b) area in *blue colour*; and (c) land use in *orange colour*. Partitioning categories: (i) forest; (ii) other wooded land (OWL); (iii) and land with trees outside forest: agricultural or urban land similar to forest (AUF); linear tree formation (LTF); small stands; agricultural or urban land similar to other wooded land (AUWL) and (iv) land with few woody plants (LFWP)

combined crown cover of trees and shrubs of more than 10 % and land predominantly under agricultural or urban use.

As international reporting is a key issue for NFIs, our classification took into account and individualised the other categories important for FAO such as small stands and Linear Tree formations (LTF). Therefore, a reference definition as close as possible to the FAO definition is given for these 2 categories:

Small Stands:

Land area between 0.05 ha and 0.5 ha and more than 20 m width with trees higher than 5 m or trees able to reach these thresholds in situ, of a crown cover above 50 %. It includes all land uses.

Linear Tree Formation (LTF):

Tree lines or hedgerows between 3 m and 20 m width and more than 25 m length.

The remaining category consisting of the rest was named:

Land with Few Woody Plants (LFWP):

Land area with trees or other woody plants which is not Forest, AUF, OWL, AUWL, LTF, or Small stands.

3.4 Comparison Between Reference Definitions and International and National Definitions

In this section the similarities and differences between the established reference definitions with both, national and international definitions on forest available for wood supply, stem quality, variables related to the change in forest resources and the area classification considering wood resources outside the forest are analysed.

3.4.1 Forest Available for Wood Supply

Two divergent categories of FAWS and related restrictions were identified by the countries participating in COST Action Usewood, with intermediate situations:

- productive forests
- forests where harvesting is not strictly forbidden

The agreed reference definition states that FAWS implies the absence of restrictions that could have a significant impact, not only on the current but also on the potential supply of wood. While productive forests with no significant restrictions are always considered as FAWS according to the reference definition, other forest areas with no significant restrictions should be also considered as FAWS.

On the other hand, countries which include all forests where harvesting is not strictly forbidden according to legal restrictions should also consider also environmental, social and economic restrictions. Although some restrictions have a legal nature, some others such as accessibility, slope or soil condition have not and should be considered. In countries where only a limited number of restrictions are considered, area and growing stock of FAWS would probably decrease if they adopt the reference definition. These two divergent definitions are related to the interpretation of potential or actual use of wood resources by countries. The reference definition includes both, actual and potential estimates.

According to Table 2.4 (Chap. 2, National definitions of FAWS), a high percentage of countries should undertake a new assessment of FAWS to obtain comparable figures at the European scale. To facilitate the harmonisation process, the reporting notes accompanying the reference definition of FAWS recommend that the three categories of restrictions are accounted for separately, if possible (i.e. environmental, social, and economic) (Alberdi et al. 2016). Also, the restriction category should be further detailed (e.g. protected areas, protected species). A separate assessment of FNAWS area and growing stock by restriction category would facilitate data comparison between countries.

The discussion on the search for an agreed definition among the countries participating in COST Action Usewood has already had some impact on NFI activity. For example, in Iceland new field data is being recorded on restrictions, in Ireland and Switzerland a definition was established and in Spain new restrictions were considered. In Italy the next NFI survey will classify FNAWS by the three restriction categories (environmental, social and economic).

3.4.2 Stem Quality

As follows from the study by Bosela et al. (2015) there is a great variability among European NFIs regarding the stem quality and timber assortment assessment. From among the NFIs only eighteen directly classify or assess stem quality (Table 2.11). Moreover, the approaches greatly differ between these NFIs. From the current status of European NFIs, Bosela et al. (2015) introduced a list of stem quality related attributes that are measured or assessed in the NFIs (Table 3.1). As follows from the table, as many as 79 % of the NFIs record some other stem damage attributes which can be useful for developing harmonised stem quality assessment in the future.

3.4.3 Change Estimation

The classification scheme of the compartments and components of change has the intention to consequently map the development an individual tree may take over time. In country-level and international reporting these are partially defined or anticipated, however a complete classification scheme was not established. Where defined, the understanding of terms may vary considerably. For example, many NFIs record during the field assessments types of fellings and types of natural losses. The distinguished types vary between countries and natural losses are defined differently. The understanding of natural losses varies also at the international reporting level. To calculate net annual increment IPCC (2006) for example subtracts the volume of "trees dying naturally from competition in the stem-exclusion stage of a stand or forest" from gross annual increment, while FAO (2000) broadly subtracts the losses to the growing stock "due to mortality from causes other than cutting by man". The reference definition for natural losses broadly includes all natural causes, such as mortality, storms, forest fires, sanitary cuts, insects or wood decay, but also considers the subsequent use of wood by the distinction into removals, residues and losses. The use of wood affected by natural causes was not subject in sustainability considerations until now.

The reference definition of net annual increment follows the approach of subtracting natural losses from gross annual increment and can serve as a sustainability indicator by comparing the net increment to the fellings (FOREST EUROPE, UNECE and FAO 2011). Both the reference definitions for gross annual increment and net annual increment rely on the growing stock definition of COST Action E43 (2010) to ensure consistency between growing stock and increment estimation. This consistency is normally also aimed at by the NFIs. Regarding common reporting this means, that a minimum dbh of 0.0 cm is applied, and that the stem increment above stump height is included. Because the increment definitions of NFIs are usually formulated on the basis of growth components (e.g. Beers 1962; Martin 1982; Van Deusen et al. 1986; Roesch et al. 1989; Eriksson 1995) which can vary depending on the sample tree selection method, a reference definition for increment has to be formulated independent of such components. However, by generally referring to "living trees over a specified area" the reference definitions for gross and net increment include the increment of all trees above the minimum dbh and living between t1 and t2. In technical terms for NFIs this means that the increment of all growth components producing increment have to be included in order to produce estimates according to the reference definition.

3.4.4 Wood Resources Outside of the Forest

The Forest Resources Assessment (FRA) programme of the Food and Agriculture Organization of the United Nations (FAO) introduced the term Trees outside Forests (TOF) in 1995 to bring the monitoring of this resource onto the political agenda (De Foresta et al. 2013; Nyssönnen and Ahti 1996; Pain-Orcet and Bellefontaine 2004). It was recognised that TOF is a nationally and globally important tree resource with a significant impact on human livelihoods and the environment (Pain-Orcet and Bellefontaine 2004).

The example of India, where 25.6 % of the national growing stock have been found outside of wooded land (FSI 2011), and for some states even more than 50 % (Ahmed 2008; Pandey 2008) underscores the importance of TOF as part of national wood resources. In addition, studies have further indicated the potential importance of TOF resources to national wood supplies world-wide (FAO 1998; Kleinn et al. 2005; MacFarlane 2009; Riemann 2003). An important development in monitoring TOF was the National Forest Monitoring and Assessment program (NFMA) of FAO, which assisted developing countries in implementing national tree resource inventories upon request. The NFMA program (Schnell et al. 2015) highlights the substantial contribution of TOF to national biomass stocks.

This very basic definition has an inclusive character as it includes all trees not taken into account in wooded land (i.e. forests and OWL). Together, the three definitions for forest, OWL, and TOF, thus, may comprise all trees that grow in a country. This means however that the perception of what TOF represents is directly linked to the definitions of forest and OWL. Nevertheless, it is worth mentioning that the term "trees outside forests" is not very appropriate and should be replaced by "trees outside wooded land" according to the definition previously mentioned (FAO 2001).

Very few countries are in a position of estimating correctly all TOF volume and biomass growing on their territory. As field surveys are expensive, the estimation of TOF is often a combination of remote sensing techniques with field samples. For example, Singh and Chand (2012) used remote sensing techniques and field samples to detect TOF biomass and provided estimates of carbon stock in the semi-arid region of southern Haryana, India, while Sheeren et al. (2009) used aerial images to discriminate small wooded areas in rural environments.

Providing precise and up-to-date information on wood resources for decision making is an important task for NFIs. Nevertheless, NFIs are mainly focused on wood resource estimation in forest and also OWL. Therefore, if resource estimates exist in some countries for OWL, precise data are rarely available for the remaining wood resources outside of forest and OWL. In the framework of a NFI programme it is hardly feasible to include the areas with TOF (non-forest and non-OWL areas) in the traditional terrestrial survey since most plots are far apart as verified with the results obtained in the questionnaire (Chap. 2). Moreover, only few trees could be visited in this case which is, in relation to the sample plots, not a cost-effective additional information source.

The cost of international reporting according to all the categories of non-wooded land is significant and countries need to maximise the use of limited resources. The proposed classification allows countries to prioritise where to assess wood resources from outside wooded land, depending on their national situation. For countries such as India in which more than one fourth of growing stock is estimated to come from TOF, this classification would be of great help. They could start to assess categories producing the main part of their wood resources from TOF and then neglect the rest or provide a rough estimation of it. Nevertheless, the effort of a survey in these areas is huge (particularly for field survey) and the cost/benefit ratio could be very high for a mostly small part of the total wood resource. Therefore for the moment, estimation of this part of wood resources is incomplete and not comparable from one country to another.

A more justifiable and effective way for estimating these resources is to use a multi-scale and multi-source inventory, combining different techniques as suggested by McRoberts and Tomppo (2007). This combined method is being used currently for around one third of the countries assessing TOF (see Chap. 2). Nowadays, remote sensing data and techniques enable to have an automatic check of some variables, although some difficulties to check land use criteria will arise. Nevertheless, some TOF terrestrial plots should also be surveyed to calibrate the design (i.e. to train remote sensing methods) and give precise information on tree species, volume, biomass, etc.

The main disadvantage of using remote sensing techniques is that the information on land use according to a specific forest definition cannot be obtained directly. For example, a temporarily unstocked area (e.g. wind throw) in the forest will be detected as non-forest in the imagery although its use remains still forest. It is an additional challenge to assess land use using remote sensing where this information is not available at national level from other land surveys. This analysis requires a combination of image classification expertise and/or external knowledge. This implies the need to interview foresters, land owners or perform in situ field visits of these areas.

The partition of the land and the attached reference definitions presented in this chapter strengthen the arguments for the use of a multi-scale inventory. Different data sets such as aerial photos, satellite images and airborne laser scanning as well as statistical ground surveys are more and more used together to estimate wood resources in a country.

3.5 Conclusion

A reference definition of FAWS was established within the framework of the COST Action Usewood, with the aim of reducing ambiguity in the existing international definitions and improve the comparability of national figures. The reference definition was agreed by NFI experts. For FAWS-harmonisation, different steps are still needed to define: (i) principles, (ii) restrictions constraining wood supply area (iii) restriction thresholds. The established reference definition defines principles and determines the different restrictions. Nevertheless, there is still a need for further analysis to investigate the relevance of different restrictions and their thresholds. For transparency, the restrictions and thresholds should be reflected when reporting.

Concerning the stem quality assessment, great differences were found. The results of the recent study by Bosela et al. (2015) indicated that the current systems are not capable of reporting stem quality in a harmonised manner at present. However, as information on the quantity alone will certainly not be sufficient for policy makers, progressive steps should be taken to develop a harmonised stem quality assessment. Due to the limited number of NFIs using some type of stem quality assessment there is even a potential to develop a standardised methodology for stem quality assessment. However great variability in measuring or assessing basic size-related variables (dbh, tree height, volume estimation, etc.) will still limit standardisation and as a result final methods towards harmonisation should be researched further.

For the purpose of change estimation, a classification scheme was developed that distinguishes and defines the compartments of living trees, standing dead trees and lying coarse woody debris. Changes in the compartments are due to the change components of gains and losses. The losses in living stems and standing dead stems are divided into fellings and natural losses which further divert into removals, residues and losses depending whether the wood is recovered or remains in the forest. The reference definitions of the compartments and change components rely on changes in terms of tree individuals independent of sample tree selection methods. In addition, the changes due to growth, mortality and cutting under sampling conditions were described by growth components and the time periods when they contribute increment as part of the sample were clarified. Based on the classifications in change and growth components common reference definitions for gross and net increment were formulated to include the increment of all trees above the minimum dbh that are living during the period between the two time points t1 and t2. The reference definition of net annual increment follows the approach of subtracting natural losses from gross annual increment and can serve as sustainability indicator by comparing the net increment to the fellings. The reference definition for natural losses broadly includes all natural causes, but also considers the subsequent use of wood by the distinction into removals, residues and losses. The use of wood affected by natural causes was not subject to sustainability considerations until now.

Concerning TOF the concept regroups a mosaic of land categories not precisely defined at FAO level. To facilitate the evaluation of wood resources contained in TOF, a land classification has been developed together with related reference definitions. This real classification improves other existing classification schemes as there is no gap and no overlapping between classes (as it is usual for a classification). It is based on common criteria and attached thresholds, being easily harmonised. It also facilitates the division of land into the most important categories in terms of wood resources depending on the national context, which is useful for decision making and prioritising categories where estimates must be calculated.

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Chapter 4
Progress Towards Harmonised Assessment of Availability and Use of Wood Resources in Europe

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4.1 Introduction

The harmonisation process of NFIs dates back to the late 1990s when the forest resources assessment reporting program FRA 2000 (FAO 2001) and its regional contribution TBFRA 2000 (UNECE/FAO 2000) introduced a homogenous set of

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definitions to be used for reporting. The harmonisation continued in subsequent global FRAs (FRA 2005, 2010, 2015) when definitions were revised based on the experiences made. At European level, the European Forestry Information and Communication System (EFICS) was established by Council Regulation (EEC) No. 1615/89. The EFICS study had the aim to collect comparable information about the forestry sector in the European Community (EFICS 1997), and revealed the need for comparable information at the international level and the existence of knowledge gaps and unsatisfied information needs concerning the forest sector (Päivinen and Köhl 2005). The harmonisation of NFIs was strongly amplified by COST Action E43 (2010) which integrated the previous efforts by EFICS (1997), FAO (2001), and UNECE/FAO (2000), and developed techniques for common reporting by establishing concepts for European NFIs, and elaborating the methods to obtain comparable estimates (Tomppo et al. 2010). The harmonisation process of NFIs continued in the subsequent COST Action Usewood (2014) as well as in many follow-up projects such as the Specific Contracts within two Framework Contracts with the DG Joint Research Centre (JRC) of the European Commission (JRC 2012). In this chapter the principle of bridge building using national and reference definitions is described and the current state of harmonisation at international level is discussed. Recent advances in the harmonisation of NFIs regarding the assessment of wood resources are presented, as well as large-scale harmonisation implementations and case studies on bridge building.

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4.2 Basic Concepts for Harmonising European NFIs

Harmonisation in terms of NFIs is the process of making data and estimates comparable across administrative borders. To achieve this goal, common reference definitions must be agreed among the countries involved in the harmonisation process (see Chap. 3). Then, each country would apply these reference definitions and store the metadata on the methods used in order to transform national data into estimates comparable between countries. These conversion methods are characterised as 'bridging functions' (Ståhl et al. 2012). Bridging functions can take different forms and include mere recalculations based on existing data as well as advanced statistical functions to convert the estimates based on existing national definitions into estimates corresponding to common reference definitions. In general, each country participating in the harmonisation process needs to develop its own bridging functions, at least as long as it conducts its basic data acquisition differently from the common reference definitions. Of course, the countries can exchange experiences and expertise among themselves to take advantage of existing data and methods developed by other countries (Fig. 4.1).

An important matter in harmonisation is whether or not necessary ancillary data as mentioned above is available to support the estimation according to the proposed and agreed reference definition. From this point of view, it is necessary to make a distinction between three general cases called *reductive* bridges, *expansive* bridges, and *neutral* bridges (Ståhl et al. 2012):

1. In the case of *reductive* bridging functions, national data are available in 'surplus', i.e. the reference definition is narrower than the national definition. For example, a country may have a national definition that includes more areas than the reference and thus the bridging function becomes a matter of identifying which parts should be excluded in order to meet the reference definition. An example applies for the Third Spanish NFI forest national definition with a minimum crown cover of 5 % instead of 10 % for the reference definition

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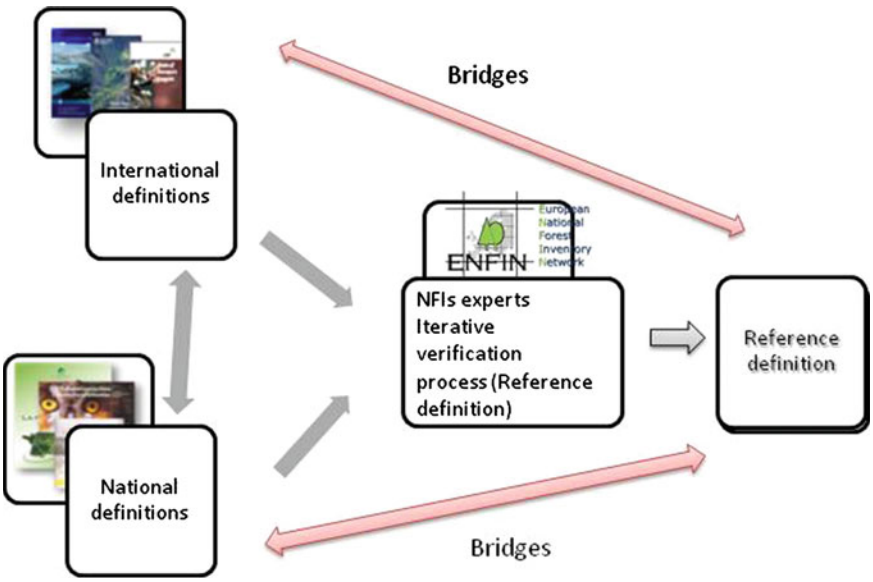

Fig. 4.1 NFIs harmonisation process

(Alberdi et al. 2010). The situation may be more complex when there are differences in more than one criteria involved.

2. The opposite situation is encountered when an expansive bridge needs to be developed. In this case the scope of the reference definition is wider than the national definition. This situation is often more complicated because the required data are generally not fully available at national level. In this case conversion methods may be computed based on auxiliary data. Such information could be obtained from pilot studies within the concerned country or data available from other countries with similar conditions. For example, when estimating growing stock (GS) the Swiss NFI measures only trees with a diameter at breast height (dbh) superior or equal to 12 cm whereas this threshold is 0 cm for the reference definition of GS agreed under COST Action E43 (Lanz et al. 2010). So an estimation of the missing part of Swiss GS is necessary to correspond with the reference definition.
3. With neutral bridges, the scope of the reference definition is the same as the national one, but internal subdivisions between different features may have been applied. In the case of the total biomass of a tree for example, the whole tree is partitioned into above ground biomass (AGB) and below ground biomass (BGB). The splitting between AGB and BGB is different among countries. Some countries specify AGB to include all tree parts above the ground level while others consider the tree parts above stump height. Concerning the subpart of AGB, the reference definition strictly specifies the ground level as dividing line. Thus conversion factors are necessary for estimating and including the

stump biomass in AGB and excluding the stump biomass from BGB. The total biomass remains unchanged and therefore this adjustment is considered as a neutral bridge.

The methodological approach of bridge building not only needs a reference definition but also a description of the full process involved. The general way of working includes an initial screening exercise of the state of the art in each country (see Chap. 1). An enquiry is conducted, for example, using a questionnaire in order to explore and highlight the differences between the definitions applied by the NFIs. The enquiry is followed by an analytical decomposition of these national definitions into criteria and a description of the differing national thresholds (Vidal et al. 2008) (see Fig. 4.1). As an illustration the example of an individual tree, the basic entity for GS and biomass estimation, can be taken. First, a reference definition of a tree is needed for the distinction from other woody plants. Second, unambiguous specifications of the elements or parts of a tree are required, because definitions related to GS and biomass estimation are usually formulated on the basis of tree parts to be considered. Thus, a reference definition of each tree element used for defining GS and biomass is also necessary. To establish a clear specification for each element, a multi-step analytical partitioning approach was proposed leading to an unambiguous definition of each tree element (Gschwantner et al. 2009). These tree elements are distinct parts of the tree that are clearly defined. Combined, these elements can describe a whole tree. In this way, a flexible scheme could be achieved that (i) serves as a basis for a broad range of reference definitions (ii) permits further partitioning into additional, smaller elements and thus (iii) facilitates the adaptation to future developments and harmonisation requirements. The accuracy and precision of this harmonised information is an essential point to be considered. It depends on many factors, e.g. the conciseness of the definitions involved, the availability and quality of data for developing and applying bridging functions, the ancillary information used, and the method applied to perform the conversion from a national to a reference definition.

4.3 Harmonisation and International Reporting

International reporting programs such as the FAO's Forest Resources Assessment (FRA) and FOREST EUROPE are important drivers for the harmonisation of forest-related information. Following the introduction of commonly applied definitions in FRA 2000 and TBFRA 2000 (FAO 2001; UNECE/FAO 2000) the comparability of estimates is still an aim to be strived for. The harmonisation in international reporting and its deficiencies are mainly linked to the differing national situations. The differences are due to different tools for forest assessment, historic backgrounds or climatic conditions as well as forestry policy issues. As a result, agreed definitions at international level must be broad enough to accommodate the circumstances of each country (e.g. Lund 2015). This lack of harmonisation which appears in international reporting can be highlighted on selected key examples. As a consequence, the effectiveness of a reference definition is ultimately tested when applied by individual countries.

4.3.1 The Example of Growing Stock Definition

The FAO (2010) defines growing stock by referring to living trees, specifying a dbh-threshold and the included tree parts. Additional specifications are given in the explanatory notes regarding the thresholds, wind-fallen trees and certain tree parts:

Growing Stock is the volume over bark of all living trees more than X cm in diameter at breast height (or above buttress if these are higher). Includes the stem from ground level or stump height up to a top diameter of Y cm, and may also include branches to a minimum diameter of W cm.

Explanatory notes:

1. *Countries must indicate the three thresholds (X, Y, W in cm) and the parts of the tree that are not included in the volume. They must also indicate whether the reported figures refer to volume above ground or above stump. These specifications should be applied consistently through the time series.*
2. *Includes windfallen living trees*
3. *Excludes smaller branches, twigs, foliage, flowers, seeds, and roots*

This definition is pragmatic, because NFIs used the criteria dbh, top diameter, and branch diameter and their associated thresholds X, Y and W according to national purposes and forest industry for a more or less long time and following country-specific traditions. Furthermore, countries consider GS either above ground level or above stump height. This point is only explicit in the FAO definition under a footnote but has some importance. Proposing a growing stock definition with flexible thresholds was the compromise to obtain a global agreement on what to consider as growing stock for the FRA reporting. Nevertheless, working this way leads to a lack of comparability between national figures. This lack of comparability can be illustrated by opposing two extreme interpretations of the definition which could lead to remarkable differences in estimates: (i) dbh-threshold = 10 cm, included tree parts = bole (wood + bark) from stump height to top diameter of 7 cm and (ii) dbh-threshold = 0 cm, included tree parts = stump, bole (wood + bark) stem top, large branches. In FRA 2010 (FAO 2010) the authors note the following about the growing stock figures presented in Table 2.13 of the FRA report: *"It is interesting to note that the growing stock figures presented in FRA 2010, including growing stock per hectare, are in general higher than those contained in the FRA 2005 report. This is because many countries have collected new and better data for FRA 2010, more countries have reported, and more effort has been made to help countries provide the best possible estimates with the weak data they often have available."*

4.3.2 The Example of Forest Definition

The definition of forest agreed by FAO and national correspondents under the FRA process is less ambiguous than it is for GS because the threshold values for the criteria of minimum area, canopy cover and minimum height are specified. Nevertheless, as each country has its own national definition used by the NFI for national purposes, the country had to find a way to provide estimates according to the international FAO definition. Often, countries approached the problem of adjusting national estimates by reclassification from national land cover/land use classes into the FAO categories (Gabler et al. 2012).

For example, in the Third Spanish NFI, the minimum crown cover for defining a forest at national level was 5 %. Therefore, a reductive bridge was applied to estimate only the part with a crown cover more than 10 % for FAO tables. The Spanish NFI uses a stratified sampling plan. The forest strata are defined with the National Forest Map elaborated by photo-interpretation using several ancillary data (such as previous NFIs, National Forest Maps, Natura 2000 information or ownership). Forest area is delimited into homogeneous "*tesserae*" (homogeneous in the main forest species, crown cover and stand stage) (MMA 2006). As crown cover of all *tesserae* is known, the ones with a crown cover lower than 10 % can be identified and therefore not considered for international reporting. The area of *tesserae* with a crown cover between 5 and 10 % is then reported as other wooded land (OWL).

Another example is the Swedish case, where forest was traditionally equal to *productive* forest and defined by law in the Swedish Forestry act (Swedish Forest Agency 2015). This definition is linked to a productivity criterion that requires an average annual productivity over the rotation period of more than 1 m^3/ha/year of stemwood over bark. Forest according to the FAO definition that did not reach the productivity criterion was defined as forest impediments. To report all the forest area to FAO, Sweden was required to build a bridge to convert national definition into the FAO one. The complete difference in the criteria used in the two definitions made the exercise somewhat difficult. The Swedish NFI thus decided since 1998 to assess both definitions of forest in the field, to facilitate reporting at a national level with the national definition and at the international level with the FAO definition. In 2008 the Swedish Forestry Act was revised in order to harmonise with the international definition and since then, Forest is defined according to the FAO definition and productive forest is defined according to the traditional definition as a sub-class of forest. This shows how NFIs can harmonise their estimates as well as their legislation by adopting international definitions but still continue to use the traditional national ones. As a consequence of this harmonisation process some countries have adopted the FAO definition and the situation has greatly improved.

4.4 Recent Harmonisation Advances at European Level

Harmonisation of forest estimates and derived information is a long term process. The duration of this process is due to the broad diversity in general ecological conditions, in the approach to forest policy and in the importance of the forest sector in different countries. A common forest policy in Europe would motivate the implementation of this process, but without this common policy approach, only small incentives can help to support the harmonisation. Nevertheless, important steps towards harmonisation at an EU level could be reached in the recent time in the short to medium term under the auspices of several EU projects.

4.4.1 Demonstration Project in Building Harmonised Information for EU Purposes

Following the 2010 Green Paper on forest protection and information in the EU (European Commission—COM 2010) and a proposal of the European Parliament, the European Commission (EC) launched a Preparatory Action (PA) in 2012 titled "Future legal base on harmonised EU forest information" with the objective to contribute to the development of a European level framework for comparable and harmonised forest information. For this purpose, the DG Joint Research Centre (JRC) of the EC established two four-year Framework Contracts with a consortium of National Forest Inventory services. Under the Framework Contracts numerous studies on various topics were conducted. The Specific Contract Biomass (SC13) was one of the first implementation steps towards a future Forest Information System for Europe (FISE) (San Miguel Ayanz et al. 2005).

The aim of the SC13 project was to develop and apply a methodology for the harmonised assessment of forest biomass at European level and to provide spatial information on biomass and other forest parameters according to the Infrastructure for Spatial Information in Europe (INSPIRE) grid at the Nomenclature of Units for Territorial Statistics (NUTS) level units. The work included the development of a definition for above ground biomass (AGB) to include the biomass of all living trees higher than 1.3 meters, including stem with bark, above ground part of the stump, living branches, dead branches and foliage. Seedlings and shrubs should be excluded.

4.4.2 COST Action Usewood Achievements

The overall objective of Action Usewood was to improve and harmonise data and information on the potential supply of wood resources at the European level. In consideration of future scenarios of supply and demand of forest products and predicted supply deficits COST Action Usewood integrated three working groups with topic-specific objectives. WG1 aimed at harmonising the assessment and estimation techniques of state and changes in wood resources based on NFIs, WG2 aimed at improving wood resources estimates combining remote sensing and NFI field data, and WG3 aimed at predicting the use of wood resources.

The Action made significant progress to achieve its objectives (i) the harmonisation of European NFIs and establishment of reference definitions on increment, harvest and assortments, forest available for wood supply, other wooded land, other land with tree cover and trees outside forest (ii) the characterisation of tools available in European countries for predicting wood resources combined with an economic analysis study on wood availability in Europe.

Below some thematic fields for harmonisation progresses are presented. Information on the forest area available for wood supply (FAWS) is an essential piece of information for international forest reporting (UNECE/FAO-FRA and SoEF) which is mainly derived from NFI data. In order to meet the information needs concerning climate change mitigation and the increasing demand for wood in Europe, it is crucial to assess the actual quantity of wood available to harvest. Economic restrictions were considered by the NFI experts participating in COST Action Usewood (2014) as one of the main group of restrictions to define and estimate FAWS.

Trees outside forest gain increasing attention due to their environmental and economic roles. The estimation of wood resources outside the forest and OWL is encouraged by international organisations (de Foresta et al. 2013) especially in the context of increasing energy wood demand as a source of renewable energy. Therefore, COST Action Usewood developed an approach to partition the total land area. This approach allows countries to prioritise their efforts towards estimating wood resources outside forest and OWL depending on their importance in the national context (Vidal et al. 2016).

Besides the general availability of wood from in or outside the forest the quality and distribution of wood assortments is a major factor for setting up targets for several environmental policies. Thus it is necessary to distinguish e.g. between fire wood resources or higher value sawn wood timber. There are currently few European NFIs that consider assessment of stem quality or that directly estimate assortments (Bosela et al. 2015). Therefore, harmonisation through bridging functions is needed.

Under the scenarios of increasing demand for wood (e.g. UNECE/FAO 2011; Mantau et al. 2010) the question of sustainable wood supply from European forests has gained considerable attention. For the availability of wood at present and in the future the balance between increment and fellings is considered as decisive, and the fellings should not exceed increment in the long run for shaping a stable growing stock (FOREST EUROPE, UNECE/FAO 2011). In COST Action Usewood (2014) the harmonisation efforts were extended from estimates of state towards the classical change estimates regularly provided by NFIs such as increment, fellings and natural losses. European NFIs apply different sampling methods for sample tree selection as e.g. concentric circular plots and angle-count sampling. Therefore, the components of change were systematically described and defined independently of the sampling method on the basis of individual trees that constitute gains or losses to the growing stock. Harmonised reporting of change estimates builds upon the common definitions of change components and agreement about how they are taken into account for comparable estimates.

4.5 Large-Scale Harmonisation Implementations and Case Studies

Within the ENFIN group the adopted way of working is (i) to agree upon reference definitions (ii) to conduct case studies in order to check if building bridges is feasible and (iii) to make large-scale harmonised estimates. Some examples of different levels of harmonisation implementations are presented.

4.5.1 Biomass Calculation

In the SC13 project (see Sect 4.1) harmonised above-ground estimates were calculated for 17 European countries. The adopted approach followed the common method developed during COST Action E43 (2010) and included the description of national biomass definitions and estimation methods, the agreement on a reference definition and the development of bridging functions to close the gaps between the national and reference definitions. To define an operative harmonised AGB definition differences in the national definitions were mapped at a first step of the project. Following differences we found:

1. Some countries have relatively good data for above ground biomass of trees but no data for estimating below ground biomass
2. The minimum criteria for the size of trees included in the biomass estimates vary from seedlings below 1.3 m height to dbh of 12 cm
3. Some countries exclude stump biomass and other countries include it
4. Dead branches are often excluded from the biomass estimates
5. Some countries have no models for including the biomass of foliage.

In the next step AGB adjustment factors for different components of AGB (by countries able to provide such factors) were collected from countries. For this purpose it was necessary to map in detail which components of biomass countries are able to estimate and which components they may use as explanatory variables to estimate the missing components. It was equally important to identify countries that could derive different correction factors for as many tree species as possible. As a second step countries that could not estimate some components of AGB may use these correction or expansion factors to complete their data.

The following correction factors were required:

- factors to include trees below a specific diameter (dbh) threshold. Several different threshold values for measuring trees are applied in different countries. Therefore, correction factors were developed to include:
- the biomass of trees below the common threshold values (2.5, 5.0, 7.5, 12.5 cm dbh)
- the biomass of branches and foliage with the help of stem biomass,
- the biomass of dead branches with the help of living branch biomass,
- the biomass of foliage with the help of living branch biomass.

Table 4.1 shows an example of the harmonisation process from two countries. Most of the correction factors developed by countries were calculated using national data, where available, and were used by other countries with similar environmental conditions; some correction factors were also obtained from literature (Ruiz-Peinado et al. 2011, 2012).

4.5.2 *Assessing Availability for Wood Supply Considering the Slope Restriction: A Case Study*

For this study, the slope of the terrain was defined as the percent slope of the NFI sampling plot or of the immediate area surrounding the plot. To test the possibility of using common reference values for terrain slope to assess the availability for wood supply of NFI plots, fixed thresholds were defined. The maximum and minimum thresholds of terrain slope were defined through expert judgement and based on NFI data. The thresholds applied for FAWS vary among countries between 35 and 140 %, respectively. The objective was to investigate the possibility of using a common reference percent slope above which the forest should be considered not available for wood supply for all countries.

Table 4.1 Examples of filled gaps by countries

Austria	– Trees with dbh <5.0 cm were added using national data and developed models – National correction factors were developed to include the above ground part of the stump – Italian correction factors were applied to include dead branches for conifers (except fir) – The foliage of larch was added using a national model and the foliage of broadleaves was included using a generic function
Sweden	– Most components of AGB were included using existing national models for the biomass components – Above ground part of stump was included, for that, correction factors were developed – For the component of dead branches Finnish correction factors were used

To analyse the effect of the thresholds, the area and the growing stock of forests characterised by the different thresholds were assessed for the five countries:

1. Min is by percent slope lower than the minimum—i.e. the area and growing stock present on forest with a terrain slope ≤35 %;
2. Max is by percent slope lower than the maximum thresholds—i.e. the area and growing stock present on forest with a terrain slope ≤140 %;
3. National is by percent slope lower than the national threshold for FAWS, if any.

For Spain, the national slope threshold is 45 %, with the exception of the Cantabrian range where it is acceptable to consider a slope threshold of 75 % for FAWS. For Ireland the national threshold is 66 %, and for Italy, Sweden and Switzerland no national threshold is defined.

In addition, Italian NFI data was analysed to assess the importance of terrain slope for forest available for wood supply. In Italy, NFI field crews classify forest as available or not available for wood supply (FNAWS) in each plot in the field while in the other four countries the classification is made a posteriori. The distribution of the Italian NFI plots into the two availability classes and by percent slope class was determined. The chi-square test was used to test for the difference between FAWS and FNAWS in relation to different thresholds of percent slope.

Table 4.2 provides an estimate of the forest area and the growing stock which could be classified as FAWS according to the two reference values and national thresholds, in the five countries. Looking at the relative forest area and growing stock below the minimum threshold, such a threshold would exclude a major portion (>65 %) of the forest area and growing stock of Italy, Spain and Switzerland. The maximum threshold would cause the exclusion of a relatively large portion of forest area (∼10 %) and growing stock only for Italy (∼5 %).

Table 4.2 Forest available for wood supply, forest area and growing stock (% of national total) estimated by applying the thresholds proposed for percent slope

Country	Attribute	Slope thresholds		
		Min (≤35 %)	Max (≤140 %)	National (% of national total)
Ireland	Forest area	96.17	100	99.5
	Growing stock	95.07	100	98.8
Italy	Forest area	36.20	90.36	–
	Growing stock	32.88	95.43	–
Spain	Forest area	22.97	99.97	92.89
	Growing stock	37.92	99.96	88.70
Sweden	Forest area	81.32	NA	–
	Growing stock	89.68	NA	–
Switzerland	Forest area	34.46	99.83	–
	Growing stock	37.27	99.89	–

“NA” means that this threshold is not applicable (e.g. slope in country is not steep enough), whereas “–” means that no data is available. Derived from Fischer et al. (2016)

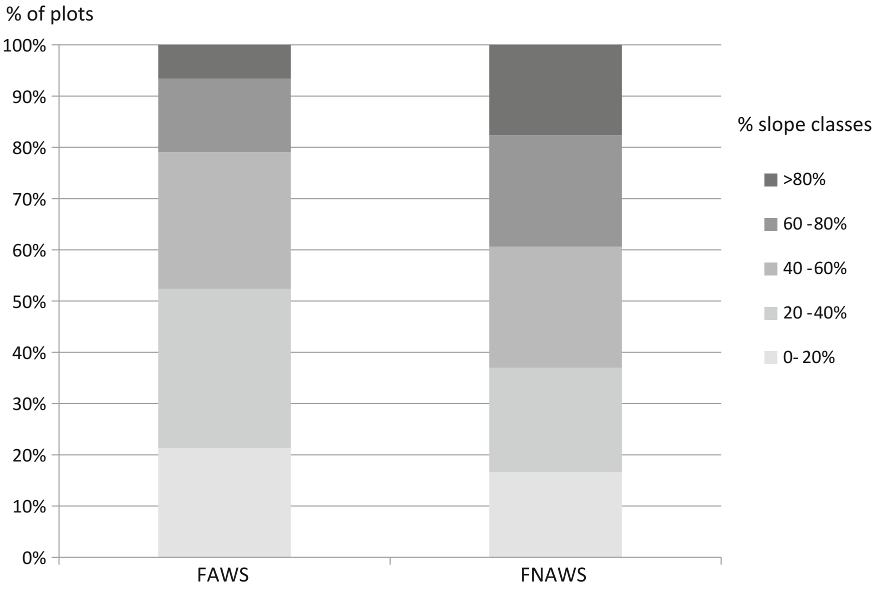

Fig. 4.2 Distribution of Italian NFI plots (n = 19,287 FAWS, n = 1647 FNAWS) by percent slope classes; *FAWS* forests available for wood supply, *FNAWS* forests not available for wood supply

Figure 4.2 shows the distribution of Italian NFI plots by percent slope classes and by FAWS and FNAWS. Compared with FAWS, FNAWS show a large proportion of plots located in steep or very steep slopes (classes 60–80 % and >80 %) and a smaller proportion in flat areas or moderate slopes (classes 0–20 % and 20–40 %). The distribution of NFI plots by percent slope classes differ significantly between FAWS and FNAWS (p-value < 0.001).

From this case study we can conclude:

(i) Slope is a key variable for economic profitability of harvesting, and is commonly available information. It can be calculated using a Geographic Information System or assessed during field measurements. For these reasons it would be a good indicator of availability for wood supply, although it should be considered together with other variables. The use of one common threshold for terrain slope over the whole Europe is not easy. Profitability of wood harvesting is influenced by the terrain morphology in the country, harvesting techniques available locally and market demand. Therefore, a common slope threshold on its own is not enough to encapsulate the variation between countries.

(ii) For harmonised reporting of FAWS/FNAWS terrain slope could be selected as reference variable together with country-specific thresholds. They could be assessed using the strong relationship between slopes and harvesting cost as proposed by Fischer et al. (2016) for Switzerland.

4.5.3 *Detection of Trees Outside Forests (TOF)*

Nowadays, new perspectives for estimating wood resources are emerging through high quality remote sensing data, new techniques regarding processing of large data sets, and regularly repeated image acquisition (Koch et al. 2008; Barrett et al. 2016). However, problems arise regarding the land use criterion, which is a key parameter in forest definitions but hardly assessable when using remotely sensed data (Waser et al. 2015). For example, a temporary unstocked area, e.g. after impacts such as fire, storm, or harvesting will be identified as non-forest area when using remote sensing data and techniques, but will in fact maintain its land use status as a forest.

This case study introduces a highly automated approach of estimating wood resources from TOF based on image-based point clouds from aerial photography, Airborne Laser Scanning (ALS) data, and the CORINE 2006 land cover (CLC2006) in a test site located at the border of Austria, Germany and Switzerland (see Fig. 4.3). The main emphasis was laid on the joint handling of national high resolution datasets based on different aerial cameras, different software packages and different digital terrain models.

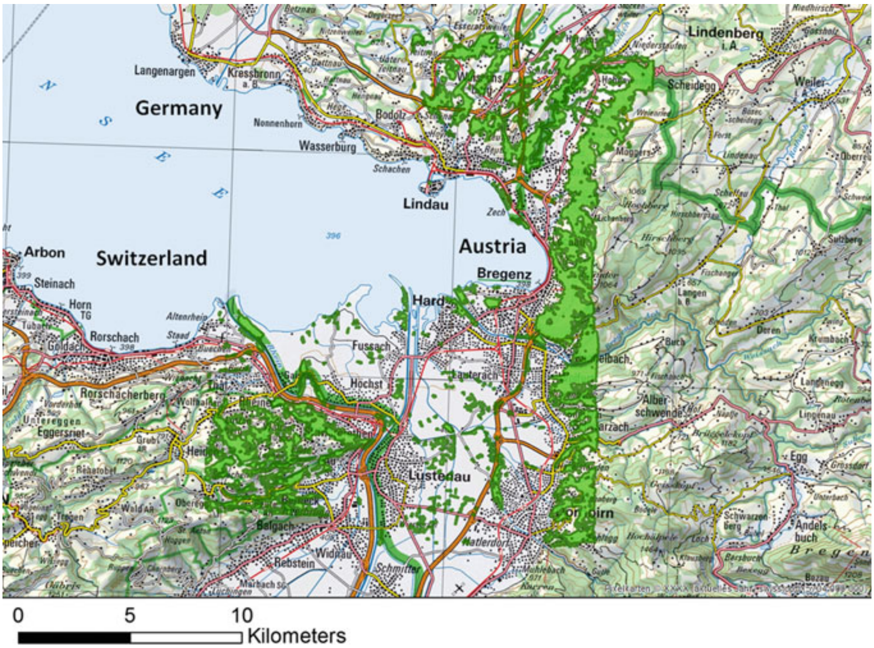

Fig. 4.3 The test site covers an area of approx. 250 km^2, is located at the borders of Lake Constance and is characterised by mixed forests, rural and urban areas with woodland embedded in a pre-alpine topography. *Source* Swisstop (From Vidal et al. 2016)

In this approach, wood resources were classified as shown in Vidal et al. (2016): (1) forest, (2) agricultural or urban land use class with the same criteria of land cover than forest (AUF), (3) OWL, and (4) Agricultural or Urban land use class with the same criteria of land cover than OWL (AUWL).

The workflow incorporates five main processing steps and starts with merging the different data from the three countries sets to one single dataset. Second, a Canopy Height Model (CHM) was calculated by subtracting a Digital Terrain Model (DTM) derived from ALS from the Digital Surface Model (DSM) which is derived from stereo-image based point clouds. More detailed information on the remote sensing input data and used image matching techniques can be found in Ginzler and Hobi (2015), or Straub et al. (2013). Third, wooded areas were extracted using the Normalized Difference Vegetation Index (NDVI) image and the CHM for the minimum tree height criteria from the three different national forest definitions (Tomppo et al. 2010) and the FAO forest definition (FAO 2010; Polley 2011). Fourth, GIS operations were applied on the wooded area using the four criteria: minimum tree height, minimum crown cover, minimum width and minimum area for each of the four forest definitions. The resulting maps included the four categories: Forest, AUF, OWL and AUWL which fulfilled the respective definitions. Fifth, the land use information from the CLC2006 data set was included in order to separate areas under forest-use (according to the CORINE definitions) from AUF, OWL and AUWL. Eleven CLC2006 classes: 111 (continuous urban fabric), 112 (discontinuous urban fabric), 121 (industrial or commercial units), 123 port areas), 124 (airports), 132 (dump sites), 133 (construction sites), 141 (green urban areas), 142 (sport and leisure facilities), 222 (fruit trees and berry plantations), 512 (inland water bodies) were used as non-forest use classes. For more detail see EEA (2015).

The maps were validated using an independent reference data set, which consisted of visual image interpretation of 1100 points in a regular grid (Fig. 4.4 as an example based on the FAO forest definition). Correspondence rates from 70 to 95 % were achieved for the different wood resources classes Forest, AUF, OWL and AUWL and were highest for Forest and AUF.

It seems that the relative coarse spatial resolution (compared to the used aerial images) of the forest and AUF land use information obtained from the CLC2006 data set had no significant effect on these two categories. Lower correspondence rates were obtained for smaller tree patches that belong to AUWL and OWL. Thus, for the estimation of other wood resources classes, e.g. small stands, groups of trees such as Linear Tree Formations (LTF) and the remaining category of this classification Land with Few Woody Plants (LFWP) the CLC2006 data set would be too general and the use of alternative data sets, e.g. topographic maps—as available for many countries—should be taken into account.

To summarise, the present study clearly revealed that besides forest the extraction of information on OWL resources is feasible with a high degree of automation for cross-border regions. No border effects were detected that influence the quality of the present approach—although country-specific input data sets were used. Thus, high resolution remote sensing data is reasonably promising to classify

Fig. 4.4 Example of a true color orthoimage with the forest mask based on the FAO definition, estimated AUF, and AUWL and OWL (From Vidal et al. 2016)

clearly defined wood resources classes such as forest, AUF, AUWL and OWL. It is the first step into the direction of a harmonised reporting and useful for cross-national comparisons.

4.5.4 Stem Quality and Assortment Assessment: A Slovak-Czech Case Study

There are several approaches to achieve harmonised estimates of timber assortments in European forests using European National Forest Inventories (Bosela et al. 2015). One possible way is using a national model developed in a neighbouring country that has similar geomorphologic and climatic conditions and similar forest structure and management practices (tree species, thinning methods applied, etc.).

This case-study aimed at testing the approach of adopting a model for assortment estimation from a neighbouring country. The study used regression models which were developed for Slovakian forests in 1990s (Petráš and Nociar 1991a, b; Mecko et al. 1993, 1994a, b). Data for the development of the models were obtained from

167 research plots which were established over the main growth regions of Slovakia taking into account tree species. In each plot, a minimum of 70–80 trees were assessed.

The tree-level model of assortments was built up using regression modelling of the proportion of quality classes and assortments dependent on tree dendrometric characteristics. From many possible parameters, the dbh, stem quality assessed visually in the field (categories A, B, C, and D) and damage to the tree were found to significantly explain the variability and were thus used as the independent variables. For taking into account tree damages, any kind of stem damage which may allow fungi to infect the wood and is older than 2 years was considered (i.e. visual signs of stem base rot, or visible rot of the knots spreading to the stem, mechanical stem damage or root swelling caused by logging, frost crack, etc.). As mentioned above, stem quality was visually assessed in the field. Only the lower 1/3 of the stem was assessed into one of four categories:

A—High quality stems, almost without knots (only healthy knots under 1 cm in diameter at the base), twisting (spiral growing), and without other technical defects. B—Average quality stems, with small technical defects. In the case of hardwood species all of the healthy or unhealthy knots with diameters under 4 cm are allowed. For spruce and fir healthy or unhealthy knots under 4 cm and for Scots pine less than 6 cm are allowed. C—Low quality stems with large technical defects, with high frequency of branches (densely branched trees), twisting up to 4 % of straight length axis. Healthy knots without limit for the size (diameter) are allowed, unhealthy knots up to a diameter of 6 cm in the case of softwood species, and up to 8 cm for hardwood species. D—Poor quality stems with unhealthy knots over 6 cm for softwood species and over 8 cm for hardwood species, which are also affected by rot. The stems are only utilised as fuelwood.

The mathematical model gives the proportion of assortment classes in each standing tree. The regression models have the following form:

$$\textit{Spruce} \quad AP_{spruce}(dbh, q, p) = b_1 + b_2 q^{b6} + b_3 dbh^{b7} p^{b8} + b_4 dbh\, q + b_5 p\, q \tag{4.1}$$

$$\textit{Beech} \quad AP_{beech}(dbh, age, q) = b_1 + b_2 q^{b6} + b_3 dbh^{b7} age^{b8} + b_4 dbh\, age + b_5 age\, q \tag{4.2}$$

where *AP*—the percentage of the particular assortment; *dbh*—tree diameter at breast height; *q*—quality class (as dummy variable: A = 1, B = 2, C = 3, D = 4); *p*—damage to stem (as dummy variable: undamaged stem = 1, damaged stem = 2); and *age*—tree age. To overcome large variability in the proportions of assortments, cumulative proportions were calculated instead (in a stepwise procedure: A1–B1, A1–C1, A1–C3, and A1–D1). Each cumulative proportion was then fitted separately and the final proportion of the respective assortment was obtained by calculating the difference between two respective regression functions.

To test whether the models have a potential to be applied to a neighbouring country the data collected in the forests of Czech Republic during a special study

(Adolt and Zapadlo 2010) were used as an independent empirical material. In total, 748 spruce and 773 beech trees were used for the study. Each stem, after cutting, was assorted into the six assortments. For this case study, the assortments were aggregated into three groups: 1 (A1 + B1), 2 (C1, C2, C3, C4 and C5), and 3 (D). Dbh, height, stem quality class and stem damage occurrence were measured and recorded for each tree. Although the stem quality class assessment on standing trees has the same meaning and purpose, there are slight differences in criteria used between Slovak and Czech methodology (see also the methodological guide of Adolt and Zapadlo (2010) used in Czech Republic case). However, we considered them to be the same for this case study as they both have the same range and apply the same principles. These parameters were then used to estimate the proportion of assortments for each tree using the Slovakian regression models. The proportions were then converted to volume. Finally, the measured and estimated assortment volumes were compared.

Total bias was calculated as the sum of absolute differences between measured and modelled volumes in the particular assortment (e.g. veneer category). Then the relative bias was calculated so that the total bias was divided by total volume sum in the respective assortment category.

The total relative bias, when measured and modelled values were compared, was found to depend on assortment classes and species (Table 4.3). In the case of beech, the lowest bias was found for the group including pulpwood and firewood (−6.2 %, 773 stem sections were classified in this category), while the largest one for veneer assortments (app. 164 %, only 31 stem sections classified in the category). The bias for roundwood was −8.8 % (351 stem sections). For spruce, the bias for veneer was even larger and reached 226 % (only 15 stem sections classified in the category), for roundwood −9.9 % (including 528 stem sections) and for firewood and pulpwood 18.5 % (746 stem sections).

The case study tested a potential way (one of several others) to produce harmonised estimates of timber assortments. However, the present status of European NFIs does not allow for developing a general way towards harmonisation of

Table 4.3 "Goodness-of-fit" of the Slovakian regression model applied to assortment data from Czech Republic

Species	Assortment group	Total bias (m3)	Relative bias (%)	MSE (%)	MSE (m3)	N
Beech	Veneer	54.6	163.6	9.1	33.4	31
	Roundwood	−35.2	−8.8	17.3	398.7	351
	Pulpwood, firewood	−19.4	−6.2	15.6	316	773
Spruce	Veneer	23.2	225.9	5.7	10.3	15
	Roundwood	−38	−9.9	24.4	384.5	528
	Pulpwood, firewood	14.9	18.5	24.9	80.2	746

Note: *MSE* Mean squared error, *N* Total number of assortments (logs) produced from cut trees assortment estimations (Bosela et al. 2015). This is because only few NFIs go beyond stem quality assessment and, in addition, because different grading standards are used across Europe. This study showed a potential of adopting a model for assortments estimation from a neighbouring country. However, only few such models exist in Europe, thus this will certainly not be the way to develop bridging functions at European level.

4.6 Evaluation of the Recent Harmonisation and Future Work

The main role of ENFIN (2014) and thus, of COST Action E43 (2010) and COST Action Usewood (2014) was the establishment of a scientific knowledge sharing network on NFIs. This network worked on the harmonisation in terms of definitions, NFI methods, collection of data, and statistical methods. The focus of this work was on harmonisation and not on standardisation as defined by Köhl et al. (2000), as the latter is not a realistic option (McRoberts et al. 2012). Nevertheless, the side effects of these exchanges over the years were to (i) adopt closer approaches through replacing some national definitions by commonly agreed reference definitions, (ii) implement new methodologies of NFIs, thus being more in line with the general approaches and (iii) estimate several variables by using reference definitions and common methodologies.

The advantage of harmonisation, compared to standardisation, is to give NFIs tools that are more flexible, something that is highly relevant when serving all the numerous information needs. Harmonisation also allows parties to maintain their national data collection protocols and consistency of their sometimes very long time-series according to national definitions. This is important since many users of NFI data use the information at a national level and benefit from being able to use information according to 'well-known' definitions, which were developed in accordance with national information needs. Many international processes demand information on forest but the definitions of different processes may vary or even change over time as for example the Growing Stock definition between 2000 and 2005 (FAO 2000a, b, 2004). Thus, there will always be a need to harmonise information coming from "support variables" so that the requirements under different agreements are fulfilled. Still, the application of standardised protocols for the acquisition of such support variables often used in international definitions simplifies the establishment of bridging functions. Thus, inventories that concentrate on the provision of high quality support variables directly are well placed TOF report according to many different needs (Ståhl et al. 2011).

The possibilities for standardisation are restricted by the wide variability of ecological and forest conditions and their political impact. For example, the minimal crown cover for the definition of forests is dependent on ecological circumstances relevant for the growth of trees. In hot and dry regions exhaustive roots systems are necessary for sufficient water supply. Possible tree densities are by far lower than in regions with high water supply. Therefore, the minimum crown cover in such dry regions is often defined by low threshold values and these ecological conditions are mirrored in national forest policy. Thus, standardisation over large areas (e.g. all of Europe) is likely to fail.

Increased collaboration among countries offers possibilities for scientific knowledge sharing and development of adequate bridging functions. In Europe, the ENFIN network provides such opportunities (ENFIN 2014). At the international scale UNECE and FAO are likely to continue to be drivers towards harmonised forest statistics through the periodic Forest Resources Assessment exercises conducted (FAO 1998, 2000a, b, 2012 and UNECE 2000).

Even if it is a difficult exercise to harmonise data, the knowledge sharing is an important step towards common approaches.

When expansive bridges are developed based on case studies or existing information from similar regions in other countries, it is important that potential sources of bias should be carefully evaluated. If case studies are conducted these could be directed to the specific areas from which data are needed. Careful selection and application protocols need to be applied so that potential selection bias does not incur bias in the resulting estimates (Gregoire and Valentine 2008).

While this chapter has focused on the development of bridging functions for applications using forest data and information, the bridging function approach should be applicable to other requirements for harmonised statistics.

Bridging functions can be applied at different levels due to the nested sampling strategies and the hierarchical estimation process. It starts from the single tree level, and finally ends up at the highest aggregation level, i.e., the general adaption of the national estimate (Ståhl et al. 2012). In many cases, especially when simple reductive bridges are applied, it is straightforward to apply the bridging function at the level of individual sampling units and then aggregate these units in order to obtain an estimate according to the reference definition. This is not only straightforward when reductive bridges are applied, but also for expansive bridges in cases where auxiliary data is available from all potential units to be included under the reference definition. For categorical data, logistic regression functions can be applied in order to obtain probability estimates. For continuous data ordinary regression techniques (Yu and Ranneby 2007) can be applied to predict values at the level of sampling units. Imputation techniques (Tomppo and Halme 2004) may also be applied to both types of data.

In case auxiliary data at the level of sampling units are not available the bridging function generally would imply to apply a conversion factor or function to the aggregated estimate according to the national definition. Thus, depending on what data are available the bridging functions are applied at different levels. In general bridges applied at a low level (e.g. sampling units) would result in higher accuracy, although this cannot be taken as a rule.

The quality of an estimate derived using a bridging function depends on many different factors, including what bridging scheme was applied. In the case of reductive bridges, estimation of variances in general should be straightforward as standard procedures should be possible to apply. In this case the application of a bridging function is not likely to deteriorate the accuracy of the estimate. However, in some cases different results have been obtained when direct assessments of categorical variables have been made as compared to using support variables for their derivation (Gregoire and Valentine 2008). With neutral bridges, often the only difference would be that new allometric functions are applied upon existing data. Provided that these functions are properly developed, there is no reason why the accuracy of estimates should be lower than in the estimate according to the national definition. But whenever models are applied to derive variables both sampling and model errors ideally should be accounted for in the estimation of variances (Ståhl et al. 2014; Berger et al. 2014).

However, when expansive bridges are applied it is likely that the accuracy of estimates will decrease. This is due to the fact that in general rather coarse model relationships or direct conversion factors need to be applied. In such cases, stratified approaches to the variance estimation can be applied where one stratum is composed of the portion of sampling units where target data are directly available; the other units are put in the second stratum. For the latter, approximate variance estimation methods may be available; e.g., this is the case when imputation techniques are applied (Tomppo and Halme 2004).

To sum up, for future work on harmonisation based on the idea of bridging functions:

- NFIs should try to include assessments into their protocol, which enable the derivation of high quality bridging possibilities.
- NFIs should concentrate on the lower aggregation levels when establishing bridges.
- A sound statistical framework and formulation of the estimation process which includes different types of bridges for the harmonisation should be developed as a basis for quality assessment.

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Chapter 5
Wood Resources Assessment beyond Europe

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5.1 Introduction

Forest ecosystems provide wood and many other services that contribute significantly to human well-being at local, national, and global scales. These contributions include the conservation of soil and water resources, mitigation of the effects of global climate change, conservation of biological diversity, improvement of urban living conditions, protection of natural and cultural heritage, subsistence resources for many rural and indigenous communities, generation of employment, as well as

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recreational opportunities (MEA 2005). Due to the importance of forests for humanity, the evolution of the world's forest functions and services, are a major concern in international agreements and processes that address environmental and development issues such as the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), the United Nations Forum on Forests (UNFF), or, the Sustainable Development Goals (SDGs).

Because woody biomass is an important renewable energy source and plays a decisive role in mitigating the effects of climate change, the issue of the availability of wood is emerging as a relevant post-Kyoto decision (COST Action Usewood 2014). Accordingly, from national to global scales, production of better information on the quantities of wood available has turned out to be of importance for assessing sustainable management decisions in forestry policy-making. Additionally, the majority of these agreements require substantial amounts of harmonised, comparable and accurate information from the parties to assess overall progress, compliance with obligations, as well as to determine the next steps of the agreements (Vidal et al. 2008; Ståhl et al. 2012).

For these and other national and international agreements that focus on sustainable environmental and forestry strategies, monitoring of forest resources has become critical for countries (Holmgren and Persson 2003; FAO 2014). The most important sources of forest data are NFIs. They have been established in many countries and provide accurate and representative information on forest attributes obtained mainly from field measurements but also from remote sensing (Cienciala et al. 2008; Tomppo et al. 2010; FAO 2014). The importance of field-based NFI has long been demonstrated through forest resource assessment (FRA) reporting, both through the value of reported inventory results and the identification of serious data gaps in countries where these inventories do not yet exist (McDicken 2015). In fact, the latest global FRA reports that forest resource data are currently generated at a greater frequency than any other time in history. Although much of the necessary information at country level is lacking in the tropics and in low-income countries, particularly in Africa, approximately 77 % of the world's forest area is currently covered by NFIs (FAO 2015). Consequently, as result of the important investment by governments in recent years to better understand forest resources, the level of availability and reliability of forest information at the global scale is greater than in previous periods (FAO 2001; Saket 2002).

The monitoring of forest resources has a long history (FAO 2014), where different approaches have been implemented for data collection during the last centuries. However, systematic forest assessments based on statistical sampling methods began in the early twentieth century (McRoberts et al. 2010). As Fig. 5.1 shows, the earliest NFIs were established at the beginning of the twentieth century in the European Nordic countries including Norway, Sweden or Finland as well as in the United States of America. Since then, new NFIs have been gradually established around the world, particularly in many European countries after World War II and in the 1960s (e.g. Germany, Austria, France, Spain or Portugal). The significant increase in NFIs developed since 2000 can be attributed to the important demand for forest information for international reporting requirements as a follow up of the 1992 Earth Rio Summit (e.g. Brazil, Canada, Great Britain, etc.). The noteworthy increment of NFIs during the last decade is also partly due to support from the National Forest Monitoring and Assessment (NFMA) programme of the United Nations Food and Agriculture Organization (FAO) carried out in a growing number of countries since 2000 (Saket et al. 2010). What started as a series of pilot projects has now developed into full scale NFIs in eighteen countries such as Brazil, Peru or Ecuador (see the corresponding country reports in this book for more detailed information), while another seventieth countries are expected to complete their firsts NFIs in the next two years (FAO 2016). Although today most countries conduct sample-based inventories, traditionally, national forest information was gathered by aggregating data from stand level inventories designed for management planning objectives (Tomppo et al. 2010; Fig. 5.1). Until recently, these systems

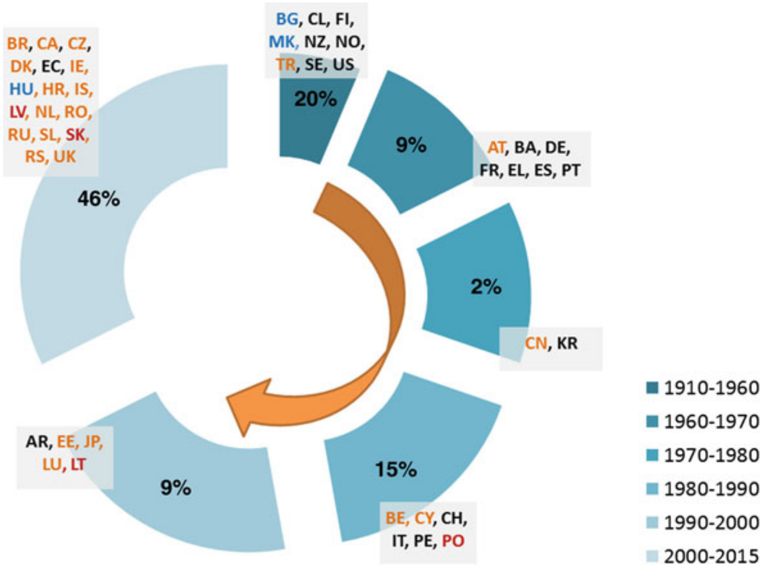

Fig. 5.1 Chronology describing the introduction of national forest surveys globally. (Note: taking into account the 46 participating countries in COST Actions E43 and Usewood, the percentage figures on the graphic detail the proportion of countries introducing forest surveys in the stated time period). The country abbreviations are located in the period where the NFI were first implemented, if that is the case. Countries with abbreviation in *black* represent those countries with NFI. Countries with abbreviation in *orange* represent those countries with previous FMPs that now have implemented a NFI. Countries with abbreviation in *red* have both FMPs and NFI ongoing. Countries with abbreviation in *blue* represent those countries with present FMPs. Countries abbreviations are the followings: *AT* Austria, *AR* Argentina, *BR* Brazil, *BE* Belgium, *BA* Bosnia- Herzegovina, *BG* Bulgaria, *BR* Brazil, *CA* Canada, *CN* China, *CL* Chile, *HR* Croatia, *CY* Cyprus, *CZ* Czech Republic, *DK* Denmark, *EC* Ecuador, *EE* Estonia, *FI* Finland, *FR* France, *DE* Germany, *EL* Greece, *HU* Hungary, *IS* Iceland, *IE* Ireland, *IT* Italy, *JP* Japan, *LV* Latvia, *LU* Luxemburg, *LT* Lithuania, *NL* Netherlands, *MK* Macedonia, *NZ* New Zealand, *NO* Norway, *PE* Peru, *PO* Poland, *PT* Portugal, *KR* Republic of Korea, *RO* Romania, *RS* Serbia, *RU* Russia, *SI* Slovenia, *SK* Slovak Republic, *ES* Spain, *SE* Sweden, *CH* Switzerland, *TK* Turkey, *UK* United Kingdom, *US* United States

based on Forest Management Plans (FMP) were particularly characteristic of Eastern European countries, but now some of these countries have also introduced statistical NFIs running in tandem with the FMP surveys, for example, Lithuania and Slovakia. Furthermore, in recent years NFIs have incorporated novel technological improvements in the form of remotely sensed data for increasing speed and cost/efficiency (McRoberts et al. 2002; McRoberts and Tomppo 2007). Although remotely sensed data cannot completely replace ground sample data (McRoberts et al. 2010), among other qualities, they can facilitate construction of accurate maps of forest attributes as well as access to the forest information in remote regions.

Similarly, the information recorded in the NFIs has evolved since the beginning of forest monitoring. Traditionally, NFIs focused on the productive capacity of forests because no other forest benefits or uses were considered (Holmgren and Persson 2003). Assessing growing stock, increment of stem-wood, wood supply and biomass of living trees were the main goals at that time. However, with the increasing concern for global deforestation (Lanly 1982; FAO 1995), the impacts of climate change (IPCC 2007) and the recognition of the importance of forests as biodiversity reservoirs (CBD 2009) and carbon stores (UNFCCC 2009), the scopes of NFIs have been enlarged and information for new variables such as deadwood, forest health, non-wood forests products and litter is now collected as well as their change assessed (Cienciala et al. 2008; Corona et al. 2011; Alberdi et al. 2014). Furthermore, forest information now includes more key aspects of sustainable forest management, comprising a three dimensional scheme of data collection: *resources* (the extent and state of the resources), *users* (who is using the resources) and *use* (how the resources are used and managed) (Morales et al. 2014).

In addition to the extensive, transparent and comprehensive data on forests required nowadays for reporting under international agreements, comparability of the submitted inventory estimates is yet to be achieved (McRoberts et al. 2010). Lack of comparability is a consequence of the diversity of the NFI definitions, sampling designs, plot configurations, measured variables and measurement protocols. The harmonisation process focuses on definitions, estimates, and comparisons among countries as a means of facilitating international reporting processes. Harmonisation has received increased attention in recent years by international institutions such as the Intergovernmental Panel on Climate Change (IPCC) and the NFMA program conducted by FAO (Saket et al. 2010). However, the most important efforts directed toward harmonisation of NFI estimates and definitions has been conducted by the European National Forest Inventory Network (ENFIN) in the framework of COST Actions E43 (Tomppo et al. 2010) and Usewood (Vidal et al. 2016). Although considerable progress has been made in developing methods to facilitate harmonisation of definitions and assessments (see e.g. Vidal et al. 2008), substantial work still remains in this field.

Chapters one to four described the harmonisation methodology developed by European COST member countries participating in the COST Actions E43 (2010) and Usewood (2014). The active participation of the US and other non-COST member countries in both COST Actions demonstrates a high level of interest in this harmonisation approach as a benchmark beyond Europe. Twelve NFIs from non-COST member countries contributed to this book in providing a country report, including: Argentina, Brazil, Canada, Chile, China, Ecuador, Japan, New Zealand, Peru, Russia, South Korea and the US. This chapter summarises the diversity of sampling methods, definitions and wood resource assessments (focused on forest available for wood supply, stem quality, change estimation and other wooded land and trees outside forest) of these countries. The differences and similarities among these and the European COST member countries are discussed. Because the countries contributing to this book account for almost 70 % of global forest area (FAO 2015), the analyses provide a global overview of the current state of the potential harmonised assessment of wood availability and use.

5.2 Diversity of Main Features of NFIs from Non-COST Member Countries

As expected, the great diversity of biomes, ranging from tropical to boreal, and corresponding forest attributes characterising the countries analysed, has led to substantially varying sampling designs and plot configurations (Table 5.1). However, a significant increase in the uniformity of fundamental NFI features such as statistical sampling designs and permanent NFI networks has been observed (FAO 2001; Tomppo et al. 2010). In fact, any of the countries analysed still relies on the aggregation of stand management inventories information as the source for national forest information. Probability sampling techniques facilitate estimation of sampling errors (Lawrence et al. 2010) and will further improve accuracy and reliability of data and information on forest resources from national to global scales. Regarding continuity of NFIs, nine of the analysed countries use permanent sample plots while three (Argentina, Ecuador and Brazil) which are currently developing their first cycles also expect to do so. Continuous monitoring inventories allow countries for assessing forest resources and cover changes over time as well as for addressing international information required by processes such as UNFCCC and Reducing Emissions from Deforestation and Forest Degradation (REDD+). Inventory cycles are typically either 5 or 10 years, although the Chilean National Forest Ecosystems Inventory (NFEI) uses a 4-year cycle (Table 5.1). In addition, Chile and Peru use annual inventories for which 20–25 % of plots are measured each year. This design is very suitable for reporting annual forest changes as required by some international commitments.

Most NFI sampling designs include systematic components based on two-dimensional grids. However, due to the high diversity of forest covers, bio-geographical regions or administrative provinces comprised (e.g. China), the grid spacing may vary from 1 × 1 km to 50 × 50 km, even in the same country (see Table 5.1). Half of the countries use cluster sampling in which multiple plots (from 3 to 8) are established in close spatial proximity. Contrary to European NFIs (Lawrence et al. 2010) where concentric circular plots are more common, half of the

Table 5.1 Features of sampling based designs used by NFIs from non-COST member countries

Country	Spacing grid/cluster (km)	Strata criteria	Number of field plots per cluster	Type of plots	Plot criteria	Permanent plots/proportion of plots	Last NFI cycle	Current/future cycle	Cycle periodicity
Argentina	10/20/50/18	Phytogeogra-phical regions	3/5/8	Circular/Rectangular	Phytogeogra-phical regions	?	1998–2005	?	?
Brazil	20 × 20	–	4	Rectangular	–	?	–	2012–2018	5
Canada	20 × 20 to 40 × 40	Terrestrial ecozones	1	Square	–	1	2000–2006	2008–2017	10
Chile	5 × 7	–	3	Circular	–	1/4	–	2015–	4
China	1 × 2 to 8 × 8	Provinces	1	Square, rectangular and circular	Provinces	1	2009–2013	2014–2018	5
Ecuador	1 × 1	Forest type	3	Square, rectangular	Forest type	–	2009–2013	2016–2019	?
Japan	4 × 4	–	1	Circular	–	1	2009–2013	2014–	5
New Zealand	4 × 4 to 8 × 8	Forest type	1	Circular	–	1	2002–2007	2009–2014	10
Peru	8 × 8 to 34 × 34	Regions	1	Different shapes	Regions	1/5	–	2014–	5
Russia	–	Forests strata	3	Circular	–	1	–	2007–	?
South Korea	4 × 4	–	4	Circular	–	1	1996–2005	2006–	10
US	2400 ha systematic hexagonal tessellation	–	4	Circular	–	1	2009–2013	2014–2018	5

?It is expected but still without specifying

–No associated information reported in the Country report countries use a mixture of square and rectangular plots as well as transects depending upon the forest type (e.g. mountain or lowland tropical forest) and the variables measured (deadwood, litter, etc.). Accordingly, the forest area represented by each type of plot is variable. Additionally, because of the greater expenses associated with measuring field plots in remote and inaccessible forests, some countries such as Canada based part of their NFIs on aerial photographs.

Some of the analysed countries (Ecuador, Brazil, Peru) represent novel or emerging NFIs which have designed their NFIs to support national policy and decision making as well as to facilitate reporting to international conventions and processes such as the UNFCCC and Kyoto reporting. Thus, NFIs in these countries include methods for collecting data for reporting carbon stored in the different carbon pools. Furthermore, most of these emerging NFIs used remote sensing in combination with field data to improve estimates of the extent of forest, land uses, area cover change and to support the preliminary stratification process (McRoberts et al. 2010).

Finally, an important divergence found among the NFIs analysed in this chapter is that in some countries such as Argentina, different inventories are used for native and productive forests. This aspect may have important implications for attempts to assess the forest available for wood supply at national scale.

5.3 Analysis of National Definitions, Monitoring and Assessment from Non-COST Member Countries

Based on the raw information provided by the questionnaires and country reports for countries participating in the COST Action Usewood regarding Forest Available for Wood Supply (FAWS), quality of wood, increment, fellings, and mortality, Other Wooded Land (OWL) and Trees Outside Forest (TOF), WG1 formulates recommendations for statistical sound data collection and wood resource estimation. For this purpose, understanding the differences among the definitions and assessments used by NFIs at national levels is essential for development of reference definitions.

As Table 5.2 shows, the majority of countries analysed in this chapter neither have a FAWS national definition nor use the definition proposed by SoEF (FOREST EUROPE, UNECE and FAO 2011). Only Japan and New Zealand have national definitions (see Table 5.3), while in Canada there are different definitions at provincial administrative levels associated with different legal restrictions. Although most of the countries do not supply information corresponding to their FAWS national definitions and estimates, their FAWS definition is closer to "productive forest" interpretations discussed in Chap. 2. Furthermore, based on the related information available from geographical information systems (protected areas/ownership maps) or NFI field plots (e.g. distance to the road in Japan NFI), five countries could assess FAWS based on national/international definitions

(Table 5.2). In addition, the majority of countries associated, in one way or another, FAWS with the three main groups of restrictions (Environmental, economic and social) accounted in the proposed reference definition recommended by Alberdi et al. (2016).

However, these countries have such diverse forest management systems and unique forest conditions that setting thresholds for the restrictions considered in a FAWS definition is challenging (Fischer et al. 2016). Examples include the different tree or stand characteristics that regulate commercial logging or sustainable forest management such as age classes in Japan, tree diameters in Brazil, or harvesting intensity in Ecuador.

Table 5.2 Summary of NFI features from the non-COST member countries for purpose of defining and estimating FAWS

Country	FAWS		Restriction considered (Alberdi et al. 2016)		
	National (N)/ International (I) definition	Potential estimation	Environmental	Economic	Social
Argentina	–	–	–	–	–
Brazil	–	–	–	–	–
Canada[a]	?	–	x	x	x
Chile	–	–	x	x	x
China	–	–	x	x	x
Ecuador	–	x	x	x	x
Japan	N	x	x	x	x
New Zealand	N	x	–	x	–
Peru	–	x	x	x	x
Russia	–	–	–	–	–
South Korea	–	–	–	–	–
US	–	x	x	x	x

[a]Reported at provincial and regional level considering specific restrictions. Different definitions between state boundaries

–No associated information reported in the Country report

Table 5.3 National definitions of FAWS from the non-COST member countries

Japan	The forest available for wood supply can be considered as those forests which have reached cutting age and do not have any legal regulation
New Zealand	All areas included in the annual National Exotic Forest Description (NEFD) survey is productive forest planted for the purpose of timber harvesting and can be assumed to be technically and legally available

Regarding wood quality estimates, Table 5.4 shows that most of the countries record some specific stem quality variables such as dead/live state, health status (with biotic/abiotic damages), top diameter, minimum commercial diameter or height, stem curvature and forking. Only five countries assess quality classes in the field for the later quantification of assortments. Most of the analysed NFIs assess a large number of timber quality variables that could be used for developing a harmonised timber quality classification. However, they often apply different thresholds due to the uniqueness of their forests and their associated forest management procedures and industries. Consequently, although there is potential for developing harmonised estimation based on the common assessment of specific variables, considerable effort will be needed before the harmonised stem quality estimation can be realised (Bosela et al. 2015).

Forest change estimation is usually based on permanent plot field measurements at two consecutive points in time. In this regard, more than 70 % of NFIs used permanent sampling plots to estimate changes, while three other (Argentina, Peru and Canada, see Table 5.1) are not yet able to report statistical estimates of change because the first measurement cycle has yet to be completed. For permanent plots, the definitions of increment and drain rely on the distinguishing and grouping sample trees into change components such as survivor, ingrowth, ongrowth, removals and natural losses. However, only four of the analysed countries clearly specified their national definitions for increment or drain: China, New Zealand, US and Chile (see Table 5.5). For other cases, the change components vary depending on the sample tree selection method, management and unique commercial aspects of the country (see e.g. China). Compared with the two basic strategies used by European NFIs to estimate increment and drain (see Chap. 2), New Zealand, US and Chile seem to be closer to the least conservative of the two whereby components such as mortality trees, cuttings or ongrowth trees are taken into account.

Table 5.4 Summary of NFIs features from the non-COST member countries with respect to wood quality assessment

Country	Stem quality parameters	Classification system	Assortment estimation
Argentina	–	–	–
Brazil	x	–	–
Canada	x	–	–
Chile	x	–	–
China	x	x	–
Ecuador	x	–	–
Japan	x	–	–
New Zealand	x	x	–
Peru	x	x	–
Russia	x	x	–
South Korea	x	–	–
US	x	–	–

–No associated information reported in the Country report

Table 5.5 National definitions of increment and drain from the non-COST member countries

Country	National definition of increment and drain
China	The increment estimated by the China's NFI is defined as the volume increment of survivor trees between two field assessment periods plus the volume of ingrowth trees that exceed the dbh-threshold of 5.0 cm between the two points in time The drain estimated by the China's NFI is defined as the volume of trees that were found to be harvested between two field assessment periods
Chile	The increment is defined as the volume of trees with dbh >8 cm over bark taken by bore extraction Drain is defined as the sum of cutting removals, household fuelwood consumption, natural losses and waste estimation
New Zealand	The drain estimates include natural mortality, thinning, pruning and the subsequent decay of deadwood and litter
US	The net annual growth of growing stock is the average annual net change in wood volume of trees with dbh ≥12.7 cm excluding losses from cutting (gross growth minus mortality) during the inter-survey period plus the total volume of trees entering in the diameter classes with dbh ≥12.7 cm through ingrowth minus the volume losses from natural causes The net annual removals of growing stock is the annual average wood volume of trees ≥12.7 cm dbh removed from the inventory by harvesting, cultural operations (such as timber-stand improvement), land clearing, or changes in land use during the inter-survey period, in addition to the volume in logging residues or mortality due to logging damage (harvest removals). This component of change also includes the volumes of growing-stock trees removed due to land use changes (other removals)

Finally, within the framework of international environmental commitments, it is increasingly important to be aware of tree resources for all land uses as well as forests such as OWL and areas with TOF. FAO (2012) defines OWL as "land with a canopy cover of 5–10 % of trees able to reach a height of 5 m in situ; or a canopy cover of more than 10 % when smaller trees, shrubs and bushes are included" while TOF "are trees and tree environments on land not defined as forest or other wooded land". Table 5.6 shows that five of the seven countries considering OWL as a land use classification meet the FAO (2012) definition, while two (Argentina and New Zealand) do not meet the threshold regarding canopy cover. However, while all the countries apply thresholds associated with area size, tree cover and height, only three apply width and one applies diameter at breast height (dbh). The absence of these two last components is a challenge for the harmonised and straightforward definition of OWL (see Chap. 3). Furthermore, three of the NFIs account for shrubs, trees or the combination in their definition of OWL, while one accounts for grassland with scarce biomass. No analysed country classified land with TOF or assessed its wood resources.

Although seven of the twelve countries can classify land as OWL, few are currently able to assess wood resources by field or other measurements in their NFIs. Most of the NFIs conduct their monitoring exclusively on lands with tree or

Table 5.6 Summary of the national thresholds and features applied for OWL national definition, FRA definition application and current or potential wood resources estimation by assessment if possible for consistency in the table from the non-COST member countries

Country	OWL							
	Area (ha)	Width (m)	Tree cover (%)	Tree height (m)	Tree dbh (cm)	Other attributes	FRA definition	Current (C)/ potential (P) assessment
Argentina	<10	–	<20	<7	–	–	–	–
Brazil	<0.5	–	<10	–	–	Shrubs	x	–
Canada	–	–	5–10	<5	–	Trees/Shrubs	x	–
Chile	–	–	–	–	–	–	–	–
China	–	–	5–10	<5	<50	Trees/Shrubs	x	C
Ecuador	–	–	–	–	–	–	–	–
Japan	–	–	–	–	–	–	–	–
New Zealand	<1	<30	<30	<5	–	Grassland with tree biomass	–	C
Peru[a]	<0.5	<20	<10	<2/5[a]	–	–	x	–
Russia	–	–	–	–	–	–	–	–
South Korea	<0.5	<20	<10	<5	–	–	x	–
US[b]	–	–	–	–	–	–	–	–

[a]The predominant vegetation is represented by woody trees with a minimum height of 2 m in its adult stage in the Costa and Sierra, and 5 m for the Amazon Forest

[b]The land use classes, OWL and land with TOF are not used in the US and are not assessed separately from other lands with tree cover. The class closest to OWL and land with TOF is Woodland which is defined as land with trees whose cover is in the range 5–10 %

–No associated information reported in the Country report

shrub cover defined or classified as forest. This constraint limits the assessment of wood resources for OWL and also for areas with TOF.

5.4 Towards a Global Assessment of Forest Resources

In 2000, FAO (2001) reported that few forest inventories provided basic and up-to-date forest data as required for national or international policy. At that time, few NFIs had repeated cycles, and many countries had only partial or no forest survey. This report highlighted the lack of national forest surveys, particularly in developing countries. However, today major improvements can be seen in forest inventory capacities at the global scale (FAO 2015). There have been important increases in the number of countries that have initiated or currently maintain institutionalised forest inventory systems. For example, the total tropical forest area that is monitored with good to very good forest inventory capacities increased from

38 % (785 million ha) in 2005 to 66 % (1350 million ha) in 2015 (Romjin et al. 2015). Moreover, as this chapter show, most of the NFIs now rely on statistical sampling designs and have permanent plot networks. As a result of concern for issues such as acidification, biodiversity, climate change and forest sustainability, data for new variables are acquired with the resulting enrichment of forest survey data. Additionally, technological advances, particularly the widespread availability of remotely sensed data, have led to greater inventory efficiencies (McRoberts et al. 2010; Barrett et al. 2016). The combination of all these enhancements will further improve the accuracy and reliability of data and information on forest resources at the global scale. And, what's more, it will provide opportunities for all countries to participate in the global forest dialogue (Saket et al. 2010) where policies and decisions making in forest management are defined.

These international requirements and processes have promoted the concepts of open data and transparency (experiences, definitions and methodologies sharing). As some of the results of this book show, these raw data are necessary to construct robust reference definitions which are needed as the first step in the harmonisation process proposed by Vidal et al. (2008). For purposes of harmonised estimation of wood availability and use, new reference definitions for forest available for wood supply (Alberdi et al. 2016), wood quality (Bosela et al. 2015), changes (Gschwantner et al. 2016), OWL and TOF (Vidal et al. 2016) have been proposed in Chap. 3. These definitions were based on data obtained from country reports and questionnaires as well as from collaborative work in COST Action Usewood. Chapter 4 presents examples of bridges between the national and the reference definitions constructed for the harmonised estimation of wood availability and use. However, the diversity of specific national parameters and thresholds that characterise forest management systems and the unique forest conditions for the participating countries means that considerable efforts will be necessary before the harmonised estimations of the target attributes can be realised.

Although much remains to be done, we are closer than ever to obtain harmonised estimation of global wood resources. These improvements are the result of capacity building programs such as those by FAO-FRA and NFMA, ENFIN, COST Actions E43 and Usewood initiatives and the very large investment by governments to meet international forest report requirements (FAO 2015). These results support the importance of multilateral cooperation, international partnerships, and experience sharing.

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Part I
National Forest Inventories Reports

Chapter 6
Argentina

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6.1 The National Forest Inventory of Native Forests in Argentina

6.1.1 History and Objectives

Located at the southern tip of South America, Argentina is a Federal Republic consisting of 23 provinces and one federal district, with a population of 40 million people and covering an area of 3.76 million km^2. At world level, Argentina is the eighth largest country in the world, with a maximum length from north to south of 3694 km and from east to west of 1423 km. Due to the geographic location, geology and topography, Argentina has different native forest types: ranging from the subtropical forests in the northern latitudes to the sub-antarctic forests in southern latitudes. The total native forest area is about 300000 km^2.

Between 1776 and 1822 policy was formulated relating to the exploitation of forests in the vicinity of the Ciudad de Buenos Aires. The object of the Council, at this time, was the protection of the common areas belonging to the colonies. It had two major objectives: (a) the provision of firewood and charcoal at fair prices, and (b) to prevent the unsustainable cutting of those forests. However, between 1820 and 1830, the vision changed towards the economic contribution that forests could make.

In 1880, a national law was enacted (N° 1054), becoming the first comprehensive and detailed regulation about several aspects of forest in the country. But in 1903 this law was replaced by the national law No. 4167, which only had two items relating to forests. Therefore, the importance of forests in national legislation was reduced.

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The Forest Technical Section (*Sección Técnica Forestal*) was created in 1932, within the structure of the Ministry of Agriculture. The national law No. 13273 was enacted in 1948, which created a unique national forestry agency with the name of National Forestry Administration. This law assigned a budget for the execution of the first Argentine forest map and can be considered the first policy step towards a national forest inventory. However, the map was never produced.

In 1973 the National Forest Institute (*Instituto Forestal Nacional*, IFONA) was created as the sole technical unit to manage the national forests. During the 1980s IFONA defined forest types and productivity classes of native forests in Argentina. This set of maps, named the "*Pre Carta Forestal*", was considered as the first step toward a complete cartography of the country. The maps were obtained from the visual analysis of satellite images data (MSS—LANDSAT) with the support of field checks. Then, the World Bank and the Inter-American Development Bank financed IFONA to design the first national forest inventory. International experts were invited to cooperate with the basic guidelines of the forest inventory and several proposals were made. Although the technical and financial aspects were approved, the project was not implemented due to institutional problems. In 1991 IFONA was dissolved and its tasks were distributed among three institutions: (1) the current Ministry of Agriculture, Livestock and Fisheries, in charge of plantation forests; (2) the current Secretariat of Environment and Sustainable Development (SADS) in charge of native forests; and (3) the National Agricultural Technology Institute in charge of the research.

6.1.2 Sampling Methods and Periodicity

In early 1990, the need of carry out a NFI in Argentina was reaffirmed due to information needs and for decision making related with national forest policy. The SADS considered the need to begin the NFI of native forests and in 1995, the first tasks associated with the planning of the national forest inventory began. The forest inventories information carried out in Argentina came from regional and provincial forest inventories. Table 6.1 shows the most important forest inventories.

As seen from Table 6.1, the data were collected using regionally different methodologies. The absence of a national forest inventory using a standardised methodology and a number of provincial or regional forest inventories are responsible for a limited knowledge about the quantitative composition and the structure of the native forest in Argentina. Moreover, this limited information constituted an obstacle for the development of forest policies. To improve this situation the Argentine government decided to undertake the First National Native Forest Inventory, called "*Primer Inventario Nacional de Bosque Nativo*" (PINBN), financed by the World Bank in 1996, with a view to:

Table 6.1 List of local forest inventories

Forest Inventory	Region	Design	Mapping
Plan Noa II (1970–1975)	Provinces of Salta, Tucumán, Jujuy and Santiago del Estero	Stratified with systematic sampling ordered on a grid of 4 × 10 km. The sampling unit was a cluster with 8 circular plots	Visual interpretation Aerial photographs Scale from 1:35,000 to 1:80,000
Provincia de Santiago Del Estero (1994)	Territorial divisions of Copo and Alberdi (north of the province)	Stratified with systematic sampling ordered on a grid of 4 × 10 km. The sampling unit was a cluster with 9 circular plots	Satellite processing Images: Landsat-TM. Scale: 1:400.000
Provincia de Tucumán (1995)	Subtropical western forest of the province	Stratified with systematic sampling ordered on a grid of 4 × 10 km. The sampling unit was a cluster with 8 circular plots	Satellite processing Images Landsat-TM Maps. Scale: 1:135.000
Provincia De Formosa (1996)	Included private property and its objective was the development of a forest management plan	Systematic sampling on a square grid of 500 × 500 m per side. The sampling unit was a rectangular plot with 50 m long and 10 m wide	Satellite processing Images Landsat-TM Maps Scale: 1:250.000
Provincia De Tierra Del Fuego (1998)	Whole Province of Tierra del Fuego	Systematic sampling on a square grid of 7.5 × 7.5 km. The sampling unit was a cluster with 4 circular plots	Satellite processing Images Landsat-TM Maps 1:750.000

– obtain basic information about native forest resources of the country for forest policy formulation
– create and maintain an updated database of these resources
– improve the operational capacity in the management and use of the database.

On February 6th of 1998, the SADS and the partnership of two Canadian companies: Simons Reid Collins and Tecsult International Limited, and an Argentine company, Aeroterra, signed a contract for consulting services for the execution of the first national inventory of native forests and the establishment of a national system of forest assessment. The three companies were identified as the Consultant. The project began in April 1998 and ended in 2007. In 2002 the Canadian companies left the project and from April 2004 Aeroterra continued with the work.

The constraints and responsibilities of the Consultant in all aspects of the technical service were defined in the Terms of Reference. These terms expressed that the methodology as a whole was an absolute responsibility of the Consultant. The SADS was the responsible for the project performed by the Consultant and the product deliverables. The following objectives were established for PINBN:

1. Provide appropriate information for the development of national forestry conservation and development policies
2. Determine the information needs at national level in relation to statistical issues and decision-making
3. Establish regional level extension, conservation status, risks and productive situation of native forests
4. Assist in planning the use of forest resources at the national level and to provide a general framework for planning at sub-national scales

The PINBN covered the native forest area included in Argentine territory. From the six phytogeography regions established in Argentina, six forest regions were named as: Selva Misionera, Selva Tucumano Boliviana, Parque Chaqueño, Región del Monte, Región del Espinal, and Bosque Andino Patagónico. Table 6.2 and Fig. 6.1 details the geographical location and boundaries of each forest region. Figure 6.1 shows a map with the location of the six defined Forest Regions and Fig. 6.2 shows the map of forest cover in Argentina.

The area corresponding with each forestry region was separated in two sub-areas: (1) native forest, and (2) non-native forest. Forest land was classified into

Table 6.2 Geographic location and boundaries of the Argentine forest regions

Forest region	Description of the geographic location and boundaries
Selva Misionera	Located in the Province of Misiones and a small portion of northeastern of the province of corrientes. It is bordered to the north and east by Brazil, on the south by Brazil and the province of corrientes, and on the west by Paraguay
Selva Tucumano Boliviana "Yungas"	The region is extended from the border with Bolivia until the north to the province of Catamarca; shows a discontinuous band in the provinces of Salta, Jujuy, Tucuman and Catamarca; its main characteristic is the altitudinal distribution of vegetation zones
Parque Chaqueño	It completely covers the province of Formosa, Chaco and Santiago del Estero, and partially the north of Santa Fe and San Luis, the east of Salta, Tucumán, Catamarca, San Juan, La Rioja and the north and west of the province of Córdoba
Monte	It covers the south of Salta, the center of Catamarca, La Rioja and San Juan; the east-central zone of Mendoza; a small strip located at the northwest of San Luis, the west of La Pampa, south of Buenos Aires, east of Neuquén; and north of Rio negro and north-east of Chubut
Espinal	Cover a strip going from the center-south of Corrientes, north and center of Entre Rios, center of Santa Fe; east, center and south of Córdoba; center and south of San Luis; and then go down to the east and center of La Pampa, concluding with a smaller surface involvement in the south of Buenos Aires
Bosque Andino patagónico	Narrow strip bordering the Andes Cordillera, and extended from the northern province of Neuquén to Tierra del Fuego at the southern end

Fig. 6.1 Map of the defined forest regions of Argentina

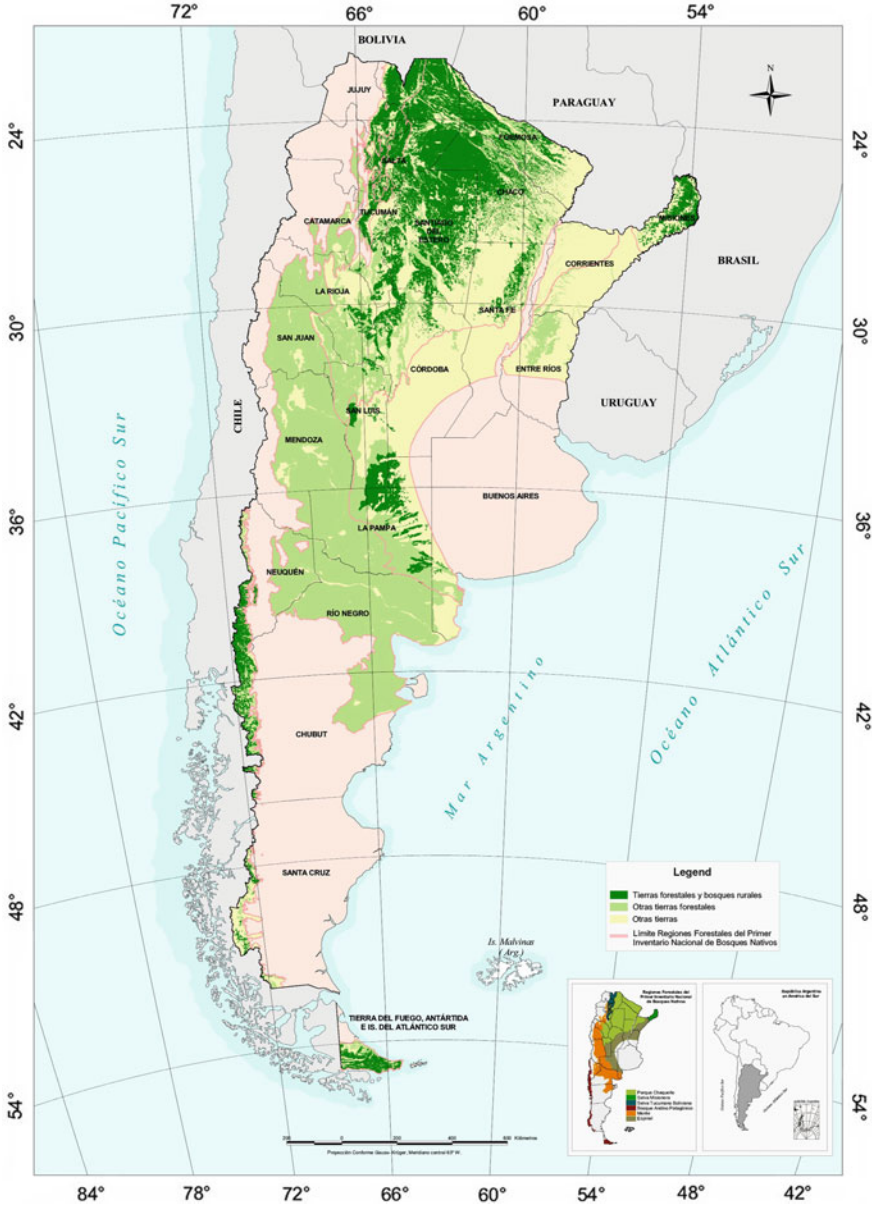

Fig. 6.2 Map of forest cover within the defined regions of Argentina

three hierarchical levels where the higher number represented a greater level of detail. Level 1 corresponds to the broadest scale and is represented by each of the six defined forest regions; so there are six level 1 regions. In each forest region of Level 1 forest lands were classified and separated into more homogeneous zones, and each of these subdivided zones correspond with an area of Level 2. This sub-classification was based on species composition and topographic aspects. Table 6.3 details the Level 1 and Level 2 land classification.

6.1.2.1 Remote Sensing

Remote Sensing was used to define and identify native forest strata and the corresponding classes of land use. These activities were performed for each particular region at Level 1 and Level 2 with the following main steps:

- Selection of satellite images
- Georeferencing
- Preliminary stratification
- Final stratification
- Analysis of the accuracy of the produced maps.

Satellite images were selected considering: (a) the extent of the inventory area, (b) the characteristics of each region, especially its topography and the phenology

Table 6.3 Land classification at level 1 and at level 2 with their corresponding names

Level 1	Level 2
Selva Misionera	Selva del Parque Iguazú
	Selva de cobertura cerrada
	Selva de cobertura variable
	Selva de cobertura abierta
Selva Tucumano Boliviana	Selva de transición
	Selva montana
	Bosque montano
Parque Chaqueño	Quebrachal
	Colonizadoras
	Bosque alto
	Bosque ribereño
Monte	No tiene Tierras Forestales
Espinal	Bosque de Caldén
	Bosque de Ñandubay
Bosque Andino patagónico	Bosque de Lenga
	Bosque de Coihue
	Bosque mixto
	Bosque de Ciprés
	Bosque de Araucaria
	Bosque de Roble pellín

of species, and (c) the level of perception and the precision of the different sensors available. The material used was preferably from LANDSAT-5 TM, and in a lesser extent from Landsat-7 TM, TERRA-ASTER and CBER 2-CCD. The material used corresponded to satellite LANDSAT 5-TM system, and in a lesser extent LANDSAT 7-TM, TERRA-ASTER and CBER 2-CCD systems.

The satellite material was processed with ERDAS IMAGINE software and supported by topographic maps provided by the Military Geographical Institute (IGM) with a scale of 1:100,000. The preliminary stratification was carried out by the visual identification method to differentiate between forest and non-forest land. A final stratification was completed on lands with native forest that could be assessed in the field and was sub-divided into two sub-categories, level 1 and level 2. In the case of non-forested areas and areas with native forest that would not be assessed, this phase was to record classes of land use. Finally, the quality of the forest maps obtained as a result of the final stratification was evaluated by performing an error matrix analysis.

The IGM developed a mapping system, composed of 20 vector layers at a scale of 1:250,000. Other digitised sources were used to update and complete this information. This action led to introduce a new category in the attribute tables. The edition of the SIG-250 charts, supplemented with data from own surveys of Aeroterra, made it possible to obtain a digital base map of the represented area. The Gauss-Krüger map projection, which divides the argentine territory in seven meridian strips numbered from west to east, was used to transfer mapping data to a flat surface. The Gauss-Krüger system is the official projection system used in Argentina.

6.1.2.2 Sampling Design

The sample design was a systematic square grid, with points located at intervals that vary for all forest regions (Table 6.4).

The sample plot unit used in the different forest regions had a very different structure, so they are described separately.

Región Espinal

The sampling unit was a cluster with three circular plots located on a square of 100 m side, where only three vertices of the square contained plots. In three vertices of the square two circular plots with different size were installed. The bigger plot, identified as Plot A, had an area of 500 m^2, where data were recorded for trees with

Table 6.4 Level 1 grid size by forest region

Forest region	Grid size (km)
Selva Misionera	10
Selva Tucumano Boliviana	20
Parque Chaqueño	50
Bosque Andino Patagónico	10
Espinal	10 18
Monte	No sampled

dbh greater than or equal to 10 cm (dbh ≥ 10 cm). The smaller plot, identified as Plot B, had an area of 12.5 m^2, where data were recorded for trees with dbh under 10 cm (dbh < 10 cm). Plot B is used to assess regeneration. Figure 6.3 show the sampling unit and the plots used in the *Región del Espinal* (Informe Regional Espinal Segunda Etapa,2007).

Región Selva Misionera, Serlva Tucumano Boliviana, Parque Chaqueño and Bosque Andino Patagónico

Each sampling unit consisted of a set of plots in a repeated sequence. Three types of subplots were used within each plot, each one associated with a range of dbh and named A, B and C. Plot A was associated with a range of dbh equal or over 30 cm (dbh ≥ 30 cm); Plot B was associated with a range of dbh equal or over 10 cm and lower than 30 cm (10 cm ≤ dbh < 30 cm); and Plot C was associated with a range of dbh lower than 10 cm (dbh < 10 cm), considered as regeneration. However, the shape of the sampling units was not the same in all regions. Figure 6.4 show the constitution of the sampling unit with the conformation of the plots and Fig. 6.5 shows the internal structure of each plot with the corresponding subplots A, B and C (Informe Regional Bosque Andino Patagónico 2007; Informe Regional Parque Chaqueño 2007; Informe Regional Selva Misionera2007; Informe Regional Selva Tucumano Boliviana 2007; Informe Regional Monte 2007).

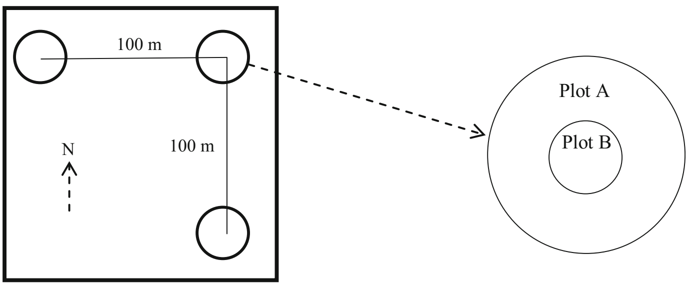

Fig. 6.3 Sampling unit with the plots used in the *Región del Espinal*

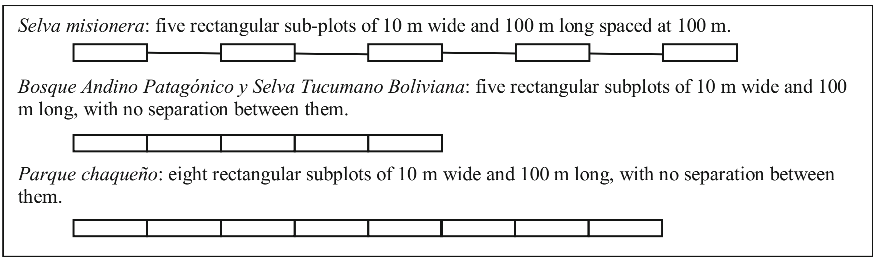

Fig. 6.4 Sampling units used in each forestry region

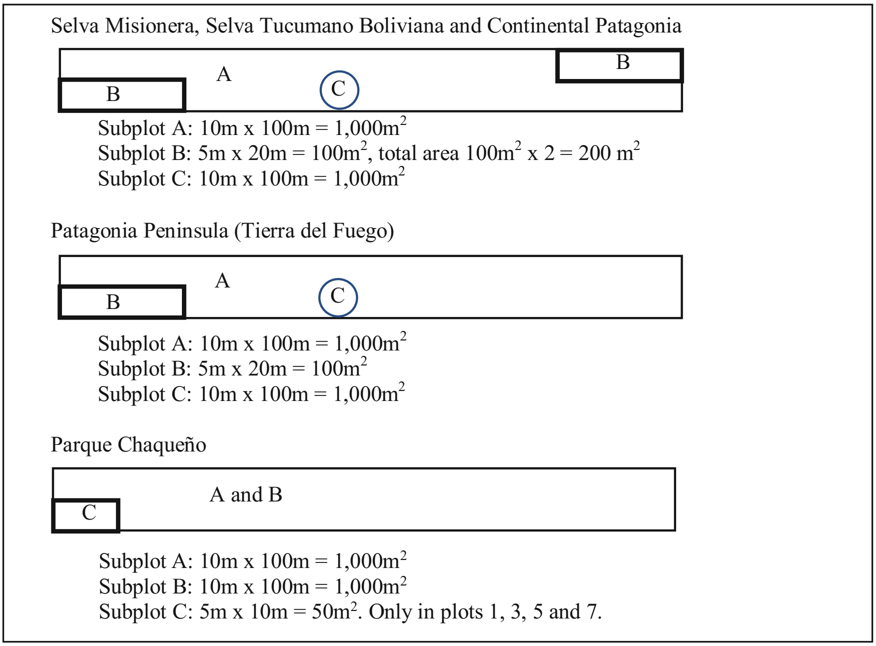

Fig. 6.5 Subplot by type of sampling unit and its dimensions

6.2 Land Use and Forest Resources

6.2.1 Classification of Land and Forests

The outputs are mainly cartographic products. There is less information associated with the structure and composition of forests (Informe Nacional, 2007).

6.2.1.1 General Land Classification

The classification used and definitions adopted were from the FRA 2000 (FAO 2001) definitions (Table 6.5).

6.2.1.2 Forest Classifications by Forest Regions and Sub-regions

The country is divided in six forest regions (Level 1) which are classified into smaller sub-regions (Level 2); nineteen sub-regions. The total number of tree species for which data were collected during the national forest inventory was 361, of which only 10 species were coniferous. Table 6.6 shows the results corresponding to the areas identified for Level 1 and Level 2, and the percentage of the total.

Table 6.5 Definitions used in the forest cover classification

Land cover	Definition
Forest land	Land with tree crown cover of more than 20 % and higher than 10 ha. The trees should be able to reach a minimum height of 7 m at maturity in situ. It may consist either of closed forest formations where trees of various storey and undergrowth cover much ground
Other forest land	Land where: (a) crown cover is greater than 5 % and less than 20 %, with trees able to reach a height of 7 m at maturity in situ; (b) crown cover is more than 20 % but the trees are not able to reach a height of 7 m at maturity in situ; (c) land where shrub cover is more than 20 %
Agroforestry land	Transition zone between forest and agricultural environment. They are a set of patchy rural forests in mixed with agricultural crops
Rural forest	Composed of the remnants of native forest in an agricultural landscape with less than 1000 ha in area. This class is not in the FRA 2000 documents
Other land	Land not classified as forest or other wooded land. Includes agricultural land, meadows and pastures, built-on areas, barren land, and others

Table 6.6 Total level 1 and level 2 native forest area

Level 1			Level 2		
Name	Area (km^2)	Area (%)	Name	Area (km^2)	%
Selva Misionera	9147	2.8	Selva del Parque Iguazú	402	0.12
			Selva de cobertura cerrada	1119	0.35
			Selva de cobertura variable	6865	2.12
			Selva de cobertura abierta	761	0.23
Selva Tucumano Boliviana	37,329	11.5	Selva de transición	17,904	5.52
			Selva montana	11,699	3.61
			Bosque montano	7726	2.38
Parque Chaqueño	212,784	65.6	Quebrachal	161,102	49.67
			Colonizadoras	24,336	7.50
			Bosque alto	25,508	7.86
			Bosque ribereño	1838	0.57
Monte	0.0	0.0	No sampled	0.0	0.0
Espinal	46,115	14.2	Bosque de Caldén	29,714	9.16
			Bosque de Ñandubay	16,401	14.2
Bosque Andino Patagónico	18,952	5.8	Bosque de Lenga	10,199	3.14
			Bosque de Coihue	1907	0.59
			Bosque mixto	5083	1.57
			Bosque de Ciprés	945	0.29
			Bosque de Araucaria	779	0.24
			Bosque de Roble pellín	39	0.01
Total	324,327	100.00	–	–	100.00

Table 6.7 Mean values of number of trees (N) per hectare, basal area (living trees) and volume (Gross Overbark)

Region	Level 2	Trees density (Stems per ha)	Basal area (m^2/ha)	Volume (m^3/ha)	Total volume (1000 m^3)
Selva Misionera	Selva protegida del Parque Iguazú	301	25.0	214	8603
	Selva de cobertura cerrada	334	24.3	211	23,611
	Selva de cobertura variable	296	19.0	163	111,900
	Selva de cobertura abierta	299	17.1	147	11,187
Selva Tucumano Boliviana	Selva de transición	344	15.3	98	175,459
	Selva Montana	297	18.2	121	141,558
	Bosque Montano	345	15.1	77	59,490
Parque Chaqueño	Quebrachal	183	6.9	31	499,416
	Bosque alto	151	6.6	31	79,075
	Bosque ribereño	98	7.5	34	6249
	Colonizadores	148	9.1	48	116,813
Bosque Andino Patagónico	Bosque de Lenga	381	41.2	487	496,691
	Bosque de Ciprés	548	22.0	130	12,285
	Bosque de Coihue	249	44.0	606	115,564
	Bosque Mixto	390	45.1	493	250,592
	Bosque de Araucaria	291	55.0	429	33,419
	Bosque de Roble pellín	288	27.3	182	710

6.2.2 *Wood Resources and Their Use*

Estimates of standing stock are based on the sample tree measurements on the plots. They are calculated as volume of stem wood over bark of living trees. Table 6.7 shows the mean values of number of trees, basal area and volume per hectare, estimated for Level 1 and Level 2.

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Chapter 7
Austria

Thomas Gschwantner, Ambros Berger, Richard Büchsenmeister and Elmar Hauk

7.1 The Austrian National Forest Inventory

7.1.1 History and Objectives

The beginning of large-scale forest surveys in Austria is marked by the "Österreichische Waldstandsaufnahme" (Austrian Forest Survey) conducted during the years 1952–1956. This survey aimed to assess the state of Austrian forests after World War II and to evaluate the potential for sustainable forest utilisation and management (Gabler and Schadauer 2008; Gschwantner et al. 2010). The need for forest statistics at both national and local level required a special survey design with the basic features of a stand-wise assessment and a combination of aerial photograph interpretation and terrestrial assessment of delineated forest stands (Braun 1960). From the experiences in this forest survey and after several pilot studies (Braun 1974) the first sample-based National Forest Inventory (NFI) was conducted during the years 1961–1970. The field assessments were based on a temporary systematic sampling grid. Also the second NFI from 1971–1980 was designed as a temporary inventory. The primary emphasis of the first two sample-based NFIs was on the assessment of the current status of the forest estate. Thereafter, the

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importance of monitoring changes in the forest resulted in the establishment of a permanent sampling grid during the third NFI from 1981–1985. All subsequent NFIs were based on this permanent sampling grid. The first re-measurement of the permanent plots was done in the fourth NFI in 1986–1990 which also included assessments on an additional temporary grid. In the fifth NFI from 1992–1996 the continuous assessment changed to a discontinuous scheme and several new and mainly ecological variables were integrated in the inventory (Schieler and Schadauer 1991). The assessment of these new variables were continued and extended in the sixth NFI from 2000–2002 which was accompanied by a reduction of the field assessment period to 3 years. The most recent seventh NFI in 2007–2009 introduced further assessments including the topics of sustainability, biomass availability, biodiversity, protective function of forests and providing data to fulfil the reporting obligations of the Kyoto Protocol. Also a step towards landscape monitoring was made to facilitate reporting of activities in the land use, land-use change and forestry (LULUCF) sector. The harmonisation efforts at the European level (Tomppo et al. 2010) led to the implementation of field assessments according to commonly agreed definitions in COST Action E43 (2010). In parallel with the national definitions, the forest and Other Wooded Land definitions of the Food and Agriculture Organization of the United Nations (FAO 2004) were also applied in the field assessments and trees below the national dbh-threshold of 5.0 cm were recorded as stem counts in two diameter classes. From 2011 to 2013 a special survey to satisfy carbon reporting requirements under Article 3.3 of the Kyoto Protocol was implemented and included a remote sensing as well as a field assessment component.

7.1.2 Sampling Methods and Periodicity

The Austrian NFI is the largest forest monitoring program in Austria and covers all federal territory. Only forest areas were assessed prior to the seventh NFI (2007–2009). However, in the most recent seventh NFI a step towards landscape monitoring was made by the assessment of the management type and land use category of each inventory plot and also outside the forest. The field measurement period lasted for 3 years. The sampling grid is systematically divided into three parts so that each year one third of the grid covering the whole of Austria is inventoried. The time span between the measurements of the two latest inventories is seven years.

The Austrian NFI uses a sampling grid which has a size of 3.889 × 3.889 km. Clusters of four sample plots are located on the intersections of the grid. The clusters are square-shaped and have a side length of 200 m. The sample plots are located at the corners of the clusters. The shape and size of the grid and clusters are uniform all over Austria. In total, there are approximately 22,300 sample plots, of which about 11,000 are located on forest land.

The sample plots consist of a large circular plot of 300 m^2, a small circular plot of 21.2 m^2 and an angle count plot. At least one tenth of the large sample plot has to be covered by forest to qualify the sample plot as forest plot and to assess the stand- and site-specific variables and to measure tree-specific variables on the sample trees. The large circular plot forms the basis of forest area estimation and stratification according to ownership categories, management types, age classes, growth classes, tree species, species mixture, and natural forest type. Stand- and site-specific variables are assessed at and assigned to the 300 m^2 plot. Forest plots that are covered by stands of different age classes, stand structure, tree species, management type, or that reveal different soil types, vegetation types, exposition, slopes, etc. are subdivided into sub-plots that are described separately. The small circular plot is used for data collection for trees with a diameter at breast height (dbh) between 5.0 and 10.4 cm inclusively. Trees with a dbh of more than 10.4 cm are sampled using Bitterlich's angle count sampling (Bitterlich 1948, 1952, 1984) and by applying a basal area factor of 4 m^2/ha.

7.1.3 Data Collection

Aside from basic data such as the allocation of sample plots to administrative regions, growth districts according to Kilian et al. (1994), ownership categories and management types, the Austrian NFI assesses three main categories of variables: stand, site and sample tree. Detailed and further information about the data collected by the Austrian NFI and the assessments and measurements of variables are available from the field assessment instructions (Hauk and Schadauer 2009).

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

- Growth classes
- Age classes in 20-year intervals
- Share of tree species in age classes
- Age sub-class in 5-year intervals if ascertainable
- Dominant height of even-aged conifer stands
- Forest structure: Crown coverage, Stand structure, Development stage, Coverage of shrubs in stands
- Stand stability: Damage, Required tending activities, Factors that influence game
- Actual woodland community
- Natural woodland community
- Regeneration
- Stand layers and their coverage
- Occurrence and abundance of woody plant species with attribution to stand layers
- Deadwood.

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

- Elevation above sea level
- Slope direction (exposition)
- Slope gradient
- Relief
- Local climate situation
- Vegetation type
- Soil moisture
- Soil layer thickness
- Soil group
- Soil movement
- Humus layer thickness
- Humus type
- Soil texture.

Sample tree variables refer to those that are measured or assessed on the sample trees. In some NFI periods variables like tree height, height to the living crown base, and upper diameter are measured only on a sub-sample of sample trees and the values of non-measured sample trees are predicted using data models (Schieler 1997; Gschwantner and Schadauer 2004). The tree-specific variables measured or assessed on sample trees are:

- Species
- Diameter at breast height
- Tree height
- Height to the living crown base
- Upper diameter at 3/10 of tree height
- Length of broken stem part for newly broken trees
- Crown radius and type of crown base
- Stem quality
- Reserved tree and trees with advanced growth
- Dead standing tree
- Forked tree
- Growth class
- Age class
- Tree class
- Stem damage
- Proposed felling in required tending activities
- Distorted tree.

7.1.4 Data Processing, Reporting, and Use of Results

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

The estimation of area has two components, on the one hand the data collected at the 300 m^2 sample plots, and on the other hand the area of the Austrian territory. The area represented by one 1/10-share of a sample plot is calculated by dividing the land area by the total number of 1/10-shares of sample plots and parts of sample plots located in the respective land area. The area of the Austrian territory, the Federal States and Forest Inspection Service districts is obtained from the official statistics of Statistik Austria (2009) and is assumed to be error-free. The area estimate of a given stratum is equal to the sum of 1/10-shares located in this stratum multiplied by the represented area of one 1/10-share.

The estimation of the volume and biomass of standing stock, growing stock, increment, and harvest is of particular interest for productive forest land. The estimation procedure includes several steps. After field data collection, the data undergo quality control procedures. Volume and biomass is then calculated for each sample tree. Different models are applied depending on the species and size of the sample tree. Since the sample trees are sampled by angle count sampling and a small circular sample plot, the per hectare values represented by the individual trees are obtained according to the respective sampling method. For each plot or sub-plot the represented volume per hectare is calculated as the sum of per hectare values represented by individual trees. These per hectare estimates are aggregated to a mean volume or biomass per hectare for productive forest and multiplied by the area of productive forest to obtain the total volume or biomass of standing stock and growing stock. Mean volumes and biomass per hectare and total volumes and biomass are also estimated for strata within productive forest like management types, ownership categories, age classes, and growth classes.

Change estimates are obtained from the assessments of two consecutive NFIs. The volume and biomass increment of sample trees is calculated as the difference between the second and the first occasion. Sample trees that have exceeded the dbh-threshold of 5.0 cm between the two NFIs are also included in the increment estimation. Increments per hectare are obtained by referring to the measurement at the first occasion. The drain is assessed by recording the sample trees that have been harvested or that have disappeared naturally since the previous field assessment. The drain of volume and biomass is calculated using the individual tree volume and biomass and the sampling probability of the first assessment.

The Austrian NFI provides estimates at different regional scales, the national level, the nine federal states, and the 75 Forest Inspection Service districts. The estimates include among others forest area, growing stock, increment, harvest, number of stems, stem damages, regeneration, and dead wood (http://bfw.ac.at/rz/wi.home). The results of the Austrian NFI are used as the basis for decision-making in forest and environmental policy, forest management, forest product industries, and for evaluating the consequences of the decisions taken. Reporting obligations of many international processes and organisations are fulfilled using the data and results of the Austrian NFI. Reporting processes include: the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 of the Kyoto Protocol, the indicators and criteria for sustainable forest management for FOREST EUROPE (FOREST EUROPE, UNECE and FAO 2011), and on the conservation status of natural habitat types under the Habitats Directive (Council of the European Communities 1992). NFI data are a valuable data source for numerous research projects and were used to develop the forest growth simulators PrognAus (Monserud and Sterba 1996; Ledermann 2006) and Caldis (Kindermann 2010), in scenario analyses to estimate the current and future potential of Austrian forests for wood and biomass supply HOBI (Neumann and Schadauer 2007; BFW 2009), in several remote sensing projects (Eysn et al. 2012; Dorigo et al. 2010; Hollaus et al. 2007, 2009a, b), for the evaluation of the protective functions of forests (Bauerhansl et al. 2010), to assess the degree of naturalness of Austrian forests (Grabherr et al. 1998), and for the development of a forest biodiversity index (Geburek et al. 2010).

7.2 Land Use and Forest Resources

7.2.1 Classification of Land and Forests

7.2.1.1 General Land Classification

The land classification system used in the Austrian NFI follows a hierarchical system of land management types (Table 7.1). At the highest level the land area is divided into forest and non-forest by applying the national forest definition. To qualify as forest, a piece of land requires a minimum area of 500 m^2, a minimum width of 10 m, and a crown cover of woody plants including shrub species of 30 %. Forest land contains the classes of productive forest, protective forest, and permanently unstocked parts of the forest. Non-forest land is distinguished into agricultural land, natural land, built-up areas and other non-forest land which are subdivided into further classes as described in Table 7.1. The details of the land classification system applied by the Austrian NFI are described in the field assessment instructions (Hauk and Schadauer 2009).

The areas of forest and non-forest land classes according to the Austrian NFI are given in Table 7.1 and the classes are compared to the definitions of the Forest Resources Assessment of FAO (2004). Since the Austrian forest definition includes shrub-land there is an overlap with the Other Wooded Land (OWL) definition of FAO (2004). The Austrian forest definition contains also areas of land that are

Table 7.1 Land use classes according to the national definition with area estimates (Seventh NFI, 2007–2009) and correspondence with FRA classes

Class name		Description	Area (1000 ha)	Corresponding FRA classes (FAO 2004)
Forest	Forest land	Productive forest, protective forest, permanently unstocked parts of the forest	3991	Forest, intersection with OWL, intersection with OL and OLwTC
Non-forest	Agricultural land	Cropland, fallow land, orchards and vineyards, land for wood energy production, windbreaks, Christmas tree plantations, grassland, grazing land	2763	OL, OLwTC, intersection with forest
	Natural land	Water bodies, reed beds, bogs, heath lands, rocks, areas of gravel and debris, landslides, other natural lands	334	OL, OLwTC
	Built-up land	Industry and commerce, mining, traffic and transport, disposal sites, tourist facilities, dwellings and parking sites, gardens and parks	496	OL, OLwTC
	Other land	Inaccessible and unproductive non-forest land	805	OL
Total land area			8388	

considered as Other Land (OL) and Other Land with Tree Cover (OLwTC) by FAO (2004). This is as a result of the smaller minimum area and smaller minimum width, and higher minimum crown cover in the national definition compared to the FAO definition. The non-forest categories correspond to OL and OLwTC depending on the crown cover. Agricultural land according to the national definition contains some elements that belong to forest according to FAO (2004) like for example land for wood energy production and Christmas tree plantations.

7.2.1.2 Forest Classifications by Use

Forest land is further sub-divided according to the forest management system, the productive and protective forest function, and stocking characteristics. The management system refers to the distinction of high forest and coppice forest. Most of the forest area (98 %) belongs to high forest and the remaining 2 % to coppice forest. With regard to wood resources the distinction of productive forest and

Table 7.2 Classes within forest land and their area (Seventh NFI, 2007–2009)

<table>
<tr><th colspan="2">Class name</th><th colspan="3">Description</th><th colspan="2">Area (1000 ha)</th></tr>
<tr><td rowspan="7">Forest land</td><td rowspan="2">Productive forest
–high forest
–coppice forest</td><td rowspan="2">Forests available for wood supply, includes forests with protective function and with yield</td><td colspan="2">Stocked or temporarily unstocked</td><td>3342</td><td rowspan="2">3367</td></tr>
<tr><td colspan="2">Shrub-land</td><td>25</td></tr>
<tr><td rowspan="3">Protective forest
–high forest</td><td rowspan="3">Forests with protective function and without yield</td><td rowspan="2">Accessible</td><td>Stocked or temporarily unstocked</td><td>188</td><td rowspan="3">500</td></tr>
<tr><td>Shrub-land</td><td>110</td></tr>
<tr><td colspan="2">Not accessible</td><td>202</td></tr>
<tr><td>Permanently unstocked parts of the forest</td><td colspan="4">Unstocked due to
–Forest management (e.g. forest roads, timber yards)
–Natural reasons</td><td>124</td></tr>
<tr><td colspan="5">Total forest land area</td><td>3991</td></tr>
</table>

protective forest is particularly relevant. Productive forest contains all forest areas that are available for wood supply and as such include protective forests with yield. The latter have protective and economic function at the same time and contribute to wood supply from regular and commercial harvests. Protective forests without yield have a mainly protective function and no or negligible yield. They are located in areas that are difficult to access or even inaccessible and often they are on sites of very poor productivity. Protective forests classified as not accessible amount to 202,000 ha. The area of productive and protective forests includes also shrub-land. Shrub-land is defined as area that fulfils the national forest definition and that is dominantly covered by shrub species. About 25,000 ha of shrub-land are included in productive forest and potentially would be available for wood production if managed accordingly. Protective forest without yield but in accessible locations has a considerably larger area of shrub-land that amounts to 110,000 ha. All resource-related estimates like standing volume, growing stock, increment, and harvest are calculated for the productive forest land category. Permanently unstocked parts of the forest are unstocked due to forest management features such as forest roads and timber yards or for natural reasons. They are a separate category in the forest classification scheme given in Table 7.2 and belong to productive as well as to protective forest areas.

7.2.1.3 Classification by Ownership Categories

The Austrian NFI distinguishes three main categories of forest ownership: small private forests, forest enterprises, and the Austrian federal forests managed by the

Table 7.3 Forest area according to the national forest definition by ownership categories (Seventh NFI, 2007–2009)

Ownership category		Area (1000 ha)
Small private forest <200 ha		2153
Forest enterprises	200–1000 ha	386
	>1000 ha	729
	Area municipalities (≥200 ha)	130
Österreichische Bundesforste AG		593
Total forest area		3991

Österreichische Bundesforste AG. Small private forest properties own forest with an area of <200 ha. Forest enterprises manage forest properties that have a size of 200 ha or more. This category is divided into three sub-categories which are Private forests with 200–1000 ha, Private forests >1000 ha, and area municipality forests of 200 ha upwards. Over half (54 %) of the Austrian forest estate belongs to category of small private forests. Private forests >1000 ha comprise 18 %, and the Österreichische Bundesforste AG manages 15 % of the Austrian forest area. The remaining forest area belongs to Private forests with 200–1000 ha (10 %) and area municipalities (3 %) (Table 7.3).

7.2.1.4 Forest Management and Cutting Systems

The forests in Austria are managed in even-aged and uneven-aged management systems. A recent study showed that about half of the stocked productive forest land is covered by stands having one age class and the remaining half is covered by stands having more than one age class. The highest share of uneven-aged forest stands is in small private forests <200 ha, whereas the highest share of even-aged stands is in enterprises >1000 ha (Prskawetz and Gschwantner 2011). In the last decennia small-scale management practices, like cutting of single stems and harvesting of small areas, have become more frequent as well as regeneration fellings and have contributed to a modest increase of uneven-aged stands. The management of even-aged forests normally incorporates the following activities during the stand development: (1) stand establishment with natural regeneration or planting, (2) enlargement of growing space and cleaning, (3) thinnings, (4) clear cutting or final cutting of remaining trees after regeneration fellings.

The harvested wood volume can be distinguished by the type of harvesting. According to the most recent NFI 2007–2009 about one third of harvested wood was felled in clear-cuts. However, it has to be noted that the minimum area-threshold for qualifying as clear-cut is 500 m^2 which is rather small and therefore may not be considered as clear-cut from other perspectives. Thinnings account for about 11 % of fellings. Regeneration fellings and final cutting of remaining trees together account for 17 %. Cutting of single stems and of small areas contributes about 15 % of the total harvest. Major storm events contributed to a high amount of wood harvested in salvage logging (12 % of the fellings) and also increased the amount of natural mortality and disappearance (9 %). Other tending activities like enlargement of growing space in young stands and clearing of damaged or dead standing trees together contribute only about 2 % of the harvested wood.

The decision to harvest trees is made by the forest owner but all operations must comply with the regulations specified in the Austrian Forest Act. In pre-mature stands clear-cuts are prohibited and also stand tending activities are not allowed to exceed a certain intensity level. Clear-cuts must not exceed a certain area and a new stand has to be established either by natural regeneration or planting at the latest at the end of the fifth year following the year of the harvest.

7.2.1.5 Legal and Other Restrictions for Wood Use

Forests in Austria have to be managed in accordance with the Austrian Forest Act (Jäger 2003). It shall ensure the sustainable management of forests and specifies limits for the area of clear-cuts, restricts the harvest in pre-mature stands by limiting the intensity of tending activities, and defines a species-specific age-limit to prevent pre-mature stands from being clear-cut. It also contains specifications for forests with protective functions, forests with special natural habitats like national parks, natural forest reserves, and nature protection areas, and for forests in recreational areas. In addition to the specifications of the Austrian Forest Act further legal restrictions can apply for national parks, natural forest reserves, and nature protection areas. The availability of wood resources is also restricted in water protection areas, military training areas, research forests, etc. Certain forest and environmental policy incentives like the promotion of habitat tree preservation also have an influence on the harvesting.

An important point with regard to the availability of wood resources is the accessibility particularly in mountainous regions. Long logging distances and steep slopes increase the hauling costs for wood. Cable crane logging is necessary in forest areas that cannot be accessed by machinery like harvesters, forwarders or tractors because of steep slopes. These logging technologies are more expensive than conventional harvesters or forest tractors and may not be economically feasible in every case. Some sites have poor productivity and render forest harvesting negligible. Ecological considerations to sustain the site productivity can also restrict the amount of removable wood resources in harvesting operations.

7.2.1.6 Further Classification of Forests

In addition to the previously described classifications of the forest area further stratifications are used in national statistics and reporting. Commonly used stratification variables are tree species, age classes and growth classes. The stratifications of the forest area are based on the field assessment of the 1/10-shares of the forest plot covered by the species, the age classes and the growth classes. Also the share

Table 7.4 Productive forest area according to the national definition by species (Seventh NFI, 2007–2009)

Tree species	Area (1000 ha)	Percent (%)
Norway spruce (*Picea abies*)	1709	50.7
Silver fir (*Abies alba*)	81	2.4
Larch (*Larix decidua*)	154	4.6
Scots pine (*Pinus sylvestris*)	152	4.5
Black pine (*Pinus nigra*)	21	0.6
Stone pine (*Pinus cembra*)	15	0.5
Other conifers	6	0.2
Beech (*Fagus sylvatica*)	336	10.0
Oak (*Quercus* spp.)	69	2.0
Other broadleaved hardwood	275	8.2
Other broadleaved softwood	142	4.2
Clearings and gaps in stands	309	9.2
Shrubs in stands	73	2.2
Shrub land	25	0.7
Total productive forest land	3367	100.0

of clearings (i.e. temporarily unstocked areas >500 m^2) and gaps in stands (i.e. openings in the stand having an area of 50–500 m^2) are included in the assessment. The coverage of shrubs in stands is collectively assessed without distinction of shrub species. Different from shrubs in stands is the category shrub-land which is predominantly covered by shrub species.

The predominant tree species in Austrian forests is Norway spruce (*Picea abies* (L.) H.Karst.) with a share of 51 % of the productive forest area. It is followed by European beech (*Fagus sylvatica* L.) with 10 %, larch (*Larix decidua* Mill.) and Scots pine (*Pinus sylvestris* L.) both with 5 %. The remaining species together cover 18 % of the forest area. The productive forest area and the coverage by the tree species is given in Table 7.4.

The age classes are assessed in intervals of 20 years. The highest age class includes all tree ages above 140 years. The area and percentage area covered by the individual age classes is given in Table 7.5. The second age class has the largest coverage among all age classes. For higher age classes beyond the second age class, the forest area covered decreases as the age classes increases.

Growth classes are defined by the tree size. Regeneration I has a height below the breast height of 1.30 m, Regeneration II has a minimum height of 1.30 m and a maximum dbh of 10.4 cm, the Pole stage has a dbh from 10.5 cm to 20.4 cm, Timber I has a dbh from 20.5 to 35.4 cm, Timber II has a dbh from 35.5 to 50.4 cm and Large timber has a dbh > 50.5 cm. The area covered by the growth classes is given in Table 7.6. Timber I has the largest coverage, followed by the growth classes Pole stage, Regeneration II and Timber II. The growth classes Regeneration I and Large timber cover much smaller areas.

Table 7.5 Productive forest area according to the national definition by age classes (Seventh NFI, 2007–2009)

Age class	Area (1000 ha)	Percent (%)
1–20 years	433	12.9
21–40 years	750	22.3
41–60 years	527	15.7
61–80 years	360	10.7
81–100 years	317	9.4
101–120 years	243	7.2
121–140 years	147	4.4
>140 years	182	5.4
Clearings and gaps in stands	309	9.2
Shrubs in stands	73	2.2
Shrub land	25	0.7
Total productive forest land	3367	100.0

Table 7.6 Productive forest area according to the national definition by growth classes (Seventh NFI, 2007–2009)

Growth class	Area (1000 ha)	Percent (%)
Regeneration I	94	2.8
Regeneration II	621	18.4
Pole stage	677	20.1
Timber I	896	26.6
Timber II	566	16.8
Large timber	107	3.2
Clearings and gaps in stands	309	9.2
Shrubs in stands	73	2.2
Shrub land	25	0.7
Total productive forest land	3367	100.0

7.2.2 *Wood Resources and Their Use*

7.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock, increment and drain are based on the sample tree measurements at the plots on productive forest land. They are calculated as volume of stem wood over bark. Stem wood according to the Austrian NFI includes all stem parts above the stump i.e. the bole with bark and stem top and conforming to the definitions of tree elements by Gschwantner et al. (2009). The minimum dbh is 5.0 cm measured over bark. Trees below this threshold are not included in regular NFI estimates. The Austrian NFI estimates the volume of standing stock which can be divided into the volume of growing stock and volume of standing dead wood. Increment and drain are calculated as mean annual estimates for the period between two consecutive NFIs. The estimation is based on the permanent sample plots and refers to the sampling probability of the first measurement. The volume of drain is

Table 7.7 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with dbh ≥ 5.0 cm over bark, including the bole (wood and bark), and stem top, and excluding the above-ground part of the stump
Increment	Volume increment of surviving trees with dbh ≥ 5.0 cm over bark plus the volume of ingrown trees into the small circular plot between two consecutive NFIs
Drain	Volume of trees with dbh ≥ 5.0 cm over bark at the first measurement that were found to be harvested in the subsequent NFI

further stratified into natural losses and nine types of harvesting. The national definitions for standing stock, increment and drain are compiled in Table 7.7.

Similar to volume estimation the Austrian NFI also calculates biomass estimates for various purposes. Stem volumes are converted to biomass by applying nationally valid wood densities and shrinkage factors. A set of species-specific biomass equations is available for estimating the biomass of branches and needles (Weiss 2006). The biomass of roots can be calculated using the model of Wirth et al. (2004) for coniferous trees and the model of Wutzler et al. (2008) for broadleaved trees.

The productive forest land in Austria has a standing volume of 1135 million m^3 of stem wood over bark of which 2.5 % are standing dead wood. About 30 million m^3 of volume increment are produced each year and almost 26 million m^3 harvested annually. Thus, the drain between 2000/2002 and 2007/2009 is about 85 % of the increment in the same time period. During the 80s and 90s of the last century this ratio was on average 65 %. The intensified utilisation of wood resources can be attributed to changes in forest policy, an increased demand for energy wood, storm damage events and attractive wood prices for forest owners.

The largest part of the standing stock volume is contributed by Norway spruce (*Picea abies* (L.) H.Karst.) (61 %) and is followed by European beech (*Fagus sylvatica* L.) (10 %), larch (*Larix decidua* Mill.) (7 %), Scots pine (*Pinus sylvestris* L.) (7 %), Silver fir (*Abies alba* Mill.) (4 %), oak species (*Quercus* spp.) (2 %), ash (*Fraxinus* spp.) (2 %) and maple (*Acer* spp.) (1 %). The remaining tree species altogether account for 6 % of the standing volume. For the increment and drain this order of tree species is similar, although Norway spruce (*Picea abies* (L.) H.Karst.) contributes a larger share of increment and is also harvested to a larger extent. Silver fir (*Abies alba* Mill.), larch (*Larix decidua* Mill.) and Scots pine (*Pinus sylvestris* L.) produce about the same increment per year, but the latter is harvested more often than the others. Table 7.8 gives the estimates of standing stock, increment and drain by tree species.

Table 7.8 The volume of standing stock, increment, and drain on productive forest land (Seventh NFI, 2007–2009)

Tree species	Standing stock (1000 m^3)	Increment (1000 m^3/year)	Drain (1000 m^3/year)
Norway spruce (*Picea abies*)	694,853	20,112	17,775
Silver fir (*Abies alba*)	49,725	1263	1026
Larch (*Larix decidua*)	75,439	1195	1044
Scots pine (*Pinus sylvestris*)	74,497	1227	1624
Black pine (*Pinus nigra*)	9154	65	146
Stone pine (*Pinus cembra*)	4784	58	31
Weymouth pine (*Pinus strobus*)	175	6	3
Douglas fir (*Pseudotsuga menziesii*)	635	43	6
Other conifers	351	28	2
Beech (*Fagus sylvatica*)	108,699	2746	1753
Oak (*Quercus* spp.)	27,429	665	564
Hornbeam (*Carpinus betulus*)	8992	246	125
Ash (*Fraxinus* spp.)	23,705	833	309
Maple (*Acer* spp.)	15,001	439	193
Elm (*Ulmus* spp.)	1468	56	45
Chestnut (*Castanea sativa*)	1340	60	47
Black locust (*Robinia pseudoacacia*)	2633	94	70
Sorbus spp. and *Prunus* spp.	3462	97	81
Birch (*Betula* spp.)	6770	206	230
Black alder (*Alnus glutinosa*)	8168	260	138
Grey alder (*Alnus incana*)	3603	126	210
Linden (*Tilia* spp.)	3488	107	41
Aspen & White poplar (*Populus tremula & alba*)	4049	150	117
Black poplar (*Populus nigra*)	502	24	58
Hybrid poplar (*Populus* spp. X)	2465	110	137
Willow (*Salix* spp.)	2616	114	98
Other broadleaves	779	41	16
Total	1,134,780	30,371	25,888

Increment and cuttings are average annual values for the period 2000/2002–2007/2009

7.2.2.2 Tree Species and Their Commercial Use

Norway spruce (*Picea abies* (L.) H.Karst.) is the most economically important tree species in Austria and is mainly used for sawn wood production and industrial round wood. According to the "Holzeinschlagsmeldung" provided by the Federal Ministry of Agriculture, Forestry, Environment and Water Management for the year 2011 (BMLUFW 2012) 56 % of the harvested wood in Austrian forests is used as sawn wood, 17 % as industrial round wood, and 27 % for energy purposes. Coniferous wood is used for sawn wood (64 %), energy production (19 %), and industrial wood (17 %). Broadleaved wood is used for energy production (71 %), industrial wood (18 %) and sawn wood (11 %). Certain broadleaved species are used for special purposes if they feature high wood quality or unique properties. In the recent years the use of wood for energy production has increased considerably. The amount of harvested fuel wood was about 2.9 million m^3 in 2001, 4.7 million m^3 in 2006, and 5.1 million m^3 in 2011.

7.3 Assessment of Wood Resources

7.3.1 Forest Available for Wood Supply

7.3.1.1 Assessment of Restrictions

The field assessments of the Austrian NFI include all sample plots in the sampling grid, with the exception of plots in inaccessible terrain which are assessed using aerial photographs. The existence of legal restrictions is not assessed in the field, but rather obtained from a post-stratification approach by intersecting sample plot locations with a GIS database that contains the areas where harvesting is restricted. Any restriction available as geo-referenced GIS-layer can be considered in assessing the forest area available for wood supply.

With regard to other restrictions and in particular to harvesting possibilities the Austrian NFI assesses several relevant variables. The slope is decisive for the use of harvesting and logging technologies. In driveable terrain technologies like harvester, forwarder, and tractor can be employed, whereas in steep areas cable cranes and cable harvesters have to be used. Another crucial factor is the distance to the nearest forest road. In field assessments the distance to the next skidding road and the distance to the next forest road were assessed for sample plot locations. These assessments are complemented by the analysis of aerial photographs and the determination of the shortest distance to the next forest road.

7.3.1.2 Estimation

In the study on the potential of Austrian forests in the period 2000–2020 for wood and biomass supply HOBI (Neumann and Schadauer 2007; BFW 2009) the legal restrictions due to nature protection and conservation were taken into account by excluding areas where harvest is prohibited like in national parks, and by limitation of harvests in protected areas according to the Habitats Directive and according to the Birds Directive. Depending on the respective research aim further areas of restricted forest utilisation can be added if GIS layers are available. NFI plots can be divided in three categories, forests without any restrictions for resource use additional to those in the forest act, forests where cuttings are partly limited, and forests where cuttings are not allowed. Work is currently on-going to estimate the forest area under the different harvest restrictions and will be available in the future.

The utilisation of wood resources also depends on the harvesting costs. In locations with difficult accessibility the harvesting costs may render harvesting uneconomic as the costs are not covered by the revenue obtained from the harvested product. To estimate the available wood resources under given economic conditions the harvesting costs (including machine costs and labour costs) are calculated and compared to the revenue achievable under the current wood price situation.

7.3.2 Wood Quality

7.3.2.1 Stem Quality and Assortments

The assortment of wood traded in Austria is defined and covered by the Austrian timber trade guidelines (Kooperationsplattform Forst Holz Papier 2006). The assortment includes diameter classes based on the mid-diameter and assortment according to the length of the log. The diameter 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) and 6 (60 cm and more). The requirements for the minimum diameter and minimum length of logs depend on the quality class. The basic quality classes for round wood are veneer logs, sawn timber and industrial round wood like pulpwood. Apart from these categories other assortments may be specified for particular purposes, such as instrument or resonance wood and mine timber. Veneer logs are of very good quality and require a minimum length of 2 m and a minimum diameter of 30 or 40 cm depending on the veneering technology. The quality classes of sawn timber contain the grades A (best quality), B, C, and Cx (lowest quality), and furthermore specify logs with butt rot and logs with low diameters. For the individual quality grades the minimum log lengths are also specified. The specifications of the quality grades are different for coniferous and broadleaved logs. Broadleaved round wood can have particular species-specific requirements. Also the minimum diameter and length requirements for coniferous and broadleaved logs for one and the same quality grade are different in several cases. Logs from broadleaved trees may be used for special purposes and thus can have particular size and quality requirements.

7.3.2.2 Assessment and Measurement

During field data collection in the Austrian NFI the stem quality of all sample trees with a dbh $\geq$ 20.5 cm is assessed. Since the stem quality assessment according to

Table 7.9 Stem quality classes as assessed by the Austrian NFI

Stem quality class	Description
1	stem upright, full-bodied, free of knots, without faults
2	stem upright, full-bodied, with some knots or little faults
3	stem crooked, knotty timber or stem conical, with bad faults

the Austrian timber trade guidelines (Kooperationsplattform Forst Holz Papier 2006) has limited applicability in the field, three classes of stem quality are distinguished. The same quality classes are used for conifers and broadleaves. Standing trees including dead standing trees are classified. The stem quality assessment concerns the lowermost third of the stem. The three stem quality classes are described in Table 7.9.

In addition, several other variables are assessed on individual sample trees that are relevant with regard to stem quality. These include the tree status dead or alive, information whether a tree is forked or not, stem damages in several classes of damages, the height of the living crown base, the upper stem diameter, and some other stand- and site-specific variables like management type and elevation above sea level.

7.3.2.3 Estimation and Models

In order to obtain volume estimates by stem quality and assortments a new timber assortment model was developed during the latest timber supply study in Austria (Eckmüllner and Schedl 2009; Eckmüllner et al. 2007; Neumann and Schadauer 2007; BFW 2009). The model can be applied to individual stems to convert them into merchantable assortments. The assortment model consists of several sub-models like taper curve models, bark thickness models, and assortment algorithms, and it requires the following variables: management type, elevation above sea level, tree species, dbh, tree height, height to the living crown base, damage from bark stripping, felling and logging, length of rotting, stem quality independent of damage, sweep of the bole. The output of merchantable assortments corresponds with the currently effective Austrian timber trade guidelines (Kooperationsplattform Forst Holz Papier 2006). According to the results of the latest timber supply study the quality classes of round wood available until 2020 are distributed on average to 3 % grade A, 45 % grade B, 23 % grade C, 4 % grade Cx and logs with butt rot, 12 % logs with low diameters and 19 % industrial round wood. However, the actual use of wood is not only driven by qualitative attributes but also by the wood market sentiment. The high demand for energy wood nowadays leads to the utilisation of lower quality classes for energy production.

7.3.3 Assessment of Change

7.3.3.1 Assessment and Measurement

The estimation of increment and drain in the Austrian NFI is based on the field measurements on permanent plots at two consecutive points in time. Sample trees can be distinguished into trees present only at the first occasion, trees present at the first and second occasion, and trees present only at the second occasion. Sample trees present at the first occasion and that are no longer present on the plots at the second occasion are recorded in the field assessments and the type of harvesting is determined. Depending on the size of a sample tree different variables are measured. For trees with a dbh ≥ 10.5 cm the dbh, tree height (h), height to the living crown base (hk), and the upper diameter at 3/10 of the tree height (d03h) are measured. For sample trees with 5.0 cm ≤ dbh ≤ 10.4 cm the dbh and h are measured. Variables such as h, hk, and d03h are measured on a sub-sample of sample trees during certain field assessment periods. Tree heights and hk were measured on all sample trees in the first NFI (1981–1985) and in the seventh NFI (2007–2009). In between, height measurements were recorded for a sub-sample of sample trees. Upper diameters were measured in the first assessment period for all sample trees and on sub-samples afterwards. Data models are applied to predict the missing values. In each inventory also the status "living" or "dead" of each sample tree is assessed.

7.3.3.2 Estimation of Increment

The increment estimated by the Austrian NFI is defined as the volume increment of survivor trees between two field assessment periods plus the volume of ingrown trees that exceed the dbh-threshold of 5.0 cm between the two points in time (Schieler 1997). This corresponds to the gross growth of the initial volume including ingrowth as defined by Beers (1962). The volume of the sample trees is calculated by applying the volume models given in formulas (7.1) and (7.2). The stem volume (V) of trees with 5.0 cm ≤ dbh ≤ 10.4 cm is calculated as:

$$V = f(c_i, \text{dbh}, h) \tag{7.1}$$

and the stem volume (V) of trees with dbh ≥ 10.5 cm is obtained from:

$$V = f(c_i, \text{dbh}, h, \text{d03h}, \text{hk}) \tag{7.2}$$

where dbh is the diameter at breast height, h the tree height, d03h the upper diameter in 3/10 of the tree height and hk the height to the living crown base. The coefficients c_i of the volume models were estimated by Braun (1969), Pollanschütz (1974) and Schieler (1988). The volume estimates contain all stem parts above stump height and include the tree elements bole plus bark and the stem top. Other change components, such as the increment of trees that between cycles die, are felled, fall over naturally, or grow into the sample as nongrowth, are not part of the increment estimate. Also the trees on land areas converted to forest or changing from forest to other land uses are not included in increment estimates. The increment estimates of the Austrian NFI are average annual increments for the time period between two field assessments. To obtain increment per hectare and total increment, the increment data of individual sample trees are converted into annual and per hectare values for each sample plot. For angle count trees the increment per hectare is calculated by referring to the dbh at the time of the first measurement. The plot-level estimates are averaged to obtain the mean increment per year and hectare and furthermore multiplied by the forest area to calculate the total increment. National estimates are gross increment and they are calculated for forest management classes, ownership categories and tree species. Also gross increment in units of biomass can be calculated, but are not part of the standard estimation procedures. These biomass increment estimates can include other tree parts apart from the stem, like branches and needles, and the below-ground parts. The biomass estimates for these tree elements are obtained by applying the models developed in a special study (Weiss 2006) and the generic models of Wirth et al. (2004) and Wutzler et al. (2008).

7.3.3.3 Estimation of Drain

The drain estimated by the Austrian NFI is defined as the volume of trees that were found to be harvested between two field assessment periods. The volume of the sample trees that are found to be harvested is calculated by using the tree measurements at the first occasion. The volume models given in formulas (7.1) and (7.2) are used. The volume estimates contain all stem parts above stump height and include the tree elements bole plus bark and the stem top. The increment of the sample trees between the measurement at the first occasion and the harvest is not taken into account in harvest estimates. The volume of felled trees on land areas converted to other land-uses is included in the drain estimates. The drain estimates of the Austrian NFI are average annual volumes of drain for the time period between two field assessments. Drain per hectare and total drain are obtained by referring to the situation and the number of trees represented by the sample trees at the time of the first assessment. National estimates are calculated for forest management classes, ownership categories, tree species and types of fellings. Drain can also be calculated in units of biomass. These estimates can include other tree parts like branches and needles, and the stump and root biomass of felled trees. The models cited beforehand (Weiss 2006; Wirth et al. 2004; Wutzler et al. 2008) with regard to biomass increments are also applied to obtain harvest biomass estimates.

Besides the periodic drain estimates of the Austrian NFI, annual statistics on the amount of wood harvested in Austrian forests are compiled in the "Holzeinschlagsmeldung", which is published by the Federal Ministry of Agriculture, Forestry, Environment and Water Management (e.g. BMLUFW 2012). These statistics are based on three methods of data collection and include a sampling survey in selected forest properties having forest areas between 2 and 200 ha, a full census in forest properties from 200 ha upwards, and expert judgement. The application of the data collection methods varies for the federal states. The estimates given by the "Holzeinschlagsmeldung" are lower compared to the NFI estimates. The differences are mainly due to the fact that the "Holzeinschlagsmeldung" reports commercial volume under bark whereas the Austrian NFI reports standing gross volume.

7.3.4 Other Wooded Land and Trees Outside Forests

7.3.4.1 Assessment and Measurement

The sampling grid of the Austrian NFI covers all land-use classes and ownership categories of the federal territory of Austria. Shrub-land is defined at the national level and is a separate category during field assessments. It broadly corresponds with the Other Wooded Land definition of FAO (2004). Measurements on trees have been limited to productive forest, i.e. the area that is available for wood production. In forests with protective function and without yield, volume was assessed in the fifth and sixth NFI (1992–1996 and 2000–2002) by expert evaluation and guided by the formula of Denzin (1929). Trees on shrub land have not been measured nor their volumes estimated. In the most recent seventh NFI 2007–2009 angle-counts were conducted on the sample plots located in forests with protective function and without yield and on shrub-land to capture the tree volume on these areas. Also site-specific and some stand-specific variables were collected. The land-use category and management type was also determined for plots located outside the forest. The trees on these plots were not subject to measurements or rough estimation during the field assessments. However, a remote sensing study focusing on the comparison of the national definition and the FAO (2004) definition of forest and other wooded land also distinguished the category of other land with tree cover.

7.3.4.2 Estimation

The area of shrub-land according to the national forest definition is included in the forest area estimate. However, separate area estimates for shrub-land are available as given in Table 7.2. The latest NFI 2007–2009 provides volume and biomass estimates for shrub-land according to the national definition. Specific models have been developed to calculate the estimates for shrub-land areas. In the most recent NFI also the definition for Other Wooded Land of FAO (2004) was applied in the field assessments. Thus, an area estimate according to the FRA definition is available. Other land with tree cover is currently not comprehensively assessed as it is not considered as the primary domain of the NFI. However, area estimates for this land category could be obtained but have not been calculated until now. Such estimates become more feasible due to the increased use of wall to wall remote sensing.

7.4 Conclusion

The availability of wood and biomass resources has become an increasingly important issue in the recent years both nationally and at a European scale. Therefore reliable data and information about the amount of wood and biomass available on a sustainable level are essential to develop strategies that take into account the multiple forest functions including: economic use, nature conservation and protection, and recreation. The Austrian NFI as the largest national forest monitoring program has continuously broadened its thematic scope since its establishment in the 1960's. Through the integration of additional data from various sources like remote sensing, but also other relevant cartographically mapped information, the Austrian NFI has become a multisource forest monitoring program that is able to answer future questions on many thematic areas. With regard to the estimation of available wood and biomass resources, the consideration of new reporting requirements will provide further methodological developments to satisfy the information needs of decision makers.

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Chapter 8
Belgium (Wallonia)

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8.1 The Belgian Regional Forest Inventory (Wallonia)

8.1.1 History and Objectives

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

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

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

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

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

8.1.2 Sampling Methods and Periodicity

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

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

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

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

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

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

8.1.3 Data Collection

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

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

8.1.4 Data Processing, Reporting and Use of Results

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

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

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

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

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

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

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

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

Change estimation of growing stock increment is obtained from the comparison of the two RFIs. Only the plots re-measured within a five year period and which were already located in forest land at RFI1 are selected for the calculations (50 % of the re-measured plots). Plots which changed their location and plots which were not forest land at RFI1 but become forest land at RFI2 are excluded. All trees of the selected plots measured at the first and/or second inventory are included in estimations. Increments per hectare are obtained by referring to the measurement at the first occasion.

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

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

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

8.2 Land Use and Forest Resources

8.2.1 Classification of Land and Forests

8.2.1.1 General Land Classification

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

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

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

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

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

Agricultural land is divided into: agricultural buildings, cropland, grassland, nursery and fallow land. The nine classes which compose the built-up land are: settlements, shops, industrial estate, major road infrastructure, minor road infrastructure, on duty railway infrastructure, disused railway infrastructure, mining, military property, others. The non-forest land with tree cover is divided into: parks, tree lines (along the river banks), hedgerows, isolated trees, orchards, Christmas trees plantations, wooded slope, and trees alignments.

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

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

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

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

8.2.1.2 Forest Classifications by Use

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

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

8.2.1.3 Classification by Ownership Categories

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

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

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

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

8.2.1.4 Forest Management and Cutting Systems

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

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

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

According to the RFI2 data already available, 56 % of stands had harvesting activities since RFI1, of which 9 % of felled high forests were clear-felled and 91 % were thinned. Three types of thinning are carried out: systematic, selective and sanitation. Three thinning intensities are also distinguished; light, medium and strong. More than 90 % of thinnings are selective. The aim of the thinnings is not described in the field.

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

8.2.1.5 Legal and Other Restrictions for Wood Use

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

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

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

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

8.2.1.6 Further Classification of Forests

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

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

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

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

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

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

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

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

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

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

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

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

8.2.2 Wood Resources and Their Use

8.2.2.1 Standing Stock, Increment and Drain

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

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

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

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

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

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

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

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

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

Tree species	Standing stock (Million m^3)	Increment (1000 m^3/year)	Drain (1000 m^3/year)
Norway spruce (*Picea abies*)	45.8	2126	2842
Other conifers	13.4	530	426
Oak (*Quercus robur*, *Quercus petraea*)	23.7	386	243
Beech (*Fagus sylvatica*)	16.1	448	427
Other broadleaves	14.8	433	206
Total	113.1	3923	4144

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

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

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

8.2.2.2 Tree Species and Their Commercial Use

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

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

8.3 Assessment of Wood Assessment of Wood Resources

8.3.1 Forest Available for Wood Supply

8.3.1.1 Assessment of Restrictions

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

8.3.1.2 Estimations

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

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

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

8.3.2 Wood Quality

8.3.2.1 Stem Quality and Assortments

In Wallonia, timber is sold standing in the forest. Sales of logs are very scarce except in private forests. Assortments are based on circumference (150 cm above ground) only. The current standards comprise seven commercial classes for broadleaves (100–119 cm, 120–149 cm, 150–179 cm, 180–199 cm, 200–219 cm, 220–249 cm, 250 cm and more) and eight commercial classes for conifers (20–39 cm, 40–59 cm, 60–69 cm, 70–89 cm, 90–119 cm, 120–149 cm, 150–179 cm, 180 cm and more) (Fédération nationale des experts forestiers 2014).

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

8.3.2.2 Assessment and Measurement

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

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

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

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

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

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

8.3.2.3 Estimation and Models

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

8.3.3 Assessment of Change

8.3.3.1 Assessment and Measurement

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

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

8.3.3.2 Estimation of Increment

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

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

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

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

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

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

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

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

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

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

$$I = k(VB - VA)/p \quad (8.3)$$

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

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

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

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

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

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

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

8.3.3.3 Estimation of Drain

The Walloon RFI defines drain as the volume of the felled trees between the two measurements periods. The volume of those trees is based on the c150 at the moment of harvest (see Sect. 8.3.3.2 for the c150 estimation procedure). Volume is calculated with the Eq. (8.2). The volume estimates concern the stem part above stump with bark but without stem top and without branches. The volume of branches until the 22 cm circumference threshold can be added if needed. The volume of trees which have reached the c150 threshold after RFI1 and have been harvested before RFI2 are excluded from the drain estimate. The volume of felled trees on land areas converted to other land-uses is included in the drain estimates. The drain estimates are referring to mean periodic volumes of drain calculated for the period between RFI1 and RFI2. The first assessment is considered as the reference situation for the total drain calculation. Walloon drain estimates are calculated for stand types, ownership categories and tree species.

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

8.3.4 Other Wooded Land and Trees Outside Forests

8.3.4.1 Assessment and Measurement

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

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

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

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

Data for the 2008 period

8.3.4.2 Estimation

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

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

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

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Chapter 9
Bosnia and Herzegovina

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9.1 The Bosnia and Herzegovina National Forest Inventory

9.1.1 History and Objectives

Bosnia and Herzegovina (BH) has valuable forest resources and a long tradition in forest activities. The Bosnian state forests have been subject to organised management in legislation and have had an economic focus since the middle of the 19th century (Dimitz 2012).

The first national forest inventory in Bosnia and Herzegovina (NFI1) was conducted in the period 1964–1968. The main purpose of this inventory was to develop systems of forest classification and to contribute to the forest sector through the development of long-term management plans. The statistical design and main

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characteristics of NFI1 was based on the methods used in the third Swedish NFI. The inventory assessed data and information about quantities and structures of forest areas, forest types, forest soil types, growing stock, yield, allowed cut, measures for reforestation and forest road infrastructure (Matić et al. 1971). Since the completion of NFI1 the forest status classification has been occasionally revised.

In more recent years, the need for a second national forest inventory was expressed in the context of forest sector development following the war. The second national forest inventory (NFI2) was completed in period 2006–2009. NFI2 was performed on the whole country area through cooperation of responsible ministries in the two entities: Federation Bosnia and Herzegovina (FBH) and Republic of Srpska (RS). It was financed by the World Bank under the Forest Development and Conservation Project (FDCP 2010).

NFI2 was designed to monitor the status and changes in all forests at a national level for the purpose of fullfilling information needs at regional, national and international level (Dundjer 2008). The general aims of NFI2 are:

- the estimation of forest resources and changes (forest area, growing stock, yield, quantity and character of cut)
- the assessment of forest health and identification of the need for forest management operations to improve the forest health status
- the comparative analysis of results in two forest inventories (the first and the second) considering the same area and national level
- to facilitate reporting to international programmes and initiatives (UN-FAO, MCPFE, Kyoto protocol, ICP and others)
- to collect data and information for scientific research.

The specific aims of the NFI2 were to estimate the:

- quantity of wood resources and the quality of wood production in forests and forested areas
- quantity of annual yield
- quantity and quality of wood to be cut to maintain continuity of production
- factors related to reforestation and proper ameliorative measures
- quantity of timber harvested
- accessibility to forest road and terrestrial characteristics
- forest health status and dead-wood quantities.

9.1.2 Sampling Methods and Periodicity

According to the NFI2 methodology (Lojo et al. 2007a), the approach applied to monitor the forest areas uses two steps, i.e. double sampling with stratification. The inventory concept was based on (1) forest and non-forested area estimations by

Table 9.1 System of concentric circles for tree selection

Diameter on breast height (cm)	0 ≤ dbh < 5	dbh < 10	dbh < 20	dbh < 30	dbh < 50	dbh < 60	dbh ≥ 80
Radius (m)	1.5	2.5	4.5	5.5	9.0	15.0	25.0

remote sensing and (2) field work for recording and measurement of wood attributes, yield, cut, forest types and other ecological elements.

Forest area estimations were based on remote sensing in two steps:

1. automatic classification of ortho-rectified fused multi-spectral and black-white images of high resolution (IRS LISS III 23 and 5.8 m) of forest cover (forest, non-forest)
2. photo interpretation of high resolution black-white images (IRS LISS III 5.8 m) of species mixture, development stage and canopy closure on sample plots (with radii 25 m) systematically distributed on 1 × 1 km grid. The grid was projected in Gauss Krueger Bessel Coordinate System—zone 6.

Automatic classification (unsupervised and supervised classification with minimum mapping unit of 0.2 ha) was performed according to CORINE standard identifying five categories: broadleaved forests, conifer forests, mixed forests, bares and other non-forested areas. Results were delivered in raster and vector formats.

Terrestrial recording was performed on sample of plots distributed on two types of systematic grids (two strata): 2 × 2 km in high forest (stratum 1) and 4 × 4 km in coppice, bushes and bare land (stratum 2). Attribute data collected are related to (1) general and administrative information, (2) site conditions and stand descriptions and (3) tree measurements and individual observations.

The sampling design was based on a systematic quadratic grid with a random start and clusters of four sample plots generated in quadratic form with a distance of 200 m between plots. Sample plots are geo-referenced and marked with hidden metal tubes to enable plots to be found for future field measurements.

Tree data collection on sample plots was based on Probability Proportional to Size (PPS) sampling using concentric circles up to 25 m radii (Matić 1977). Tree selection was based on diameter at breast (dbh) height and radius of concentric circles (Table 9.1). Other attribute data were assessed on various plot area sizes, including: regeneration (0.7 and 0.9 m), regeneration quality (7 m), dead biomass (7 m), stand description (25 m).

9.1.3 Data Collection

The methodology used in the NFI2 was based and developed according to long-term domestic classification systems. The most important forest attributes (areas and wood volume) are estimated using standard statistical methods and procedures. Beside, common forest information and estimates about areas and wood volume, the NFI2 methodology also considered:

- Estimates of registered and un-registered annual cut in m^3/ha
- Estimates of tree quality classes (national technical classification systems—four classes)
- Estimates of assortment structures for the total growing stock (tree logs—veneer and rotary, saw logs, round-wood and small wood, paper and fuel wood)
- Estimates of potential wood energy (from fuel wood, small branches, forest residuals, sawmill residue and coppice forests)
- Information about abiotic damage (wind, fire, frost, heavy hail stones, other damages)
- Information about biotic damage (insect, pathogen, wild, other damages)
- Forest health and vitality (good, bad)
- Trunk damage (damage width classes)
- Tree crown defoliation (five classes)
- Tree species biodiversity
- Regeneration information (height and diameter distributions)
- Estimates of dead wood in different forms (laying, assortment, old stumps, one-year stumps, standing dead tress)
- Estimates of wood biomass (t/ha)
- Estimates of carbon quantity (t/ha)
- Estimates of wood energy potential (ton of coal equivalent per year (tce/y) and —ton of oil equivalent per year (toe/y)).

Stand variables

Multiple stand and site variables were collected on each sample plot, including:

- Stratum
- Ownership
- Plot accessibility
- Administrative unit
- Altitude
- Slope terrain
- Exposition
- Harvesting restriction
- Homogeneity
- Rockiness
- FAO forest classification (native forest, productive forest, half-nature productive forest, culture)
- Regeneration (natural, natural with artificial regeneration, artificial regeneration, shoots)
- Stand structure
- Development stage
- Age of dominant trees
- Canopy

- Mixture
- Damage
- Management system
- Enhancements required
- Competing vegetation
- Raw humus
- Grazing
- Erosion
- Micro-relief shape
- Reforestation need
- Dead wood
- Forest structure (crown coverage, stand structure, development stage)
- Stand stability

Tree variables
Tree-specific variables included:

- Species, diameter at breast height
- Quality class
- Increment
- Social status
- Crown damage
- Stem damage
- Tree height
- Disease presence
- Cause of damage
- Defoliation
- Stump quality
- Legal/illegal cut.

9.1.4 Data Processing, Reporting and Use of Results

Forest area and forest attributes estimates are based on the described sampling plan. The forest area is determined on the basis of the number of sample plots distributed on different classification units. The most important forest attributes (growing stock, wood volume, increment) are calculated for each sample tree, then aggregated for sample plot and using conversion factor recalculated on a per ha area basis.

Change estimates
Change estimates are provided for area and growing stock. They are expressed as the difference between two NFI's with a time difference of 41 years. Preliminary results showed significant changes for area and growing stock (Lojo et al. 2008). Changes in growing stock are calculated for all productive forest. Results are

presented in total wood volume (tree volume including small branches and needles for conifers, without stump) while such results were published in the NFI1.

As one of the stated aims of inventory was to facilitate international reporting, the methodology was developed taking into consideration FAO/FRA (FAO 2010) and MCPFE definitions (MCPFE-UNECE/FAO 2006). The national definitions included in the methodology are compatible with the international reporting definitions, such as FRA.

Publication of the official NFI2 results, containing tabular and graphical results with associated discussion, has been prepared in local language (Lojo et al. 2016).

9.2 Land Use and Forest Resources

9.2.1 Classification of Land and Forests

9.2.1.1 General Land Classification

According to the NFI 2 methodology (Lojo et al. 2007b) forests are defined as:

> Areas of land covered with specified forest trees on the surface/area larger than 0.16 ha, minimum width 20 m, with soil cover level higher than 20 %, regardless of age, raised from seed or stump sprout other root sucker.

Other areas covering agricultural land, orchard, urban surfaces, town parks, public roads and permanent water surface/watercourse (main river watercourse and lakes) were not assessed.

Also included as forest are areas with smaller soil cover on temporarily deforested areas, which can be a result of natural disasters or human activities (clear cutting/felling). On these areas tree growth is expected in the near future and a soil cover of a minimum of 20 %. All those areas are included regardless on purpose of their use.

Forest areas also include surfaces of (i) forest roads (with one lane width up to a maximum of 5 m maximum if they are placed inside forest complex; (ii) watercourse with riverbed up to 7 m width; (iii) areas with lanes/riding cut whose basic function is to protect forest from fire and devastating effects of the wind; (iv) shelter belts (width wider than 20 m and minimum surface 0.16 ha).

In this category the following features are excluded: watercourse surfaces with riverbed wider than 7 m width or public roads (width more than 5 m, with two lines), sterile compact stone surfaces inside forest with diameter larger than 10 m."

Nationally, Other Wooded land is described as:

> In this category all areas, regardless of size, which do not qualify as forest are included. This includes scrub and bare, productive or unproductive areas (sterile compact stone surfaces inside forest with diameter larger than 10 m) and all the other areas inside forest complex or forest land, which are or can be used for forestry production or accomplishment of other forest benefits even forest protection.

Table 9.2 Forest accessibility classes by area based on the national definition (Second NFI, 2006–2009)

Class name	Area (1000 ha)	Area (%)
Accessible	2664	82
Restricted topographically	155.2	5
Restricted access	11.8	0
War-mined	420.1	13
Total forest land	3231	100

Forest areas and non-forested areas relevant for forestry sector, defined according national definition, covers more than 60 % of total area of the country. Around 55 % are forested areas while the rest belongs to other categories.

Out of total forest area (3,231,000 ha), 82 % are accessible, about 5 % are restricted topographically, about 0.4 % are restricted accesses and the remaining 420,100 ha are inaccessible due to high risk of mines from the past war (Table 9.2).

9.2.1.2 Forest Classification by Use

According to the Methodology (Lojo et al. 2007b) all forests and areas inside forest administrative unit are divided into different vegetation types: high forest, coppice forest, shrubs, bare lands and other wooded land. Vegetation types are connected with land-use classes for national and international reporting for FAO (Table 9.3).

The high and coppice forests represent all productive forest. Also, the high and coppice forests are the most important management units for strategic planning. Shrubs and bare lands belong to the other forested land. The other land is a category within forest and forested land but without forest production of interest.

High forest with natural regeneration dominates and covers more than 50 % of forested area, coppice forest covers more than 40 % and other forest categories appears less the 1 % of total forest area (i.e. sprouts, OLwTC, other forest land).

Table 9.3 Classification of forest land by area based on the national definition (Second NFI, 2006–2009)

National classification		Area (1000 ha)	Corresponding FAO classes (FAO 2004)
Productive forest:	1. High forest	1652	Forest
	2. Coppice forest	1252	
Other wooded land Shrubs and bare land	3. Shrubs	131	Intersection with OWL
	4. Bare land	187	OL
Other unproductive wooded land	5. Other unproductive wooded land	9	Intersection with OWL
	All forest, forested and other land (1 + 2 + 3 + 4+5)	3231	FAO forest (1 + 2 + 3 + 5)

In high forest areas with natural regeneration broadleaved forests prevail on about 50 % of area, mixed broadleave-conifer forests occupy about 30 % and the remaining 20 % are conifer forests. In coppice forest broadleaved forests dominate.

9.2.1.3 Classification by Ownership Categories

Two types of ownership are registered in NFI2: the state owned and private owned forests. The majority of the forest area (2,260,000 ha or 70 %) is state owned.

9.2.1.4 Forest Management and Cutting Systems

The prevailing management system relates to selective cutting while other management systems appear on smaller areas (felling of groups of trees due to regeneration, felling of groups of trees on large area, clear cut of groups of trees, clear cut on large areas, thinning in even-aged stands, sanitary cut, no cut). The highest growing stock and increment (m^3/ha) appears in selective forests, particularly in high conifer forests and high mixed beech (*Fagus sylvatica*), fir (*Abies alba*) and spruce (*Picea abies*) forests. Beech is the most dominant broadleaved while the fir is the most common conifer. Coppice forests contain low productive beech, sessile oak, thermopile oak and other coppice forest.

It is worth noting that more than 90 % of forests are native uneven-aged multilayered mixed forests that demand specific classification systems, sampling rules, forest management system and other considerations. These forests are characterised by: selection system of management of forests, two-layers, group of trees-selective and structurally even-aged forests systems management. Less than 10 % of forests are even-aged forest stands.

About 70 % of forests appear below 1000 m above sea level, on low slope terrain, distributed equally on all exposition (north, south, east, west). High conifer forests and high mixed beech, fir and spruce forests dominate in the middle altitudinal belt.

9.2.1.5 Legal and Other Restrictions for Wood Use

All productive accessible forests are available for regular use. Within productive forests (high and coppice forests) some areas are designated as forest of special purpose. They are related to:

- Water protected zones
- Protected national parks
- Biodiversity conservation
- Seed stands
- Forest nursery

Table 9.4 Productive forest area based on the national definition by species (Second NFI, 2006–2009)

Tree species	Area (1000 ha)	Area (%)
Beech forest (*Fagus sylvatica*)	670	31
Conifer forests and mixed conifers/broadleaves forests in area beech and fir (with spruce) forests	599	28
Pine forests (*Pinus* spp.)	136	0
Common oak forests (*Qurecus robur*)	52	6
Sessile oak forests (*Quercus petrea*)	356	2
Thermopile oak forests (*Quercus* sp.)	225	16
Wilow, poplar and alder forest	30	10
Pioneers forest communities	35	1
Exotic forest stands	30	2
Secondary beech forest	41	1

- Experimental plots
- Recreational forest
- Forest of importance for military defence.

Routine forest management is restricted in protected national parks and reserves. About 40 % of the forested productive area is accessible, which means (1) without mines from the war or (2) accessible by foot or other means and with no relief problems. More than 400,000 ha are assigned as inaccessible due to high risk of mines left from past war.

9.2.1.6 Further Classification of Forests

National classification by species considers dominant species and group of specific species (Table 9.4). Forests can also be classified according to age of dominant trees in 10 year classes up to 20 years and then in 20 years width classes up to 140 years and more.

9.2.2 Wood Resource and Their Use

9.2.2.1 Standing Stock, Increment and Drain

According to the national definition, wood volume estimates are expressed in m^3/ha and represents total tree volume on those trees with a diameter on breast height (dbh) above 7 cm (Table 9.5). Total tree volume is trunk volume with bark, large and small branches (needles) without stump to tip. Tree volume with dbh above

Table 9.5 Definitions for volume of standing stock and increment

Quantity	Definition
Standing stock	Tree volume where dbh is above 7 cm, including large branches volume (above 7 cm), bark included and without stump
Increment	Tree volume increment was determined as the difference between current tree volume and tree volume ten years ago (without bark)

7 cm is trunk with large branches volume (above 7 cm), bark included and without stump. The wood increment for trees with dbh above 7 cm was generated on the same way using different volume tariffs.

Total biomass was calculated using total tree volume estimates multiplying them with wood density for broadleaves and conifers according to IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). Then total biomass is multiplied by BEF (biomass expansion factor) according to IPCC Good Practice Guidance for LULUCF (IPCC 2003). Finally for underground biomass shoot-root ratio was used (broadleaves 0.35 and conifers 0.32). The total carbon content of the wood was expressed multiplying biomass by 0.5 conversion factor.

Forest available for wood supply contains productive forest land that includes accessible high and coppice forests. The volume of standing stock and increment are given in Table 9.6. Average growing stock calculated for productive forests (high and coppice) achieves about 200.6 m^3/ha with growing stock of 266.0 m^3/ha in high and 97.4 m^3/ha in coppice forest. About 11.2 million m^3 of volume increment are produced per year and about 5.8 million m^3 is harvested annually. The highest growing stock and increment is found in conifer forests and mixed conifer/broadleaf forests with beech, fir and spruce.

Table 9.6 The volume of standing stock and increment on productive forest land (Second NFI, 2006–2009)

Forest types	Standing stock (1000 m^3)	Increment (1000 m^3)
Beech forest	145,796	3825
Conifer forests and mixed conifers/broadleaves forests in area beech and fir (with spruce) forests	185,598	4734
Pine forests	19,682	582
Common oak forests	9442	241
Sessile oak forests	47,027	1112
Thermopile oak forests	8870	269
Wilow, poplar and alder forest	3454	64
Pioneers forest communities	2432	567
Artifical alohtone forest stands	3307	120
Secondary beech forest	10,112	248
Total	435,721	11.252

9.2.2.2 Tree Species and Their Commercial Use

The highest growing stock and increment (m^3/ha) appears in selective forests, particularly in high conifer forests and high mixed beech, fir and spruce forests. The prevailing management system is related to selective cutting while other management systems appear on smaller areas (felling of groups of trees due to regeneration, felling of groups of trees on large area, clear cut of groups of trees, clear cut on large areas, thinning in even-aged stands, sanitary cut, no cut). The most important species are beech, fir and spruce.

9.3 Assessment of Wood Resources

9.3.1 Forest Available for Wood Supply

9.3.1.1 Assessment of Restrictions

Two types of restrictions in sample plot terrestrial measurement occurred in BH inventory: topographically inaccessible plots and plots on war-mined areas. Topographically inaccessible plots were distributed on high slope terrain. Such areas are classified as "inaccessible productive forest" and included in "other wooded land" category.

Forested areas with mines from past war are distributed mainly at the forest border and at the former war confrontation lines. Such areas are marked and planned for the mine cleaning.

9.3.1.2 Estimations

The estimates for inaccessible areas are taken from similar accessible areas and those values are pronounced as official.

9.3.2 Wood Quality

9.3.2.1 Stem Quality and Assortments

Two classification systems for wood quality are in use in BH forest management. The first one is related to the stem quality of standing trees according to silvicultural aspects (UTK) while the second one is related to the quality classes of technical characteristic for assortments (TK) (Matić 1977).

The UTK classification provides important information for growing stock and yield estimation while the TK classification supports estimation of assortments of wood products held in growing stock. Each tree with a DBH of over 5 cm on the inventory plots is classified into one of three classes: I, II or III.

The TK classification arises from the UTK classification. A tree can be classified in one of the four TK classes: I, II, III, IV for dbh above 20 cm, and three TK classes for dbh below 20 cm dbh. This classification in combination with wood quality (quality classes) provides the insight about the products for the timber industry.

9.3.2.2 Assessment and Measurement

Stem quality classification system of standing trees according to silvicultural aspects (UTK)

According to UTK classification all healthy trees with normal form are classified into the *first class* (I). These trees are used for making the best quality logs in the wood industry or there is a good chance that, for young trees, they could be of this quality (veneer logs, logs for rotary cutting and saw logs). The crown also must be healthy and normally shaped with leaves/needles of a healthy colour. A deformation in the first metre in height from ground level may be tolerated. Stem must be clean and straight with living branches thinner than 3 cm and dry branches thinner than 2 cm. In the first UTK class the following attributes are not tolerated: curvature, tree fork (in above 1/3 of height can be tolerated), twisting, injury (lower than 5 cm horizontally can be tolerated), damage of the crown, suppression from other trees, damaged or dry top and infections (less than two bushes of *Viscum album* or *Melampsorella caryophyllacearum can be tolerated*). Also, if the tree crown is eccentric or extremely wide with thick branches, the tree will not be classified as the first class.

In the third UTK class (III) healthy trees with poor form are included. These trees are used for producing cellulose wood, fire wood and logs of the lowest quality only. Also included in the third class are all very damaged, infected and injured trees.

In the second UTK class (II), all trees that do not belong to the first or third class are classified.

Quality classes of technical characteristic for assortments system (TK)

Criteria for quality classes of technical characteristics for assortments system arise from the stem quality of standing trees according to silvicultural aspects.

The first quality class contains all trees of the first UTK class and all trees that are II and III UTK classes, if they satisfy the stem criteria. The stem criterion assumes the log is one or more pieces which in length is at least 1/3 of height from below (for fir and spruce, 1/4 for pines and 1/5 for beech). They must be clean and slightly tapered. One log (piece) cannot be shorter than 4 m for spruce and fir, 3 m for pines and 2 m for beech. On this part of stem the following attributes can be tolerated: deformation of the first part of stem from below (this depends on the tree species and diameter class—range is from 1 to 2 m), living branches thinner than 4 cm and dry branches lower than 2 cm, damage up to 5 cm horizontally, curvature up to 2 % for pines and up to 3 % for beech, groove up to 5 % of average diameter.

These classes are used for producing logs of the best quality for wood industry veneer logs, logs for rotary cutting and saw logs of the I and II class according to the assortments classification (JUS standards).

In the second quality class all trees of II UTK class and all trees of III UTK class that cannot be classified in the first class of technical characteristics (with small defects).

In the third quality class all trees which are not suitable to produce saw logs with minimal size and quality (the damaged trees affected by rotting are classified in the III class instead of the II class).

In the fourth quality class all tress of the III UTK with low quality from which can be produced fire wood and cellulose only. These are healthy trees with low quality from which cannot be produced saw log. Also included in the fourth quality class, are infected and rotten trees, as well as trees with large technical defects.

9.3.2.3 Estimation and Models

The model for grading standing trees into quality and assortment classes is based on tree dbh and TK quality classes (I, II, III, IV).

Annual assortment projections for a 10 year period were generated using data from the second NFI for veneer logs, saw logs, firewood, wood sliver and refuse and bark (Table 9.7). The projection is based on tree marking and technical classification applied in the management planning system. The tree marking identifies the trees to be removed in the coming years from a silvicultural point of view.

Table 9.7 The assortment according (Second NFI, 2006–2009)

Assortment	Conifers (m^3/year)	Broadleaves (m^3/year)	Total (m^3/year)
Veneer logs	17,811	158,758	176,569
Saw logs	1,810,659	2,045,883	3,856,542
Firewood	563,552	–	563,552
Wood sliver	338,888	1,700,669	2,039,558
Harvest loss and bark	21,933	3,157,867	3,179,801
Total	2,752,844	7,063,178	9,816,022

9.3.3 Assessment of Change

9.3.3.1 Assessment and Measurement

Changes to the forest resource between the two national forest inventories (the NFI1 1964–1967 and NFI2 2006–2009) have been already reported in preliminary results from NFI2 for the first test area (the north-west of Bosnia).

Wood volume estimation in NFI2 for all forests originating from the seed was based on species volume tables with two explanatory parameters (dbh and height) used in the first national forest inventory also. Volume tables for the following species were used:

1. Silver fir (*Abies alba*)
2. Spruce (*Picea* spp.)
3. Scot's pine (*Pinus syilvestris*)
4. Black pine (*Pinus nigra*)
5. Oak (*Quercus* sp.)
6. Beech (*Fagus* sp.).

These tables were published in the work "Grundner—Schwappah Massentaflen" (Schober 1952). For all other broadleaved tree species present in Bosnian forests (hornbeam, *Carpinus* sp.; maple, *Acer* spp.; ash, *Fraxinus* spp.) volume tables for beech were used.

9.3.3.2 Estimation of Growing Stock and Increment

Calculation of volume increment was based on local volume tariffs for the main tree species in Bosnia (Matić et al. 1963). For forests raised from stump sprout other root sucker, local tables were used (Drinić et al. 1990). Volume tariffs for these forests in BH were generated in 2004 (Koprivica and Maunaga 2004).

Tree volume increment was determined as the difference between current tree volume and tree volume ten years ago. It is interesting that tree volume increment calculation does not include the bark volume.

Due to lack of tree height data, tree volume in the first period was estimated using local volume tariffs (site index tariffs) which were made for main tree species in Bosnia (Matić et al. 1971; Drinić et al. 1990). Tables are based on three parameters: tree species, breast height diameter and tree height. Tree heights were used to determine site quality comparing them with site index curves given in Matić et al. (1963). For forest raised from stump sprout other root sucker local tariffs made by Koprivica and Maunaga (2004) were used.

Diameter increment for the ten year period was determined coring trees on the breast height and assessing ring width. From appropriate tariff sequence of tree volume, based on current tree diameter and tree diameter ten years ago, volume increment was calculated as difference between current tree volume and tree volume ten years ago.

Summing total tree volume increment and multiplying it with conversion factors, total wood increment was calculated and expressed in m^3/ha. Following the calculation of per hectare estimates for each tree, increment was calculated by tree species, classification and spatial units of forest.

An increase in forest area, growing stock and yield in high and coppice forests, has been observed as the primary output (Lojo et al. 2008).

9.3.4 Other Wooded Land and Trees Outside Forests

In NFI2, the category *Other wooded land* (OWL) was included in the inventory while *Trees outside forest* (TOF) were not. However, the national definition of OWL is not consistent with the FAO/FRA and/or FOREST EUROPE definitions.

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Chapter 10
Brazil

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10.1 The Brazilian National Forest Inventory

10.1.1 History and Objectives

Brazil is the largest country in Latin America, occupying an area of 8.5 million km^2, of which approximately 4.9 million km^2 are covered by forests (FAO 2015). Despite the importance of its forest resources, until recently the country did not have a national forest inventory to support public policies and strategic projects to promote the use and conservation of forest resources.

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In the 1980s Brazil had the unique edition of a national forest inventory, the main objective of which was to generate information on timber stock of natural and planted forests (Brena 1995; Machado 1984). Until that time, most national forest inventories had mainly focused on timber production (Holmgren and Persson 2002), covering specific regions to meet particular demand of information, as to support colonisation or planning programs. More recently, with the recognition of the wide range of values that forests provide, for production of goods, environmental services and social benefits, as well as for the emergence of new technologies, some Brazilian states have taken the initiative to undertake state forest inventories (Vibrans et al. 2012; Scolforo et al. 2008). Despite the positive aspects of state initiatives, for a country the size of Brazil, considering the high biodiversity, environmental, anthropogenic and economic gradients, the most appropriate alternative is to produce information about Brazilian forests based on a nationwide system, with a standardised methodology that meets the main national demands for forest information.

In 2005, the Ministry of Environment began a participatory process to develop a standard methodology for a national forest resource inventory, with the participation of national and international institutions. This is considered the starting point of the new National Forest Inventory of Brazil (NFI-BR) (Freitas et al. 2008).

The NFI-BR aims at producing information on forest resources, to support the formulation of public policies of use, restoration and conservation. The Brazilian Forest Service (BFS), an agency of the Ministry of Environment, is responsible for its coordination, in partnership with other institutions such as Embrapa, state environmental agencies, universities and research institutions.

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Among the motivations for the NFI-BR development is the strategic importance of forest resources, at national and global scales. However, there is still a lack of qualitative and quantitative information about Brazilian forests, to support national demands and also the Brazilian participation in the international agenda on forests, such as the FAO Global Forest Resources Assessment and the conventions on climate change (UNFCCC) and biodiversity (CBD) (Freitas et al. 2010).

This document aims at describing the main features of the National Forest Inventory of Brazil (NFI-BR), addressing methodological aspects and the status of its implementation.

10.1.2 Sampling Methods and Sources of Data

The demand for different data at varied scales makes the NFI-BR a multisource forest inventory, with a methodological framework that uses different databases to produce results on the state of forest resources nationally and allows the monitoring of forest resources over time.

10.1.2.1 Field Plots Sampling Design

The procedure for field data collection is based on systematic sampling with the distribution of clusters on a national network of sample points 648 seconds equidistant, which is approximately 20 km between sample points at Equator Line. The NFI-BR cycle is 5 years, although the first cycle is taking more than that. For the first cycle it is planned to collect data on all sampling points of the grid, whether or not they are on areas covered by forests. The grid of NFI-BR can also be applied at different intensities, such as 10 × 10 km, 5 × 5 km, 2.5 × 2.5 km, etc., to meet different goals and levels of accuracy. The intensification of the grid can be required, for example, to meet specific demands of states and municipalities, becoming a as a complementary part of the national network.

10.1.2.2 Sample Plots for Biophysical Data

The cluster is the sample unit and consists of four rectangular subunits of fixed area in a cross-shaped spatial arrangement (Fig. 10.1). The size of each cluster subunit is 1000 m^2 (20 × 50 m), where all trees with diameter at breast height (dbh) ≥ 10 cm are measured. Exclusively for the Amazon region, the subunits are 2000 m^2 (20 × 100 m) to improve data capturing of larger trees (dbh ≥ 40 cm). At the end of the first NFI-BR cycle approximately 15,000 clusters will have been measured.

Plot configuration for the NFI-BR is one cluster of 4 subunits of 1000 m^2 (20 × 50 m), a distance of 50 m from the grid sampling point, north-south oriented. Each subunit is divided into 10 × 10 m subplots. Two perpendicular 10 m transect lines crossing the centre of the cluster are used to measure necromass and litter. For

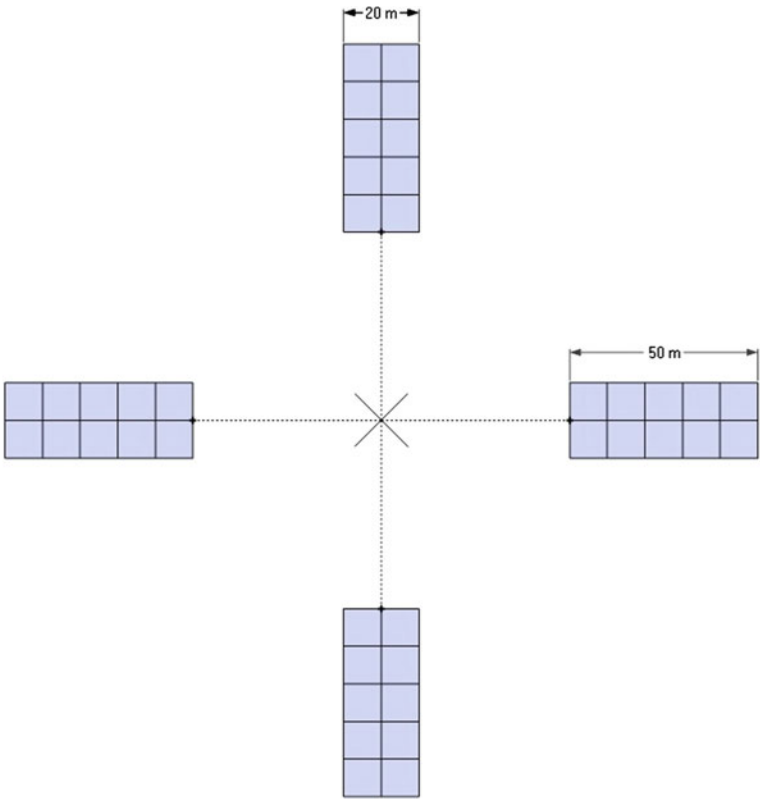

Fig. 10.1 NFI-BR sample plot design

Amazon region the size of each subunit is 2000 m^2 (20 × 100 m), extended to capture data of larger trees, with dbh ≥ 40 cm).

Data collected within each subunit comprise variables such as the tree species name, some classic dendrometric variables (dbh, height), qualitative variables such as stem quality and tree health, as well as some less traditional variables in forest inventories as necromass, litter and soil characteristics. Within each cluster subunit a classification of the predominant land use is recorded for each subplot of 10 × 10 m.

This large dataset will facilitate the characterisation of the forest environment in each sample point. Data collection is carried out by hired companies through a competitive process.

10.1.2.3 Interviews for Socio-environmental Data

As part of the field data collection, NFI-BR socio-environmental component aims to assess the relationship between people and forest resources. Around each cluster (2 km radius) up to four residents are interviewed to provide qualitative information to characterise how local communities perceive and use their forest resources. The interviewees respond, among many issues, about the importance of the forest in contributing to family income, the use of timber and non-timber forest products and which forest services are most valued by them. One part of the questionnaire is designed to capture the individual perception on the importance of forests and other sections cover topics. These topics encompass the demand on planted forests and forest restoration, adaptation to climate change and how much the respondents know about Brazilian laws related to forest uses and on public policies that may encourage them to manage forest resources.

10.1.2.4 Sample Units for Landscape Analysis

The landscape component of NFI-BR aims to analyse portions of the Brazilian territory through some qualitative indicators, such as the degree of forest fragmentation and the presence of riparian vegetation alongside rivers. Remote sensing techniques are used in digital image processing and spatial analysis, based on Rapid Eye and Landsat 8 satellite images.

The data are extracted from Landscape Sample Units (LSUs), which represent a source of intermediate data between the mapping and field data. Each LSU consists of a 100 km^2 polygon, with a center point that coincides with the NFI-BR grid, but at 40 × 40 km. Data from field clusters are integrated into the LSUs in order to provide information about ground truth in image classification procedures using Object Based Image Analysis (OBIA). The classification of LSUs into land cover/land use classes is based on satellite imagery and is an important source of information, as well as serves as input for other types of analysis on landscape. The following classes are being mapped: natural forest, planted forest, agriculture/pasture, natural grasslands, bare soil, urban areas and water bodies. Trees Outside Forest (TOF) represent a specific theme within the LSUs analysis and different approaches are being tested to discriminate and classify them using Rapid Eye imagery. By means of Morphological Spatial Pattern Analysis (MSPA) it is possible to assess the connectivity among forest patches (Vogt et al. 2007; Saura et al. 2011). Furthermore, the LSUs' analysis will also allow the identification of structural riparian corridors and connectors as well as their ranking (Clerici and Vogt 2012) with reference to conservation priority. This is especially important due to recent changes in the Brazilian Forest Law (BRAZIL 2012) concerning the extent of forest vegetation to be restored along rivers and water bodies.

10.1.2.5 Vegetation Mapping for Area Estimates

There are several government and non-government initiatives for vegetation mapping across the country. Many of them are adding good quality information on the vegetation types distributed all over the territory. They are state or regional initiatives, with different purposes and using different methods. The NFI-BR standard procedure will be also used to evaluate available initiatives aimed at updating these maps to support the planning of field activities, the national forest area estimates and the inferences made by the integration of field data and remote sensing.

10.1.3 Programmes Associated with the NFI

A set of associated programmes are intended to support the NFI-BR by improving methods and procedures, as well as producing additional information, that by its nature will not come from data collected in the regular procedures and components described in previous sections.

10.1.3.1 Field Crew Training

The standard NFI field crew consists of five people, which may be directly involved in biophysical data collection within the cluster and the social-environmental interviews. The team leader is responsible for coordinating the work and recording data; a technical assistant coordinates botanical sample collection and the second assistant is responsible for interviewing people. Besides these three technicians, there are two workers for hard tasks, such as path opening, climbing trees and sampling.

Each field crew must participate in eight-day training on NFI-BR methodology before starting the fieldwork. The training program comprises all procedures to collect data of each NFI-BR variable, how to use a GPS as well as first aid, safety and how to proceed in dealing with local communities. During the training all teams also have the opportunity to practice on the installation of clusters in several situations that may happen during fieldwork.

There are already over 300 people trained and able to participate in field teams. The experience of training adopted by NFI-BR format has proven necessary in order to assure standardisation of the proposed methodology, which is considered complex due to the large number of variables and the limited time of measuring in each cluster.

10.1.3.2 Quality Control and Assessment

The evaluation of quality control is one of the key points to assure credibility and the quality of national forest inventories. Quality control of NFI-BR is carried out at different levels.

The first level is an inspection and evaluation of each crew in the field, immediately after the field data collection starts. The evaluation and Quality Control teams monitor the work of data collection by the field teams for a few days, interacting with them and observing their difficulties, clarifying doubts and assessing compliance with the protocols, procedures and the use of recommended materials and equipment.

At a second level, during the data collection season a BFS Quality Control team visit several randomly selected clusters, having at hand the registration forms that were filled by the field teams. At this point the degree of compliance to NFI-BR methodology is carefully checked. This is done by recording a set of verifiers, including aspects such as proper allocation of the cluster, plot size, number of trees measured, number of identified species and land use classification, among others. In addition, to confirm the application of the social-environmental interview, at least one indicated residence is visited.

Moreover, each dataset sent to Brazilian Forest Service by the contractors goes through an evaluation process. It is evaluated to ensure that all fields are filled and that the data is of good quality and is consistent. This assessment is made for each set of data that is sent by the company and may imply a return to the field to data re-collection where issues have been identified.

The quality of botanical samples collected in the field are also assessed by experts as soon as the samples are received by the herbarium, aiming at checking the quality for botanical identification by comparison with herbarium's collection. Similar procedures are adopted by the laboratory in charge of the analysis, in order to verify the quality of soil samples, by checking if there was no violation of the packaging and any material loss during transport. Soil samples are collected at the cluster central point, at two depths (0–20 and 30–50 cm) for chemical analysis.

10.1.3.3 Botanical Identification in National Herbaria

Estimates suggest that there are more than 16,000 tree species in the Amazon region alone, many of which are still unknown and rare (ter Steege 2013). Of course, this great diversity impacts directly the NFI-BR fieldwork. Furthermore, a wide variety of tree species are known by different common names in different regions and it has been increasingly difficult to find para-taxonomists able to identify tree species in the field. Thus, the NFI-BR main strategy is to collect as much tree species botanical samples as possible for identification by experts in herbaria. The Brazilian Forest Service has established partnerships with herbaria in each state where data collection is ongoing. These herbaria receive the samples for identification by scientific name. The result is sent to the Brazilian Forest Service to merge with data of trees originally recorded in the field forms. By December 2014 approximately 126,000 field samples had been collected and sent to 14 different herbaria. One of each fertile sample collected in the country is also sent to Rio de Janeiro Botanical Garden, where a collection of species identified by NFI-BR is being formed. A challenge faced is the difficulty of collecting botanical samples, especially in the Amazon region due to the large size of the trees. Another challenge has been the identification of sterile specimens in herbaria, as it is not possible to find reproductive material for all species during field work.

10.1.3.4 Forest Research

The Research Program, coordinated by BFS in partnership with Embrapa Forestry, is designed to (i) improve the methodology adopted in all NFI-BR components and other associated programs; (ii) identify gaps of information or knowledge in the currently adopted methodology; (iii) establish partnership with research institutions enhancing NFI-BR results; (iv) provide NFI-BR with results that may be incorporated into the core methodology.

One of the main results expected from the NFI-BR is to improve the estimates of volume, biomass and carbon stocks existing in Brazilian forests. This will be possible because the field dataset will report the wide variation in carbon density among forest types, environmental gradients, stages of regeneration and degree of use and degradation of forests across the country. However, to improve actual estimation, appropriate allometric equations for each region, forest type and forest conditions should be used. The Brazilian Forest Service is carrying on a compilation of allometric equations available in literature to use in data processing and to identify gaps. For the identified gaps new data will be collected to develop new equations in partnership with research institutions. This initiative covers not only new allometric equations for standing trees, but other mathematical relationships to estimates carbon in all pools proposed by the IPCC (2006).

10.1.4 Data Processing and Analysis

Field data are sent to the Brazilian Forest Service, samples of plant material to an accredited herbarium for species identification and soil samples are sent to a laboratory for chemical analysis and carbon stock determination. The result of these analysis returns to BFS for data processing and analysis.

As the NFI-BR is based on a systematic sampling with clusters uniformly distributed over the entire country territory on “forest” and “non-forest” sites, the field data are also used to estimate the area of forest. The determination of volume, biomass and the number of trees is done by ratio estimators. The assessment of forest quality is based on the analysis of qualitative variables such as stem quality and health, evidence of harvesting and the general environmental condition within each subunit. Each sampling point of the grid is permanent and the changes are estimated by the difference in stocks among two occasions. Up to six months after the end of data collection, a summary report on forest conditions is prepared by state. This report presents strategic results on the extent of forests, biological diversity, forest production and environmental importance of forests for that state. In some cases, this period may be longer since the data processing depends on the completion of the botanical identification of tree species by herbaria. At the end of the cycle, detailed results will be presented and data will be available on internet.

10.1.5 NFI Cycle 1: Status of Implementation

The field data collection began in 2012 and up until December 2015 it was carried out simultaneously in 13 Brazilian states (Fig. 10.2). At the end of 2015, nearly 4,500 clusters were assessed, corresponding to approximately 148 million hectares. Two thousand tree species were already identified and 11,000 people interviewed in the NFI-BR socio-environmental component. The completion of the first cycle is scheduled for 2018. Among the challenges are the size of the country, the need for partnerships with states and institutions, as well as to guarantee funds for the second cycle.

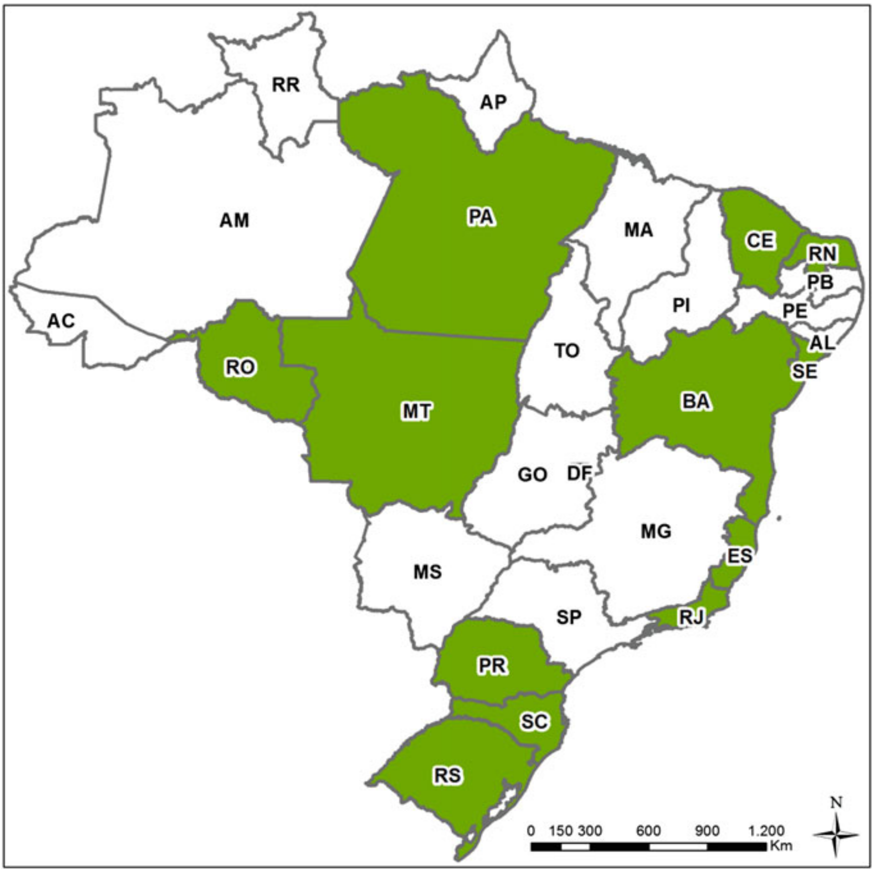

Fig. 10.2 NFI implementation by 2015 in 13 states (*RS* Rio Grande do Sul; *SC* Santa Catarina; *PR* Paraná; *RJ* Rio de Janeiro; *ES* Espírito Santo; *BA* Bahia; *DF* Distrito Federal; *SE* Sergipe; *RN* Rio Grande do Norte; *CE* Ceará; *MT* Mato Grosso; *RO* Rondônia; *PA* Pará)

10.1.6 NFI Results: Potential Applications

NFI-BR produces estimates at national and regional scale, per biome, state and in some cases by municipality. The data will be used to support strategic planning by federal government and states as well as to improve reporting to the international agenda on forests. This agenda includes the global assessment of forest resources (FRA/FAO), as well as demands for forest information from international conventions on climate change (UNFCCC), endangered species (CITES), biological diversity (CBD), and to combat desertification (UNCCD). More specifically, the NFI-BR results will be used to:

1. Estimate biomass and carbon stocks of forests
2. Provide knowledge on the Brazilian flora and regular production of biodiversity indicators
3. Estimate the stock of timber and non-timber forest products
4. Identify areas for expansion of planted forests and forest management
5. Identify priority areas for protection and forest restoration
6. Identify the occurrence and geographical distribution of forest species, including endangered species
7. Characterise the importance and use of forests by rural population
8. Support and plan of forest concessions
9. Support forest management at the municipal level
10. Landscape analysis and planning, as design programs to reduce forest fragmentation and forest restoration
11. Provide society with data and information, including uses for research, education, private sector and non-governmental institutions.

10.2 Land Classification and Forest Resources

10.2.1 Classification of Land Use and Forests

10.2.1.1 Forest Classification, Land Cover and Land Use

The NFI-BR adopts the definition of forest proposed by the United Nations Food and Agriculture Organization (2010), which establishes minimum values for evaluation in situ for area (0.5 ha), tree height (5 m) and canopy cover (10 %), besides the land use. For evaluations based on remote sensing the Brazilian vegetation classification (IBGE—Brazilian Institute of Geography and Statistics 2012) and the FAO definition, based on the attributes considered in FAO forest definition are both used. Thus, each type of vegetation mapped can be computed as forest or no forest.

For field evaluations, however, NFI-BR uses a land cover and land use classification that is more practical (Table 10.1) and requires no special knowledge on the different forest types in the country by the team leaders. This classification is used to describe the main land cover and land use class on each 10 × 10 m subplot, within each subunit of the cluster. It is important to note that the purpose of this classification in the field is to allow area estimates for different land classes, especially forested area, and also to facilitate data processing according to specific vegetation type characteristics. By doing so, the most appropriate allometric equation can be more appropriately chosen. Each of NFI code is ultimately linked to seven grand classes (Forest; other land with trees; Shrub; Natural grassland; Agriculture; Other anthropogenic areas; Other natural areas). NFI field classification also allows processing data for different purposes (FAO/FRA or IPCC classes, for example).

10.2.1.2 Classification by Ownership Categories

Since 2006, the BFS coordinates the National Registry of Public Forests (CNFP), in order to support forest concession system in public lands. Until November 2015, near 315 million ha of public forests were registered, including national forests, national parks, state forests, indigenous land, military areas, community forests and other lands of public domain. After the adoption of the new forest code (Law 12651/2012), BFS is also organising a national registry for private lands, called Environmental Rural Registry (CAR). This registry is focused on the compliance of each private landowner with environmental laws, including the requirement of maintaining a proportional area of each property covered by forest or any previous natural vegetation. This proportion varies according to the biome where the property is located. For example, for Cerrado biome, a minimum of 35 % of each private property should be covered by natural vegetation, while for Amazon biome it is required to keep 80 %. Law enforcement is being successfully achieved through the implementation of the CAR system. It is publically available on the internet, based on an open map server system, where updated satellite imageries allow each owner to register the property boundaries and land cover/land use classes. The information added by each owner is then validated by the government. The CAR registry will be soon considered a pre-requisite for obtaining financial credit for agriculture practices. By January 2016, approximately 263 million ha were registered in CAR, corresponding to approximately 66 % of the expected total area of private lands to be registered. Both CNFP and CAR systems are important to identify forests by ownership categories. As NFI data collection is based on a systematic sampling, its processing can provide results that will aim to characterise and to report on the quality of forests in public and private lands.

Table 10.1 Land cover/land use classes adopted in field work. Each 10 × 10 m subplot within each cluster subunit is assigned with the predominant land cover/land use (NFI code)

Grand class	Equivalent FAO class	National land classes	
		Intermediate category	Land use/cover classes or typical vegetation type
1	Forest	Natural forest	Typical forest
1	Forest	Natural forest	Mangrove (wooded)
1	Forest	Natural forest	Restinga
1	Forest	Natural forest	Cerrado
1	Forest	Natural forest	Caatinga
1	Forest	Natural forest	Campinarana
1	Forest	Planted forest	Any planted forest
2	Other land	Other land with trees	Forest fragments (<0.5 ha)
2	Other land	Other land with trees	Urban wooded lands
2	Other land	Other land with trees	Other areas with scattered trees
3	Other wooded land	Shrub	Any vegetation type with natural predominance of shrubs
4	Other land	Natural grassland	Natural grassland in any biome
5	Other land	Agriculture	Fruit tree plantation
5	Other land	Agriculture	Perennial bush crops
5	Other land	Agriculture	Short-cycle crops
5	Other land	Agriculture	Agroforestry system
5	Other land	Agriculture	Cultivated pasture
6	Other land	Other anthropogenic areas	Exposed soil, bare land
6	Other land	Other anthropogenic areas	Mining
6	Other land	Other anthropogenic areas	Rural infrastructure
6	Other land	Other anthropogenic areas	Roads
6	Other land	Other anthropogenic areas	Urban influence
7	Other land	Other natural areas	Beaches, dunes and sand areas
7	Other land	Other natural areas	Rocky outcrop
7	Water	Other natural areas	Open water

A correspondence with FAO definitions is also presented

10.2.1.3 Forest Management, Wood Resources and Their Use

Balancing forest protection and production is a permanent challenge for any country, but Brazil has made impressive progress toward this objective. For example, natural forest area estimation for 2015 is around 58 % of the country. The statistic considers all six biomes (Amazon, Caatinga, Savanna, Atlantic Forest, Pampa and Pantanal), given the FAO definition of forests (FAO 2015). Deforestation rates in the Brazilian Amazon have decreased significantly since 2004, stabilising around 6,000 km^2 $year^{-1}$ in the last five years, according to researchers of Brazil's National Space Research Institute and other institutions (Aguiar et al. 2016).

Forest management for timber production from natural forests, in Brazil, is carried out mainly in the high tropical forests of Amazon region and the dry forests of Caatinga. For Amazon, forest management is based on a polycyclic system, with selective logging of commercial trees with dbh ≥ 50 cm, given a maximum allowable cut of 30 m^3 ha^{-1} and a 35-year cutting cycle. A pre-harvesting 100 % inventory of commercial species is required for authorising cut and low impact logging techniques are required to avoid damage to soil and remaining tree species. For the dry forests of Caatinga, the forest management system is based on clear cutting, over a 15-year cutting cycle. The large majority of tree species of Caatinga have the ability to coppice. In both, Amazon and Caatinga, the total area is generally divided into stands, according to the annual cutting cycle. Although so far there is no formal role of the NFI in monitoring the quality of forest management, an indicative may be obtained by analysing data from NFI clusters located within areas licensed for forest management, though differences in scale and approaches shall not be disregarded.

Regarding wood forest products, in 2014, Brazilian native forests have contributed with around 50.8 million m^3, of which 13.8 million m^3 for industrial purposes (pulp, sawnwood, laminate flooring and wood panels) and 37 million m^3 for fuel (28.9 million m^3 for firewood and 8.1 million m^3 for charcoal) (BFS 2015).

In addition to the natural forest areas, of the 851 million hectares of Brazilian lands, 23.3 % is occupied by pasture, 6.2 % is planted with crops and 3.5 % accounts for infrastructure networks and urban lands. Brazil has 7.74 million hectares of planted eucalyptus, pine and other species used in the production of wood panels and laminate flooring, pulp, paper, energy production and biomass. That area equals 0.9 % of domestic territory. The Brazilian planted tree industry is responsible for 91 % of all the wood produced for industrial purposes in the country (IBÁ 2015). In 2014, gross revenue of the planted tree industry represented 5.5 % of the Industrial Gross Domestic Product (GDP) (IBÁ 2015) and planted forests produced near 239 million m^3, of which 132.7 million m^3 for industrial purposes and almost 106 million m^3 for fuel (56 million m^3 for firewood and 50 million m^3 for charcoal) (BFS 2013).

Below the umbrella of NFI-BR, some land use and land cover (LULC) classes, such as mangroves and planted forests have received special attention to ensure the development of appropriate methodology to capture reliable information, considering specific spatial characteristics that make them difficult to be monitored. Nevertheless, for planted forests it is necessary a specific and complementary methodology, aiming to capture information on genus, age classes and management regime. This methodology is being designed by the NFI team and will be tested in a pilot area still in 2016.

Despite all of these challenges, Brazil's activities in the overall effort against climate change and in the commitment regarding monitoring LULC represent one of the most important covenants made by any single country to date, having reduced its emissions by 41 % (GWP-100; IPCC SAR) in 2012 in relation to 2005 levels (MCTI 2014). Additionally, Brazil intends to adopt further measures (intended Nationally Determined Contribution—iNDC) that are consistent with the 2 °C temperature target. Specifically regarding land use change and forests, it is worthy to mention the commitment of restoring and reforesting 12 million hectares of forests by 2030, for multiple purposes and enhancing sustainable native forest management systems, through georeferencing and tracking systems applicable to native forest management, with the purpose of decreasing illegal and unsustainable practices (BRASIL 2015).

10.3 Conclusion

The NFI-BR is an important source of information on Brazilian forests even before completing its first cycle. The major difference and strength compared to other Brazilian monitoring systems is undoubtedly the field data collection using a standardised methodology throughout the national territory, including the challenging socio-environmental and the landscape analysis components. The existence of associated programs, such as training and quality control ensures the reduction of non-sampling errors and improves data quality. The NFI-BR sampling design also enhances the sample data by intensifying the grid. Flexibility to change variables at each cycle, depending on the demand for information, is also a benefit.

Another advantage of the NFI-BR is that it captures field data on forest and non-forest sites. Furthermore it also provides information on other land use classes and trees outside forests. Compared to traditional inventories, although a higher investment in time and funding is demanded due to the absence of any pre-stratification analysis, this type of information is still considered of high relevance, as it will track transition between land use classes, when data of different occasions are available.

Data produced by the NFI-BR will be useful to improve national estimates of volume, biomass and carbon stocks in Brazilian forests. The NFI-BR will also provide updated information on the state of forests and its relation to other land use/land cover classes at country level, playing an important role in the monitoring of national programs, whether aiming at the forest restoration or conservation, expansion of productive forestry systems or stimulating planted forests, in order to achieve SFM goals. The completion of the survey will enable Brazil to fulfill national and international reporting obligations and to monitor the sustainable development of the forest resource in the country.

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Chapter 11
Bulgaria

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11.1 The Bulgarian National Forest Inventory

11.1.1 History and Objectives

11.1.1.1 Forest Management Planning

Bulgaria has more than 110 years history of forest monitoring and forest management planning. The first State Service on Measuring and Organisation of Bulgarian Forests was created in 1901, when the first of three Forest Management Plans (FMP) were established. During the period from 1901 to 1919, 225,000 ha were inventoried and described during the FMP process (Raykov 2006).

Regardless of the strict requirements of forest laws, prior to 1944 only 28 % of forest areas were monitored using FMP's. The share of the whole forest area monitored in FMP for the different kinds of ownership is the following: 50 % for state forests, 22 % for the municipality forests and 8 % for the private forests. After the end of the Second World War, the forest sector and the Forest Management Organisation in Bulgaria developed quickly in order to satisfy the requirements of the time. During this period the State Service for the organisation of forests were transformed into an institute for research and development in agriculture and forestry (Agrolesproekt). From 1950 to 1954, 2,890,000 ha were inventoried and described in FMP's. During this period FMP's were completed for all forest areas. Forest management plans and programs specify the allowable amount of forest resources to be felled and issue guidelines to achieve the objectives of forest

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management for the area for the following 10 years. All forest management works undertaken are in accordance with the approved FMP's (Raykov 2006).

In the period 1955–1980 the original basis of the FMP process was improved by incorporating scientific methods. FMP were elaborated on the basis of forest types. During more recent years, Agrolesproekt invested considerably in new techniques and technologies. GPS was introduced into the FMP process. Now the country has completed GIS maps of the forest estate and attribute data can be captured in real time. Combined with the use of precise satellite images and remote analysis, the FMP data provides a comprehensive forest inventory and FMP for the next decade. The GIS system also increased the precision and effectiveness of the field work. FMP data are a valuable basis for the analysis, monitoring, assessment of global tendencies in our forests, as well as for planning, etc.

After 1997, with the restoration of forest property to former owners, private companies began to implement FMP in competitive conditions. According to Bulgarian forest Law (The Forest Act 2011) it is necessary to establish the state of resources by undertaking an inventory of the forest areas. Data from FMPs are public and the access to them is determined by the Forest Act (2011).

Forest plans are prepared for forest areas that are owned by the state, municipal property, private individuals and companies. Areas used for the purposes of national security and defence are excluded. There are two types of forest plans depending on the size of the holding:

1. Forest Management Plan
   Forest management plans for state owned forests regardless of forest area. Forests owned by individuals, legal persons and their associations with a total area up to 2 ha.
2. Forest Program
   Forest areas, the property of individuals, legal persons and their associations with a total land area of their estate from 2 to 50 ha are made forest programs. State forests do not have to prepare forest programs.

11.1.1.2 National Forest Inventory

Since 2011, it is mandatory to carry out a National Forest Inventory (NFI) due to the implementation of forest legislation (Forest Act 2011) for the purposes of developing state forest policy and the forestry sector.

The decision to implement the NFI will be decided by the Council of Ministers following recommendation by the Minister of Agriculture and Food. The management of the NFI shall be entrusted to the Executive Forest Agency (EFA) and funded from the state budget. Until now, due to the lack of financial resources, Bulgaria has not started a NFI.

The Minister of Agriculture and Food specifies conditions and procedures to prepare and to update the inventory of forest areas, regional plans for development of forest territories, hunting management plans, as well as forestry plans and programs.

During the FMP forests are described using quantitative and qualitative parameters. The accuracy of the estimates is between 5 and 10 %. Permanent sample plots will be used to monitor the forests according to a methodology approved by the EFA. The boundaries of separate parts of the forests, assessed by the FMP, will be used for stratification purposes to implement a statistical NFI.

The NFI will be undertaken to (i) facilitate the management of forest resources, (ii) identify sectors for investment, (iii) monitor and control ongoing biological-ecological processes, (iv) monitor sustainability of harvesting (v) inform forest policy and strategy at country and regional level.

The classification and evaluation indicators of the NFI should be consistent with the previous measurements and Forest Management Plans, as well as with other European NFI's. General statistical information concerning forests from the NFI should also be consistent with current forestry statistics in the Republic of Bulgaria.

As the NFI is currently not in place, the subsequent sections will focus on the FMP.

11.1.2 Sampling Methods and Periodicity

After 1955, when all forests were inventoried using Forest Management Plans, about 15–20 State Forest Enterprises (SFE) and State Hunting/Game Enterprises (SH/GE) were assessed each year. The state forest area is divided into compartments and sub-compartments. The boundaries of the compartments are natural terrain features, such as ridges, valleys, rivers, lakes, or man-made features. In the absence of sufficient natural and man-made features, boundaries are formed within the forest by felling trees and painting the border trees. The area of compartments ranges from 40 to 80 ha for clear cutting method of harvesting and from 5 to 25 ha for the selective harvestings. Stratification is based on forest maps produced in the previous inventory cycle. Sub-compartments are the smallest territorial units of forests and remain relatively constant as they are the basis for forests inventory and management. The main variables that define a sub-compartment are species and management system.

During the inventory, forests are described using quantitative and qualitative parameters which outline the set of activities and operations within the compartments and sub-compartments. The range of parameters and evaluation indicators is mandatory for all forests, as determined according to the needs of forest management practices and the requirements of international agreements and documents, to which Bulgaria is a party.

11.1.3 Data Collection

This section describes the attributes assessed:

General Information—number of compartment, the number of sub-compartments, rotation age, felling, type of forest

1. Quantitative tree attributes—composition in tree species, tree species crown cover area, tree species age, stand density index, average diameter, average height, productivity class, stock, use (removals)
2. Text description of the forest cover—origin, form, structure, condition, type of mixture, trees above the forest, Landscape Assessment
3. Habitat description—exposure, slope, altitude, relief, bedrock, soil nature, habitat, optimal future species composition, litter, coverage of grass, shrubs, technical valuable medicinal plants
4. Reforestation—composition, age, height and percentage of cover
5. Health Record
6. Biodiversity
7. Accessibility—transportation distance in meters to forest road; road category, distance to the closest settlement and category of the cutting area, and some other particulars referred to in methodology for economic evaluation of forest lands. Distances are measured from the base forest map
8. Planned activities—Cutting, Thinning, Schedule for reforestation, land preparation
9. Other information.

11.1.4 Data Processing, Reporting and Use of Results

The data processing consists of the following steps:

1. Estimation of tree volume for sample tree
2. Estimation of stand volume
3. Establishment of the quantity of timber assortment by categories
4. Establishment of the current increment.

Sample tree volume is estimated with general volume functions using diameter at breast height (dbh), form factor (F), and height (h) as regressors. Volume is expressed in cubic meters (m^3).

Data and results from the Forest Management Plans and Programmes are used for national and regional forest statistics, for international reporting (Global FRA, FOREST EUROPE, Natura 2000 Network directive reporting, etc.). Also, the data are used for the management of forest units, planning forest and harvesting activities, research and for the estimation of future production potential of timber and forest bioenergy.

11.2 Land Use and Forest Resources

11.2.1 Classification of Land and Forests

11.2.1.1 General Land Classification

In the national land use classification system, the total land of country is divided into six categories: Agriculture land, Forest land, Settlements and other urbanized lands, Water bodies, Mining and quarrying areas and Transport and infrastructure (National Statistic Institute 2012) (Table 11.1).

11.2.1.2 Forest Classification by Use

For the purposes of national Forest Law, forests are defined as:

1. Land occupied by forest tree vegetation in an area of not less than 0.1 ha, tree height of the stand at maturity is not less than 5 m, a width of the stand, as measured between the stems of the trees in the forest edge, is not <10 m, and projection of the crowns at least 10 % of the area of the forest
2. Areas which are in the process of renewal and have not yet reached but are expected to reach a minimum projection of 10 % canopy and tree height of 5 m
3. Areas as a result of human activity or natural causes that are temporarily treeless, but are subject to renewal
4. Protective forest belts and strips of trees with an area greater than 0.1 ha, and a width over 10 m
5. Plantations used for the protection against the harmful effects to water
6. Mountain pine (*Pinus mugo*) formations
7. Communities of trees or shrubs located near water bodies.

Table 11.1 Land use/land cover class areas according to the national and FRA (2010) definitions

Type of territory (according to Bulgarian legislation)	Area (1000 ha)	Type of territory (according to FRA (2010))
Total area	11,100	Total area
Agricultural	6376	Other land (OL)
Forest	3716	Forest, OWL
Settlements and other urbanized territories	460	OL, partly OLwT (other lands with trees)
Water bodies	201	OL
Mining and quarrying	271	OL
Transport and infrastructure territories	76	OL

Forest areas for the purposes of the Law are:

1. Forests defined above in the previous paragraph
2. Bare, unproductive forest lands and other areas for forestry activity
3. Karsts formations, located in the lands of items 1 and 2 above
4. Protecting forest belts with dimensions smaller than 0.1 ha and a width of 10 m.

The provisions of the Law for forests shall not be applied to:

1. Parks and gardens in urban areas (Protected Areas Act 1998)
2. Forests and lands in national parks and reserves (Protected Areas Act 1998)
3. Forest tree species in agricultural areas
4. Areas covered with forest vegetation within the scope of national and local roads and railways.

According to FRA (2010) forest territories are divided into the following categories: forest, other wooded land (OWL), other lands (OL) and other lands with tree cover (OLwTC). According to Bulgarian forestry legislation all afforested lands are considered forest territories i.e. afforested area, plus the area of Mountain pine formation. Non-forested areas subject to afforestation are forest territories as well, but if at the time of assessment they are area without forest cover, then they are classified as OL (Table 11.2).

Table 11.2 Distribution of forest area (1000 ha) by ownership, according to national definitions

Ownership	Types of area (1000 ha)				Total area (1000 ha)
	Forest area	Area of Mountain pine (*Pinus mugo*)	Non-forest areas for afforestation	Non wood productive area	
1. State	2730.5	21.6	53.3	261.4	3066.8
–State forests	2611.6	0.2	52	221.8	2885.6
–MoEW's* forests	108.3	21.4	1.3	38.9	169.9
–Educational and experimental forests	10.6	–	0	0.7	11.3
2. Community	465.4	0	10.2	28.1	503.7
3. Private legal persons	405.2	0.4	5.5	10.8	421.9
4. Private juridical entities	27.5	–	0.5	1.9	29.9
5. Forests of religious organisations	18.1	1.7	0.4	3	23.2
6. Forests in agricultural land	90.9	–	0.8	0.9	92.6
Total	3737.5	23.8	70.8	306	4138.1
FRA area class	Forests	OWL	OL	OL	

*MoEW—Ministry of Environment and Waters

11.2.1.3 Classification by Ownership Categories

In Table 11.2 Bulgarian forest land information is presented also for the different forest ownership categories. Public ownership (state and community) is the dominant class in Bulgaria's forests, occupying 74 % of the total forest area.

11.2.1.4 Forest Management and Cutting Systems

The main purpose of forest felling is to enhance natural regeneration, to improve forest growing conditions and to achieve the objectives set out in the forest plans and programs. In the case of damage caused by biotic and/or abiotic effects, felling is implemented to improve the health of crops as well as to reduce and prevent the risk of further loss. Logging is conducted on the basis of a written permit issued by the director of State Forest Enterprise or licensed foresters. When conducting felling the following general principles are applied:

1. Creating tree species diversity, while maintaining a single occurring specimens of valuable tree species
2. Conservation of the habitats of forest animals and birds
3. Maintenance of forest fruit trees
4. Preserve trees on the edge of the forest, regardless of the stem and crown quality, if they are in good health
5. Conservation of the diversity in forest stands by maintaining rare forms and those characterised by high productivity, good stem form and valuable technical properties of the wood
6. Protection of biotope wood, including standing and lying dead wood, hollow trees and nests.

Thinnings are conducted during the period from the emergence of the plants until maturity and are carried out to achieve the following main objectives:

1. Regulating the composition and origin of stands depending on their functions and goals
2. Improve growth and increase the productivity of crops and the quality of the wood
3. Selection of trees in stands
4. Improving security and the special functions of forests
5. Improve the health and sustainability of stands
6. Maintenance and protection of forest biodiversity
7. Reduce the risk of the occurrence of forest fires
8. Shortening the period for the production of quality wood.

The intensity and repetition of thinning depends on the stand density index, the openness of the stand canopy, species composition, age and stand condition. The thinning types are: lighting, tending, thinning, severance thinning, selective thinning and thinning for individual production of quality wood.

Regeneration fellings carried out in mature stands aim to:

1. Provide an opening to create a new generation of forest
2. Guide the process of regeneration
3. Regulate species composition and the direction of change in species composition
4. Protect and restoring biodiversity and gene pool
5. Produce and extract wood quality
6. Create and maintain uneven-aged forests.

The type of restoration felling, the intervals at which it takes place and the duration of the renewal period shall be determined by the management objective, silvicultural system being implemented, plant health, site conditions, composition, quantity, quality and spatial arrangement of undergrowth. Regeneration fellings include three main categories:

1. Gradual—Gradual felling is a regeneration felling with advance and simultaneous seed regeneration in which the mature standing forest is cut in two or more times during the renewal period
2. Selective—Selective cutting are held in high stem forests by periodically over the entire area of the plantation removing single or groups of trees of a certain size, without going to final felling. Selective felling combine simultaneous cultivation and regeneration of the plantation and applied to achieve and maintain uniformity of spatial and age structure of the plantation and to improve their quantitative and qualitative indicators
3. Clearcut—Clearcuts are felling, followed by regeneration. They occur in poplar, linden and willow forests, as well as stands managed for coppicing.

11.2.1.5 Legal and Other Restrictions

Forest areas according to their predominant functions are divided into three categories (The Forests Act 2011) (Table 11.3):

1. Protected forests for the protection of soil, water, urban areas, buildings and other infrastructures; tree lines and forest belts for protection as well as forests created for erosion control

2. Special forests:

   - Within the boundaries of protected areas declared under the Biodiversity Act (2002) as well as those under which other protection laws are defined
   - For seed crops and gardens, nursery, experienced and geographical cultures of forest tree and shrub species, arboretums, research, training and experimental forests, nests, up to 200 m around the tourist lodges and sites of religious significance; bases for intensive management of wildlife
   - With recreational importance, of maintaining the landscape and with high conservation value

3. Commercial forests that are not covered in above mentioned categories and whose management aim is the sustainable production of timber and non-timber forest products, as well as the provision of services.

Forests in Bulgaria have to be managed in accordance with the Bulgarian Forest Act, 2011 and several other Acts. They ensure the sustainable management of forests and specify limits for the area of clear-cuts, restrict the harvest in pre-mature stands by limiting the intensity of tending activities, and define species-specific age-limit to prevent pre-mature clear-cutting of stands. They also contain specifications for forests with protective functions, forests with special natural habitats like national parks, natural forest reserves, and nature protection areas, and for forests in recreational areas. The availability of wood resources is also restricted in plans for the management of protected territories, water protection areas, military training areas, research forests, etc.

An important point with regard to the availability of wood resources is the accessibility, particularly in mountainous regions. Long logging distances and steep slopes increase the haulage costs. Cable crane logging is necessary in forest areas that cannot be accessed due to steep slopes. These logging technologies are more expensive than conventional methods and may not be economically feasible in every case. Some sites have poor productivity and render forest management operations irrelevant. Ecological considerations to sustain the site productivity can also restrict the amount of wood removed in harvesting operations.

11.2.1.6 Further Classification of Forests

The classification of the Bulgarian forest area by dominant species is presented in Table 11.4. The dominant species are Oak species (*Quercus robur*, *Quercus petraea*, *Quercus pubescens*, etc.), Scots pine (*Pinus sylvestris*), beech (*Fagus sylvatica*) and turkey oak (*Quercus cerris*).

Tables 11.5 and 11.6 describe the tree species distribution within the forest estate. Scots pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*) are the two most important forest tree species, with oak species (*Quercus robur*, *Quercus petraea*, *Quercus pubescens*, etc.) being the most important coppice species in the low stem

Table 11.3 Total forest area (1000 ha) and volume (1000 m^3) by predominant function categories and by tree species groups

Categories	Total (coniferous + broadleaved)			Coniferous			Broadleaved		
	Total area	Afforested area	Volume	Total area	Afforested area	Volume	Total area	Afforested area	Volume
Protected	519	439	79,437	164	144	35,873	355	295	43,564
Special	1065	935	192,687	380	317	85,323	685	618	107,384
Commercial	2554	2387	372,230	735	684	166,044	1819	1703	206,186
Total forest	4138	3760	644,353	1279	1145	287,239	2859	2615	357,114
Incl. Natura 2000	1224	1111	215,081	363	334	91,590	861	777	123,491

Table 11.4 Forest area classified by dominant species according to national definitions

Tree species	Area (1000 ha)
I. **Coniferous**	**1071.3**
–Scots pine (*Pinus sylvestris*)	555.1
–Black pine (*Pinus nigra*)	287.5
–Spruce (*Picea abies*)	160.4
–Fir (*Abies alba*)	32.4
–Others (total)	35.9
II. **Deciduous high stem**	**909.3**
–Beech (*Fagus sylvatica*)	443.0
–Oak (*Quercus* sp.)	199.7
–Turkey oak (*Querqus cerris*)	68.5
–Hornbeams (*Carpinus betulus*)	52.1
–Lime (*Tilia* sp.)	46.8
–Poplar (*Populus* sp.)	23.5
–Others (total)	760
III. **Coppice forests and low stem forests—total**	**1756.9**
–Oak (*Quercus* sp.)	718.7
–Turkey oak (*Querqus cerris*)	339.0
–Beech (*Fagus sylvatica*)	172.3
–Black locust (*Robinia pseudoacacia*)	150.6
–Oriental hornbeam (*Carpinus orientalis*)	142.3
–Hornbeam—(*Carpinus betulus*)	104.8
–Lime (*Tilia* sp.)	9.4
–Others (total)	119.9
Deciduous high stem—total	909.4
High stem—total	1980.7
Total forest area	3737.6

forests. Distribution by age classes is more regular in the broadleaf forests, while in the coniferous forests 47 % are in the 21–40 age class.

11.2.2 *Wood Resources and Their Use*

11.2.2.1 Standing Stock, Increment and Drain

The total stock of Bulgarian forests is about 645 million m^3 with an annual increment of 14.458 million m^3. The share of coniferous in total growing stock is 44.5 % and in the annual increment 48.2 %. The calculation of volume of coniferous are made without bark and of deciduous species with bark. The main indicators for Bulgarian forests at the beginning of the 21 century are showed in Table 11.7.

Table 11.5 Distribution of forest area (2010) of high stem forests (1000 ha) depending on their functions (according to classification of Law for forests—2011)

Tree species	Total area (1000 ha)	Age classes—years								Average age
		10–20	21–40	41–60	61–80	81–100	101–120	121–140	Over 140	
I. **Coniferous**	**1071.3**	**119.3**	**450.3**	**187.8**	**89.1**	**115.1**	**73.7**	**25.3**	**10.7**	**50**
Scots pine (*Pinus sylvestris*)	555.1	62.5	248.9	92.9	53.6	60.7	30.0	5.5	1.0	47
Black pine (*Pinus nigra*)	160.4	12.6	36.2	13.8	17.2	35.8	28.8	12.2	3.8	73
Spruce (*Picea abies*)	287.5	39.0	146.9	73.5	12.4	7.9	4.9	1.9	1.1	38
Fir (*Abies alba*)	32.4	0.9	4.6	3.1	3.3	6.8	7.0	4.3	2.4	87
Macedonian pine (*Pinus peuce*)	13.9	0.8	1.1	1.1	2.0	3.4	2.6	0.9	2.1	90
Bosnian pine (*Pinus leucodermis*)	1.3	0.0	0.1	0.1	0.2	0.3	0.1	0.1	0.4	104
Douglas fir (*Pseudotsuga menziesii*)	7.4	0.9	5.5	0.9	0.0	0.0	0.0	0.0	0.0	30
Larix spp.	0.6	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	32
Others (total)	12.7	2.5	6.6	2.3	0.3	0.4	0.3	0.3	0.0	37
II. **Broadleaved high stem**	**901.8**	**115.9**	**167.1**	**127.7**	**78.8**	**113.5**	**119.4**	**93.2**	**86.4**	**74**
Beech (*Fagus sylvatica*)	440.9	24.3	53.5	41.4	40.7	75.1	79.7	62.9	63.4	91
–Oak (*Quercus* sp.)	198.2	28.0	43.2	23.7	15.7	25.6	26.7	19.8	15.5	71
–Turkey oak (*Quercus cerris*)	68.5	17.3	13.2	11.8	5.7	5.0	5.9	5.4	4.2	58
–Hornbeams (*Carpinus betulus*)	51.3	6.4	14.5	11.7	5.1	4.1	4.6	3.0	1.9	58
Elm (*Ulmus* sp.)	2.0	0.3	0.7	0.6	0.1	0.1	0.1	0.2	0.1	52
Fraxinus spp.	15.0	2.2	4.7	4.9	1.3	1.0	0.4	0.3	0.3	47
Lime (*Tilia* sp.)	46.8	7.6	12.7	18.7	6.2	0.8	0.5	0.2	0.1	43
Poplar (*Populus* sp.)	23.5	19.5	3.1	0.8	0.1	0.0	0.0	0.0	0.0	14
Aspen (*Populus tremula*)	6.4	1.0	1.6	1.7	12.9	0.6	0.2	0.0	0.0	63
Maple (*Acer* sp.)	4.3	1.6	1.3	0.5	0.1	0.1	0.2	0.2	0.3	43
Birch (*Betula alba*)	9.1	1.6	5.0	1.6	0.5	0.2	0.0	0.0	0.0	35

(continued)

Table 11.5 (continued)

Tree species	Total area (1000 ha)	Age classes—years								Average age
		10–20	21–40	41–60	61–80	81–100	101–120	121–140	Over 140	
Chestnut (*Castanea sativa*)	2.6	0.4	0.8	0.7	0.1	0.1	0.0	0.1	0.4	59
Walnut (*Juglans regia*)	7.2	0.7	5.2	1.2	0.0	0.0	0.0	0.0	0.0	32
Others (total)	26.2	5.0	7.6	8.2	1.9	0.8	1.1	1.1	0.3	46
III. **For reconstruction**	**7.5**	**0.2**	**0.9**	**1.8**	**1.2**	**1.7**	**0.6**	**0.7**	**0.5**	**77**
Beech (*Fagus sylvatica*)	2.1	0.0	0.0	0.1	0.3	0.7	0.2	0.4	0.3	102
Oak (*Quercus* sp.)	1.5	0.0	0.2	0.4	0.3	0.3	0.1	0.1	0.1	70
Turkey oak (*Quercus cerris*)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58
Hornbeam (*Carpinus betulus*)	0.8	0.0	0.1	0.1	0.1	0.2	0.1	0.2	0.0	89
Oriental hornbeam (*Carpinus orientalis*)	1.9	0.1	0.5	0.8	0.3	0.2	0.1	0.0	0.0	54
Others (total)	1.3	0.1	0.1	0.3	0.2	0.3	0.1	0.1	0.0	73
Broadleaved high stem—total	909.4	116.1	167.9	129.5	80.0	115.2	120.0	93.9	86.8	74
High stem—total	1980.7	235.3	618.3	317.3	169.1	230.3	193.7	119.2	97.5	61

Table 11.6 Distribution of forest area (1000 ha) of low stem forests depending on their functions according to national definitions (2010)

Tree species	Total Area (1000 ha)	Age classes—years													Average age
		1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	Over 61	
Coppice for conversion	**1320.9**	21.2	**25.4**	**34.5**	**41.1**	**36.0**	**39.5**	**35.9**	**73.2**	**97.5**	**195.0**	**168.9**	**211.4**	**341.3**	**48**
Oak (*Quercus* sp.)	649.2	10.6	13.1	16.4	18.7	15.5	18.0	16.9	37.9	53.0	101.1	82.3	103.0	162.8	48
Turkey oak (*Quercus cerris*)	312.2	6.1	5.5	8.0	10.4	9.2	8.9	8.1	16.6	25.4	50.5	49.7	52.1	61.8	47
Beech (*Fagus sylvatica*)	169.9	0.8	1.1	1.8	2.9	3.3	4.2	3.8	6.8	6.3	19.6	14.1	29.2	76.2	53
Hornbeam (*Carpinus betulus*)	96.9	1.3	1.8	3.2	3.6	3.3	3.5	2.9	5.6	7.0	12.4	12.8	15.5	23.9	47
Lime (*Tilia* sp.)	7.7	0.2	0.2	0.2	0.4	0.4	0.4	0.3	0.5	0.7	1.1	1.1	1.0	1.3	44
Others (total)	85.0	2.2	3.7	4.9	5.2	4.3	4.6	4.0	5.8	5.0	10.3	9.0	10.6	15.3	41
Low stem—total	**436.0**	**46.0**	**47.4**	**49.7**	**43.5**	**29.9**	**29.8**	**19.2**	**27.3**	**22.2**	**33.6**	**22.9**	**27.9**	**36.6**	**29**
Oak (*Quercus* sp.)	69.5	4.3	3.7	5.1	6.4	5.4	6.8	3.9	5.9	3.9	7.8	3.1	6.2	6.9	34
Turkey oak (*Quercus cerris*)	26.8	2.3	1.9	2.2	3.0	2.9	2.7	2.3	1.6	1.2	1.9	1.2	1.4	2.3	30
Beech (*Fagus silvatica*)	2.4	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.4	0.7	42
Black locust (*Robinia pseudoacacia*)	150.6	31.8	30.9	27.6	19.4	11.3	8.7	5.6	5.1	3.7	3.0	2.4	0.6	0.4	16
Hornbeam (*Carpinus betulus*)	7.9	0.6	0.5	0.7	0.8	0.5	0.5	0.3	0.5	0.4	0.8	0.4	0.8	1.2	35
Oriental hornbeam (*Carpinus orientalis*)	142.3	4.3	6.7	10.1	10.8	7.5	8.5	5.5	11.4	10.2	16.9	12.8	16.3	21.5	39
Lime (*Tilia* sp.)	1.7	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.2	0.2	35
Others (total)	34.9	2.5	3.4	3.7	2.9	2.1	2.5	1.6	2.5	2.5	2.8	2.7	2.2	3.5	32
Total	1756.9	67.1	72.8	84.2	84.7	65.9	69.3	55.1	100.5	119.6	228.6	191.8	239.4	378.0	

Table 11.7 Bulgarian forests in the beginning of 21st century

Indicators	Units	Coniferous	Broadleaved high forest	For reconstruction	For conversion	Low-stemmed	Total
1. Forest area	1000 ha	1071	902	8	1321	436	3738
	%	28.6	24.1	0.2	35.4	11.7	100
2. Total growing stock	1000 m^3	287,118	186,234	382	153,032	18,164	644,930
	%	44.5	28.9	0.1	23.7	2.8	100
3. Increment	1000 m^3	6973	3163	7.1	3303	1012	14,458
	%	48.2	21.9	0.1	22.8	7.0	100
4. Increment per ha	m^3	6.51	3.51	0.94	2.50	2.30	3.87
5. Average age	Years	50	74	77	50	30	54
6. Average site class[a]		2.94	2.91	–	3.53	4.11	3.22
7. Annual harvest[b]	1000 m^3	3044	2325	12	2007	788	8176
8. Annual harvest per ha	m^3	2.84	2.58	1.50	1.52	1.81	2.19
9. Fellings	1000 m^3	2515	1558	–	2191	462	6.726
10. Share of fellings from the annual harvest plan	%	82.6	67.9	–	109.2	58.6	82.3

[a]The scale is between 1 and 5, with 1 the best and 5 the worst
[b]Annual harvest plan according to the Management plan

11.2.2.2 Tree Species and Their Commercial Use

The data in Table 11.8 show that the total removals are less than the annual increment and more than 50 % of the removals is used for firewood. More than 60 % from removals are from broadleaved and the share of high-stem beech is about 18 %. The highest share of firewood is in coppice species.

Table 11.8 Fellings and removals in the period 2006–2010 (1000 m^3)

	2006	2007	2008	2009	2010	Total 2006–2010	Average 2006–2010
Total							
Fellings	7234	6785	7317	5465	6726	33,527	6705
Removals	5992	5696	6071	4599	5669	28,027	5605
Industrial timber	2582	2571	2710	1662	2363	11,888	2377
Firewood and loppings	3410	3125	3361	2937	3306	16,139	3227
Coniferous							
Fellings	2785	2675	2953	1679	2515	12,607	2521
Removals	2125	2067	2281	1300	1961	9734	1946
Industrial timber	1646	1599	1733	894	1454	7326	1465
Firewood and loppings	479	468	548	406	507	2408	481
Broadleaved							
Fellings	4449	4110	4364	3786	4211	20,920	4184
Removals	3867	3629	3790	3299	3708	18,293	3659
Industrial timber	936	972	977	768	909	4562	912
Firewood and loppings	2931	2657	2813	2531	2799	13,731	2746
High-stem beech							
Fellings	807	758	856	687	771	3879	775
Removals	714	670	745	598	675	3402	680
Industrial timber	222	211	221	135	166	955	191
Firewood and loppings	492	459	524	463	509	2447	489
High-stem oak							
Fellings	252	256	216	180	205	1109	221
Removals	215	215	181	152	174	937	187
Industrial timber	51	63	52	36	47	249	49
Firewood and loppings	164	152	129	116	127	688	137
Other broadleaved high-stemmed							
Fellings	770	683	580	478	582	3093	618
Removals	668	604	510	423	511	2716	543
Industrial timber	271	257	243	205	244	1220	244
Firewood and loppings	397	347	267	218	267	1496	299
Coppice							
Fellings	2710	2140	2354	2126	2348	11,678	2335
Removals	2270	2140	2354	2126	2348	11,238	2247
Industrial timber	392	441	461	392	452	2138	427
Firewood and loppings	1878	1699	1893	1734	1896	9100	1820

11.3 Assessment of Wood Resources

11.3.1 Forest Available for Wood Supply

11.3.1.1 Assessment of Restrictions

The following factors mainly affect the availability of forests for wood supply.

A. Protected areas
Forests within the ecological network are determined in accordance with Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna, called Habitats Directive. According to this law protected areas are declared in the country as part of the national ecological network. These are places of the territory that meet the requirements for the presence of biological diversity, for certain plant and animal species.
B. Recreation areas
Areas reserved for recreation include areas established by owner's decision (state forests) or land use planning at municipal or county level. These areas are managed mainly for recreation values and forestry operations must be planned accordingly. In most cases, forestry is not profitable in these areas. The aim of forest operations, in these areas is to maintain and enhance recreation values. Normally, in these forests the rotation age is increase by one age class (20 years for high stemmed forests).
C. Protected biotopes, key habitats
The forest act defines a number of biotopes that may not be managed or can only be managed carefully so that the natural elements are not endangered. Here the rotation length is increased and the availability of wood for supply decreases.
D. Protective functions
In some forest areas forest operations are limited because these forests are devoted to the protection of soil, water, urban areas, buildings and objects of the infrastructure; tree lines, forest belts for protection as well as forests, created by technical projects for erosion control. Protection of forests in high altitudes causes limitations to forestry operations in mountains.
E. Special forest areas
These areas are (i) within the boundaries of protected areas under the Protected Areas and Protected Areas declared under the Biological Diversity Act (ii) those on which under other laws are defined and introduced special status and modes (seed crops and gardens, nursery, experienced and geographical cultures of forest tree and shrub species, arboretums, research, training and experimental forests, nests, up to 200 m around the tourist lodges and sites of religious significance) (iii) basis for intensive management of wildlife (iv) with recreational importance, of maintaining the landscape and with high conservation value. The forest operations in these forests are carried out very carefully and according to special requirements.

F. Other restricted areas (e.g. military)
   The military forest areas in Bulgaria are insignificant and the restrictions in them do not have important meaning.

In Bulgaria the availability of forest land for wood supply in the inaccessible areas has an important influence. These are forest areas to which no roads are available and in which it is not possible to carry out harvesting. During the forest inventory the volume of wood in inaccessible areas is calculated and included in the total volume, but in practice it is not possible to harvest this timber.

It is important to highlight that about two thirds of forests are owned by state and managed by foresters. The expectations of managers are to receive income mainly from felling. Private and municipality owners also expect to maximise the income from their forests.

11.3.1.2 Estimation

In all above mentioned forest areas with restrictions the measurement and establishment of forest volume is the same as in other forest areas. Calculating volume for felling is in accordance to the requirement of Forest law and other specific laws which are connected with the restrictions.

11.3.2 Wood Quality

11.3.2.1 Stem Quality and Assortments

Using volume and assortment tables, data on the volume and assortment structure of the standing tree stem is generated. For this purpose it is necessary to obtain dbh data in 4 cm diameter classes and the height in metres (m). When determining the assortment structure it is necessary to make a qualitative assessment of the stem. These operations are usually performed in conjunction with forest development inventory or at the stage of marking trees for cutting. The goal is not only to determine the volume stock of a stand for logging, but also to determine the assortment structure and an assessment of tree quality. Trees are divided into three groups:

1. Industrial wood
   Wood are considered perfectly healthy trees which, due to mechanical damage or bends, means that no more than 25 % has non industrial part.
2. Semi industrial wood
   Wood is related those trees which industrial wood is between 25 and 75 % of the total.
3. Fuel wood
   Wood unfit for industrial wood, i.e. >75 % fuelwood.

Before, a stem assortment structure is estimated into the industrial wood and fuel wood groups, the previously graded semi industrial wood is distributed equally into the two previous groups. Further practical assortment is done only for industrial stems according to the relevant tree species assortment tables, based on dbh and height grades.

11.3.2.2 Assessment and Measurement

As trees of certain standing timber are assessed independently from each other it is not necessary to measure the height of each. The method of establishing the height grade is recorded and can be estimated from a sample of heights on 10 trees with diameter approximately equal to the average diameter of the stand.

Trees, whose heights will be measured, are chosen uniformly from the entire stand. They should not be damaged, forked or with broken tops. The heights are measured by a hypsometer with an accuracy of 1 m. For each tree assessed for height the corresponding dbh with an accuracy of 1 cm is recorded. The mean height and the average diameter are calculated for the stand, which in turn is used to determine the species specific height grade for the callipered stand. In mixed stands of two or more tree species the height grade is calculated as described above for each tree species separately. For more accurate measurements for research purposes a large number of heights are measured to compile curve heights.

11.3.2.3 Estimation and Models

The data on the number of stems by age class and tree species, and height grades are carried in a form, called the "muster list". After calculating the volume of the stems from the volume table, aboveground stems in dbh class is derived. The dbh class is multiplied by the number of stems in the extent and collected, give the whole volume of the callipered stand. The classification of timber according to assortment category and class of assortments is presented in Table 11.9.

Table 11.9 Classification of timber according category of assortments and class of assortments

Category of assortment	Class of assortment	Assortment size	
		Diameter at the small end (for deciduous with bark) cm	Maximum length (m)
Large industrial timber	Ia	50 and up	4; 5
	I	From 30 to 49	4; 5
	II	From 18 to 29	4; 5
Mean industrial timber	III	From 15 to 17	3; 4; 5
	IV	From 11 to 14	3; 4; 5
	V	From 5 to 10	3; 4; 5
Small industrial timber	VI	From 3 to 7	2; 3

11.3.3 Assessment of Change

11.3.3.1 Assessment and Measurement

The estimation of stock and volume of assortments is based on the field measurements and the use of different methods (full calipering, mathematic-statistical methods, table methods, etc.). Species specific assortment and volume tables are used.

11.3.3.2 Estimation of Increment

The current increment of callipered stands is calculated using increment tables or indirectly by the formula of Schneider (Chapman 1921).

11.3.3.3 Estimation of Drain

Cuttings and removals are estimated using official removal statistics collected and published every year from national statistic. Before the inventory and elaboration of Forest Management Plan (every 10 years) the volume and structure of cuttings and removals are received from forest enterprise and are analysed.

11.3.4 Other Wooded Land and Trees Outside Forests

The trees on other wooded land and trees outside forests are not subject of the forest development inventories in Bulgaria.

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Chapter 12
Canada

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12.1 Canada's National Forest Inventory

12.1.1 History and Objectives

Canada's National Forest Inventory (NFI) is undertaken as a collaborative program involving ten provinces, two territories and the federal government. Most of Canada's forests are on publicly owned land. Provinces and territories have constitutional responsibility for the management of forests on most publicly owned land, and develop legislation, regulations, policies, and practices to support their forest stewardship. They also maintain forest inventory programs. The NFI program complements these programs by providing strategic-level data and information

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products that are consistent across all jurisdictions and forest types in Canada (Gillis et al. 2010).

Forest inventory data from across Canada were first summarised into a computerised national dataset in 1981 (Bonnor 1982). This dataset, referred to as "Canada's Forest Inventory" (CanFI), was updated periodically, with the last update published in 2006 (Forestry Canada 1988; Lowe et al. 1994; Power and Gillis 2006). The need for a new, design-based NFI was recognised in the 1990s (Barker et al. 1996). The variety of standards and protocols used by provincial and territorial inventory programs and inconsistency over time made it impossible to generate consistent national information or assess forest change at the national scale. Consensus on the NFI design was reached in 1997 and plot establishment was completed during 2000–2006. The target population is Canada's entire non-Arctic land base, stratified for reporting purposes into 12 terrestrial ecozones (Ecological Stratification Working Group 1996; Fig. 12.1). The data are used for national and international reporting, for supporting forest research and policy development, and for responding to national and international enquiries about Canada's forests. The NFI program is currently completing its first ten-year re-measurement cycle (2008–2017).

Fig. 12.1 The terrestrial ecozones of Canada (Ecological Stratification Working Group 1996)

12.1.2 Sampling Procedures

Canada's NFI includes a field survey component and a remote sensing survey component (Gillis et al. 2010). The remote sensing survey consists of square (2 × 2 km; 400 ha) sample units located on a systematic national sampling grid (every 20 km). The current survey has been reduced to units spaced every 40 km in some ecozones (Fig. 12.2). In total, there are 13,158 sample units included in the current (first re-measurement) survey. Permanent field survey units (ground plots) are maintained in a subset of the forested remote sensing survey sample units.

12.1.2.1 Remote Sensing Survey

Stereo photography flown at scales ranging from 1:10,000 to 1:20,000 are the preferred imagery data for the NFI remote sensing survey due to their high degree of spatial detail and the opportunity they present to interpret and measure land cover and forest attributes stereoscopically (Gillis and Leckie 1993). NFI remote sensing survey plots are therefore commonly referred to as 'photo-plots', even though some of the image data are acquired by sensors mounted on orbiting satellites (Falkowski et al. 2009). During NFI establishment, northern portions of the survey that could not be completed in time were done using a medium resolution remote sensing land cover product (Wulder et al. 2008).

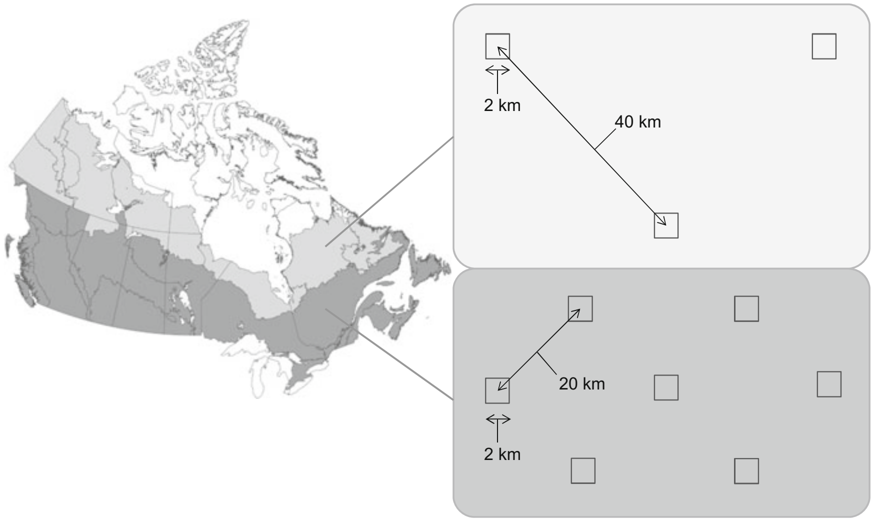

Fig. 12.2 NFI remote sensing survey sampling densities for first re-measurement (T1: 2008–2017). In southern Canada (*dark grey*), 2 × 2 km photo-plots are located on a 20 × 20 km grid and in the north (*light grey*) on a 40 × 40 km grid

At the outset of the first re-measurement cycle (T1: 2008–2017), NFI photo-plots were divided into two 'panels'. Each panel included one half of the survey plots distributed evenly across the sampling frame. The first panel (P1) was to be surveyed during the first five years of the ten-year re-measurement period, and the second panel (P2) was to be surveyed during the second five years. In this way, the sub-sample available at the T1 mid-point could be used to produce mid-cycle statistical reports without geographic bias. When it became evident that the P1 and P2 surveys would not be completed as planned because of poor alignment with provincial and territorial inventory program activities, the survey was adjusted to align better with provincial and territorial inventory activities by relaxing the two-panel approach and focussing instead on completing the photo-plot survey over the ten year period.

12.1.2.2 Field Survey

The NFI field survey program maintains 1116 ground plots across Canada (Fig. 12.3). These plots are measured over ten years with, on average, one tenth of the plots measured each year. The plot design consists of two transects for assessing woody debris and surface substrate; four microplots for destructive sampling of

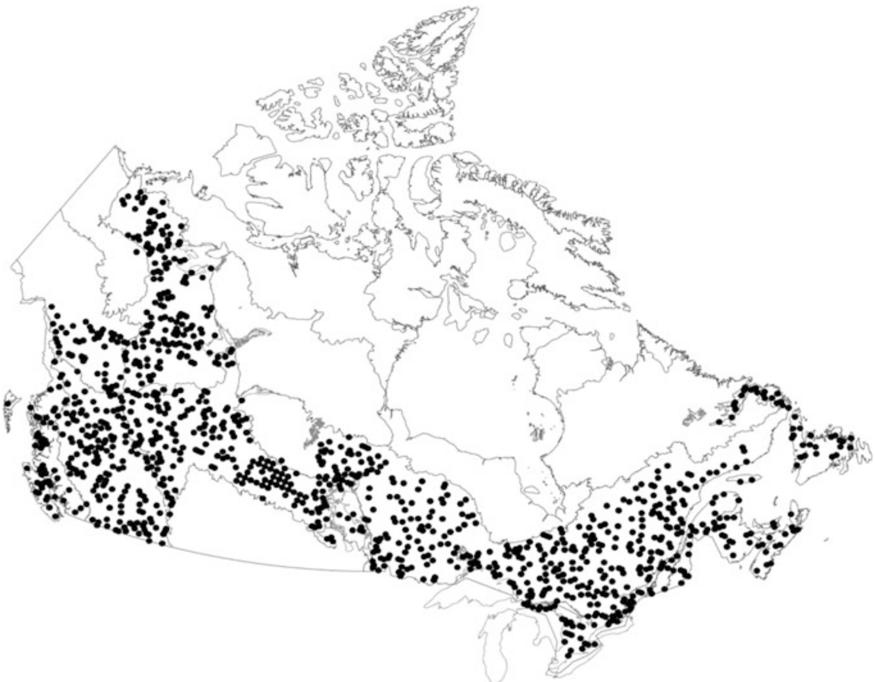

Fig. 12.3 NFI ground-plots (field plots)

understory vegetation, forest floor organic material and soils; two ecological plots for assessing biodiversity; a soil pit; a large tree plot; and a small tree, shrub and stump plot (NFI Task Force 2008; Gillis et al. 2010). While 1116 is a small number of ground plots for a country the size of Canada, the high per unit costs associated with field sampling make it challenging to maintain even this number. Many plots are remote and crews must be flown in over long distances by helicopter or float plane.

The plots are used to support the photo-plot sampling program and provide data for research (e.g. Shaw et al. 2013; Neigh et al. 2013; Zhang et al. 2014; Mansuy et al. 2014; Girardin et al. 2015). These plots provide an important complement to the much larger networks of permanent and temporary sample plots (PSP and TSP) that are established and maintained annually by the provinces and territories for their respective inventories. It has been a long-standing goal for the NFI team to exploit these data in connection with remotely sensed imagery. Issues surrounding geo-location accuracy of these plots and harmonization of data are the greatest obstacles to progress.

12.1.2.3 Data Collection

Photo interpreted attributes constitute the core data in the NFI. Four data-layers of information are sought for each photo-plot: (i) land cover, (ii) land use, (iii) ownership, and (iv) protection status (Gillis et al. 2010). Attributes and classification are described in detail in the NFI Photo Plot Data Dictionary (available online at: nfi.nfis.org).

Data collection at NFI ground-plots is described in Canada's National Forest Inventory Ground Sampling Guidelines (also available online at: nfi.nfis.org).

12.1.2.4 Data Processing, Reporting and Use of Information Products

During NFI establishment, collaborating government agencies developed reporting strategies and designed a suite of standard statistical estimators and indicators to meet the information needs of the Montreal Process and the Canadian Council of Forest Ministers Criteria and Indicators (CCFM 2003; Montreal Process 2009). Baseline reports, based on NFI establishment data (collected during 2000–2006), were published on the NFI website in 2009 (accessible at: nfi.nfis.org). The baseline reports have since been updated in response to changes in data compilation routines and statistical estimation procedures.

The standard strata for statistical estimation are the 'NFI Units', which are derived from the geographic intersection of provincial and territorial borders with the Terrestrial Ecozones of Canada mapped at a 1:1,000,000 scale (Ecological Stratification Working Group 1996). The NFI sampling density does not provide sufficient accuracy to support reporting for all NFI Units because some are quite small. Estimates produced for NFI Units are summed up to provide reporting for 12

Terrestrial Ecozones. National reports are produced by summing across all NFI Units. The NFI also produces separate reports for the Boreal Zone (Brandt 2009) and will produce reports for FAO ecological zones (CEC 2011).

Estimators of NFI attributes are computed on a per stratum basis and combined to a national or ecozone estimate assuming stratified random sampling and known strata areas and hence strata weights. There are two basic types of estimators: those that relate to areas with a certain attribute (e.g. cover type coniferous); and those that relate to per unit area values (e.g. volume per ha).

Area defined attributes are estimated by first estimating the mean area-proportion of the attribute in the NFI sample of photo-plots. The total area is then obtained by multiplying this proportion with a known total area obtained from an official statistic. The standard error of an area estimate is obtained as for stratified random sampling of a proportion and multiplied by the total known area.

Two different types of estimators are provided in our inventory results. The first type has the entire landbase as the population of interest. Here traditional design-based estimators of means and variances for simple random sampling within a stratum, region, or inventory unit are used (Cochran 1977, Chap. 2). Weighted estimators are used whereby weights are proportional to the area of a photo-plot that resides within the population of interest.

The second type of estimator is a ratio estimator for single stage sampling with clusters of unequal sizes. Here the sample frame is the land in a specified condition class (e.g. treed and coniferous). For each 400 ha photo plot we obtain the total of an attribute value (e.g. total volume) and the total area in the specified condition class (coniferous). Means and approximate variances are computed as for ratio estimators (Cochran 1977, Chap. 6). Volume is a derived attribute from photo-interpretation of one or more of the following: species composition, height of leading species, basal area or stocking or crown closure (by species), and age. To the extent possible, the photo-interpretation is by visible stand layers. Local and regional look-up tables, volume equations, and yield tables are also used where deemed appropriate by the provincial or territorial forest inventory agency supplying the volume data to the NFI. Volumes are calculated for the main stem (without bark), including stump and top as well as dead and decayed wood for all trees greater than 1.3 m tall. The NFI will produce its first estimates of volume changes and increments when enough re-measurement data have been processed, loaded into the central NFI database, and made available to the estimation routines.

Map products have been produced from NFI data by Beaudoin et al. (2014) using the *k* nearest neighbours (*k*NN) method with 26 geospatial data layers including MODIS spectral data and climatic and topographic variables. Progress is also being made toward the production of more advanced products at substantially higher spatial resolution (e.g. White et al. 2014; Hermosilla et al. 2015). This progress is welcome because more and more research applications require spatially-explicit inputs about forest ecosystems, and visually engaging maps communicate information to some audiences in a way that statistical reports cannot.

12.2 Land Use and Forest Resources

12.2.1 General Classification of Land and Forests

Canada uses a hierarchical land cover classification system. At the highest level, the land base is classified as vegetated or non-vegetated; at the second level, vegetated land is classified as treed or non-treed. The land cover is considered to be treed if at least 10 % of the area, by crown cover, consists of tree species of any size. In total, five levels of classification are specified: (i) land base, (ii) land cover type, (iii) landscape position, (iv) vegetation type, and (v) density class (refer to the NFI Photo Plot Data Dictionary for details; available online at: nfi.nfis.org). Table 12.1 reports the estimated area in each of the first- and second-level land classes for the surveyed portion of Canada (the three Arctic ecozones and very small areas in the Taiga Plains and Hudson Plains ecozones that are in Nunavut are not surveyed by the NFI).

'Forest' is not a land cover class because the area of forest cannot be inferred from the current land cover alone. Some treed lands are not forest (e.g. lands predominantly under agricultural or urban land use) and some forest lands are not treed (e.g. lands that are temporarily non-stocked). It is important to distinguish between the 'forest area' and the 'treed area' (often referred to as the area of 'forest cover') to avoid interpreting treed area gains and losses as forest area gains and losses. In Canada, treed area gains and losses occur far more frequently, are far less enduring than forest area gains or losses, and have substantially different impacts on forest resource availability and ecosystem services.

Canada has an estimated forest area of 347.6 million hectares, where 'forest' is defined following the FAO (2012) definition:

> Land with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

This definition of forest creates some uncertainty when applied in Canada. The area of greatest concern is where land cover does not currently meet the 5 m tree

Table 12.1 Area by land cover class

Level 1 (land base)	Level 2 (land cover type)	Area (million ha)
Vegetated	Treed	362.1
	Non-treed	227.7
	Sub-total	589.8
Non-vegetated	Land	58.6
	Water	87.4
	Sub-total	146.0
Total*		735.8

*Note that the total area of Canada includes both the total reported here plus the total area not surveyed by the NFI, which includes the Arctic ecozones and small portions of the Taiga Plains and Hudson Plains ecozones that are in Nunavut height threshold and the available land cover attributes fail to provide a clear indication about the capacity of the in situ vegetation to attain or exceed this threshold. Distinguishing between young, post-disturbance tree cover and shrub cover that will never attain 5 m can be difficult when relying solely on photo-interpreted forest attributes, especially those derived from satellite imagery. This is a particularly acute challenge in unmanaged forests where records of natural disturbances and site quality indicators are often lacking. Forest area is therefore estimated with more certainty in the managed forest and with less certainty in the unmanaged forest. These uncertainties will lessen when multiple successive inventory cycles provide a greater temporal scope affording improved consistency across time.

Estimation of forest area change between successive inventory cycles is not yet possible because the NFI is currently in the midst of its second cycle (first re-measurement). A special-purpose national system outside of the NFI is used to monitor and report on the area of deforestation (Dyk et al. 2015). The NFI survey (13,158 plots; 400 ha each) does not afford a sufficiently precise estimation of the area of deforestation in Canada, which is very small relative to the area of Canada's forest. The most current estimated rate of deforestation is 46 thousand ha per year, or 0.01 % of Canada's forest area per year (NRCan 2014). The area of afforestation in the recent past has been even smaller (<10,000 ha per year; White and Kurz 2005), and no special-purpose system is currently monitoring afforestation in Canada. Canada has therefore reported a small net forest area loss in the 2015 Global Forest Resource Assessment (FRA; FAO 2015) and in reports to the UNFCCC (e.g. Environment Canada 2015).

12.2.2 Classification by Ownership Categories

Most of Canada's forests are on publicly-owned, 'crown' land. Public ownership in Canada can be broken down into several sub-categories (Table 12.2), including provincial, territorial, federal and municipal. A relatively small area of forest is under the jurisdiction of municipal governments. Federally reserved lands include national parks, national defense establishments, and other reserves.

Crown forests under provincial and territorial jurisdiction are managed according to the legislation and regulations established by provincial and territorial governments. Various agreements have been made by provincial and territorial governments to allow sustainable private extraction of forest timber resources on crown lands. These agreements are referred to as 'tenures' (CCFM 2006). Management plans are in place for 206 million ha, and large areas are certified under one or another independently verified forest certification scheme (54 million ha under FSC; 58 million ha under the *Programme for the Endorsement of Forest Certification* (PEFC); and 44 million ha under Canadian Standards Association (CSA) as of 2012). Some of Canada's forests have no tenures and no formal management plans; no commercial timber extraction occurs in these forests.

Table 12.2 Forest area by ownership

Ownership category	Forest area (million ha)	Area (%)
Public (sub-total)	324.5	93.3
Federal	5.4	1.6
Provincial or territorial	311.3	89.6
Municipal	0.9	0.3
Aboriginal	6.8	2.0
Private	21.7	6.2
Other*	1.5	0.4
Total	347.6	

*Ownership information is missing or not available

Information about tenures, forest management plans and third party certification is maintained outside of the NFI.

12.2.3 Wood Resources and Their Use

The total volume in Canada's forest is estimated to be 47 billion cubic meters. Spruce (*Picea* spp.) is the predominant species group in Canada; black spruce (*P. mariana*) is found across most of Canada (Farrar 1995) and is, by far, this country's most common tree species. Other important species groups are Poplar (*Populus* spp.), Pine (*Pinus* spp.), Fir (*Abies* spp.), Hemlock (*Tsuga* spp.), Douglas-fir (*Pseudotsuga menziesii*), Birch (*Betula* spp.) and Maple (*Acer* spp.) (Table 12.3).

Table 12.3 Total tree volume by species group

Species group	Total tree volume (million m^3)	Volume (%)
Spruce (*Picea* spp.)	22,383	47.3
Pine (*Pinus* spp.)	5611	11.9
Fir (*Abies* spp.)	3499	7.4
Hemlock (*Tsuga* spp.)	2741	5.8
Douglas-fir (*Pseudotsuga menziesii*)	1653	3.5
Larch (*Larix* spp.)	298	0.6
Cedar and other conifers	1267	2.7
Unspecified conifers	344	0.7
Poplar (*Populus* spp.)	6176	13.1
Birch (*Betula* spp.)	1575	3.3
Maple (*Acer* spp.)	1403	3.0
Other hardwoods	223	0.5
Unspecified hardwoods	101	0.2
Unclassified	46	0.1
Grand total	47,320	

Mean volume densities vary regionally. Most of Canada's forests are located in boreal and taiga ecozones (Fig. 12.4). Mean volume densities are generally higher in western Canada compared to eastern Canada. The highest volume densities are found in the Pacific Maritime ecozone, where temperate climate and infrequent natural disturbances allow long-lived species such as Douglas-fir, Sitka Spruce (*Picea sitchensis*), Western Redcedar (*Thuja plicata*) and others to attain very large sizes.

A variety of silvicultural practices and harvesting systems are used in Canada, tailored to the different operational and ecological circumstances across the country. Ecosystem-based management systems are used to minimise the differences between natural forests and those contributing to timber supply (Gauthier et al. 2009). Current scientific understanding of natural disturbance regimes and stand dynamics is used to design silvicultural systems, harvesting methods and landscape management strategies that will sustain productivity and biodiversity in managed areas by preserving key forest processes and attributes at multiple temporal and spatial scales.

12.3 Assessment of Wood Resources

12.3.1 Forest Available for Wood Supply

The forest area available for wood (timber) supply is sometimes reported by Canadian provinces and territories, but it is not reported at the national level. Canadian ecosystem-based management systems take both the available and restricted forest areas into consideration when evaluating progress toward timber and non-timber management goals. Classification of land into different categories of restriction and availability for one type of management or another is done during the planning process, but the emphasis is on assessing the sustainable supply of timber and the flow of other benefits from the managed land base as a whole.

Detailed timber supply analyses are conducted by provincial and territorial governments for each crown forest management unit to support the determination of allowable annual cut (AAC) levels. These AAC levels are reported to the public. The restrictions placed on harvesting in crown forests differ between jurisdictions (provinces and territories) because each has its own legislation and regulations. Restrictions are made to protect environmentally sensitive areas, riparian management areas, wildlife management areas and sensitive terrain areas. Inoperable areas and low productivity timber areas are also accounted for when determining AAC levels, and these levels may be adjusted to shift the balance between pursuit of timber and non-timber objectives for a management unit without identifying specifically parcels of reserved land.

The current harvest level in Canada (148 million m^3 in 2012) is well below the estimated sustainable wood supply (227 million m^3 in 2012) (NRCan 2014). The

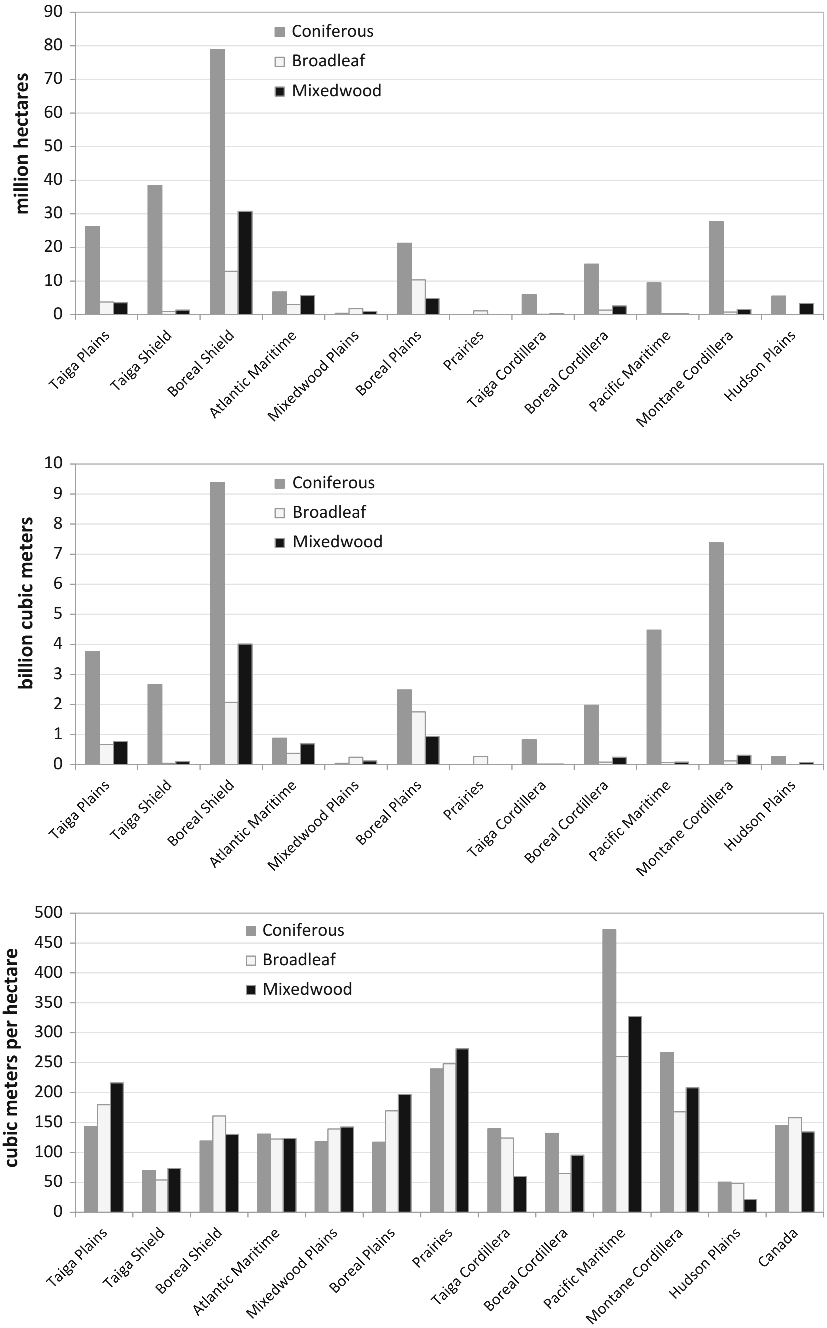

Fig. 12.4 Forest area, total volume and mean volume density by ecozone and forest type

gap between wood supply and wood harvest is expected to narrow as harvest levels increase slowly in response to the recovery of North American demand for wood products and the available wood supply declines as a result of natural disturbance impacts.

12.3.2 Assessment of Change

The NFI is not yet in a position to report statistical estimates of increment, harvest, disturbance depletions or other changes because the first re-measurement cycle is still in the process of being completed. Harvest and disturbance data are, however, compiled from provincial and territorial sources in the National Forestry Database (NFD; accessible online at nfdp.ccfm.org). The NFI and NFD are complemented by national science programs that monitor forest change (e.g. Guindon et al. 2014; Hermosilla et al. 2016). The federal government's *Forest Change* science program brings together several such initiatives into a national tracking system (Ste-Marie et al. 2015). Integration of programs such as these with the NFI and NFD, and completion of the first NFI re-measurement, will soon make it possible to assess forest change at the national level, including assessment of remote wilderness forests for which we historically had very little information.

12.3.3 Other Wooded Land and Trees Outside the Forest

Canada's NFI uses the FAO definition of forests (as described in Sect. 12.2), but most foresters in Canada would not consider lands having <25 % crown cover at maturity to be 'forests'. Estimates of national forest and other wooded land areas prior to establishment of the NFI have therefore varied over the years, depending on definitions and assessment techniques used. National estimates are most sensitive to monitoring and assessment of boreal- and taiga-tundra ecotones, which are very large. Canada relies on remote sensing to monitor these systems, and it can be very difficult to definitively classify lands as 'forest' or 'other wooded land' using the FAO definition. It would be beneficial to have an operational definition of forest that can be applied in the field and directly in remote sensing image interpretation, rather than inferring what is or is not 'forest' using measured forest inventory attributes and assumptions about future stand development where mature tree cover is expected but not currently present.

Other wooded lands and trees outside of forests also occur in southern Canada, and these provide important environmental services. Shelterbelts are planted and maintained on agricultural lands to mitigate the effects of wind erosion (Wiseman et al. 2009) and to provide habitat for wildlife. Farmers often allow woody vegetation to grow on previously cleared agricultural lands when economic conditions do not favour continued cultivation. In some regions, anecdotal evidence suggests that the area of wooded agricultural land has increased significantly since the mid-twentieth century, but no estimates of this increase have been produced yet. In other areas, the conversion of wooded lands to agricultural land uses continues.

Municipalities in Canada maintain urban 'forests' that provide a multitude of benefits to Canada's increasingly urbanised population. Detailed inventories and assessments have been done at the municipal level. Highly successful urban and rural tree planting programs have been implemented, and considerable efforts have been made to manage urban and rural tree health problems caused by alien invasive insects and diseases, such as emerald ash borer (*Agrilus planipennis* Fairmaire) and Dutch elm disease.

12.4 Conclusion

Canada's NFI is a key element of this country's national forest data and information infrastructure. The computing infrastructure for NFI data management and information dissemination is provided by the National Forest Information System (NFIS; accessible at: nfis.org), which also provides the computing and online data delivery infrastructure for NFD. The NFI and NFD are used in combination, together with data from other federal, provincial and territorial government sources, to produce the information needed for annual state of the forest reporting (e.g. NRCan 2014), for FRA, and to meet other international reporting obligations and domestic data demands.

An important challenge facing Canada's NFI is the development of new inventory technologies. Computer science and software engineering advances have enabled the development of more robust data loading and validation tools, and new remote sensing technologies create opportunities to collect new types of data (e.g. White et al. 2013, 2014). Canada's NFI is perhaps more susceptible to technological change than most NFI programs because of its reliance on contemporary remote sensing technology. Canada's size and lack of a clearly legislated mandate for NFI make it necessary to align the NFI program delivery with provincial and territorial inventory programs, which means that as these programs adopt new remote sensing technologies, so must the NFI. From a NFI perspective, however, any change to established protocols must be approached carefully to ensure that temporal consistency in the data is not compromised.

Meeting all demands for information about national forest resources and their availability is challenging, particularly as new demands for information emerge. NFI programs must evolve to meet emerging demands for forest information, but NFI programs have considerable intrinsic inertia and cannot change direction quickly or easily. NFI programs must also collaborate in order to achieve the level of harmonisation that is needed internationally (Tomppo et al. 2010).

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Chapter 13
Chile

Carlos Bahamondez, Marjorie Martin and Yasna Rojas

13.1 The Chilean National Forest Ecosystem Inventory (NFEI)

13.1.1 Historical Aspects and Objectives

Chile has applied permanent inventory techniques since the 1980s. However, an important precursor to this occurred much earlier in 1944–45 when the Chilean government in cooperation with the USDA Forest Service completed a project titled "Forest resources of Chile, basis for industrial expansion" (Haig 1945). This project was the first application of inventory techniques in Chile and latin America, which promoted new developments such as the use of aerial photos as a base for mapping. The project also developed the capacity of professionals working in forestry. Among other positive effects this first inventory highlighted serious concerns about the sustainability of forests at that time. Unfortunately, this initiative was not designed to provide permanent monitoring and no continuous forest inventory was established at that time.

The focus of the 1944 forest inventory was on wood supply and production potential given the state and condition of forests at that time. Nowadays the paradigm of reporting on growing stock has moved to a multifunctional concept, to address the sustainability of forests ecosystem after Brundtland commission (1987) and the Rio Summit in 1992. All the conventions and agreements existing today are

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the result of processes such as, the United Nation Framework Climate Change Convention (UNFCCC), the Convention on Biodiversity (CBD) and the various forest agreements such as the Montreal Process, the Helsinki Process (currently FOREST EUROPE) and others.

In fact, all these organisations are periodically requesting countries to provide data and information related to ecological, economical and social issues of their forests resources. Given the wide range of information required, it is clear the necessity of a large scale forest ecosystem inventory at national level.

13.1.2 Sampling Methods and Periodicity

The total area of Chile is 75.6 million ha, of which forests occupy 16.5 million ha. Natural forest cover 13.5 million ha. The difference are mainly plantations of *Pine* spp. and *Eucalyptus* spp. forests. The Chilean National Forest Ecosystem Inventory (NFEI) was designed to satisfy the national and international demand for data and information with regard to the ecosystem as a whole. The design considered bio-physical, biodiversity and socioeconomic issues under a multilevel and multisource inventory design (Scheuder et al. 1993). The NFEI aims to further secure the forest ecosystem integrity by tracking through time the state and condition of a set of key monitoring elements.

Sample plots are located on a systematic sampling grid, 5 km in the East-West and 7 km in the North-South directions (INFOR 2014). This grid was a result of a specific autocovariance study performed in 1995 to decide objectively the best grid layout for the whole country. The sample unit used is a cluster of three circular sample plots of 500 m^2 organized as nested circular sample plot for efficiency reasons. To increase the efficiency of field data collection three sample units are taken on an inverted "L" shape, where the vertex corresponds to the sample unit 1 according to Fig. 13.1.

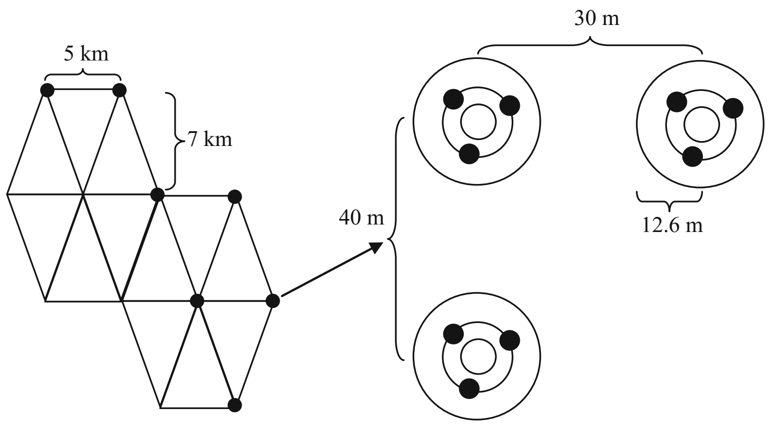

Fig. 13.1 NFEI sampling design details

Field measurements are performed on a 4 year cycle where every year one quarter of the field plots are assessed annually. Annual estimates are calculated by combining new ground truth data, remeasured sample plots and corrected projections for those plots not visited in previous year. Correction is based on a calibration generated by the remeasurement plots (Kangas 1991).

The nested disposition of the circular sample plot (Fig. 13.1) consists of three concentric circles of fixed radius associated to trees sizes, the largest radius of 12.62 m, involves trees larger than 25 cm of diameter at breast height (dbh), trees with dbh > 8 cm are measured within the radius of 6.23 m and trees with dbh > 4 cm are in a radius of 2.0 m. The three small solid circles correspond to vegetation and regeneration and soil subplots.

13.1.3 Data Collection

The rationale of the forest ecosystem inventory in Chile is based on a requirement for national and international data about ecosystem as a whole. That means the design of the inventory considers biophysical, biodiversity and socioeconomics issues. Its goal is to monitor the integrity of the forest ecosystem and ecosystem stressors as the key elements to collect.

As a conceptual framework the four stages decribed by Holling (1973) (Liberation, Organization, Exploitation and Conservation) are used as guidance during the planning stage to identify suitable variables to explain the natural dynamics of forest ecosystems.

A hierarchical approach (Kay 1984) to the forest ecosystem was applied identifying those key elements at several temporal and spatial scales. The resolution of what is operationally measurable is in line with our technological capacity of detecting changes, which are usually described annually. Basically, a hierarchic system was devised according three operationally measurable levels (Fig. 13.2) tree level, trees and neighbours and, stand level. Given the resources available, these levels represent the best selection of variables at both temporal and spatial scale. The decision on the final variables to collect in the field was made possible through the use of stepwise regression analysis.

The main variables collected during field work are described below:

Tree level: Measurement on trees at stem and crown level involves dbh, bark thickness, health status, types of damage or disease, causing agent, crown diameter, crown dominance according to Kraft (1884), crown health and relative location. From all the trees selected according to the concentric plot arrangement, detailed measurements on species commercial height, total height, height at the origin of the crown canopy, the height to one third of the total height are collected from the sample trees of the different concentric plots. Similarly, the diameters at the aforementioned heights are measured. Additionally, dbh growth is measured by core extraction. Within the three circular subplots of 1.0 m^2 each one (Fig. 13.1),

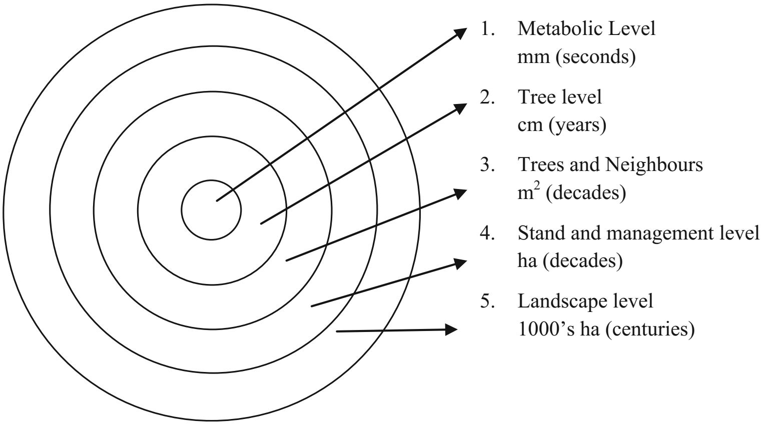

Fig. 13.2 Hierarchical approach to ecosystem, measurable levels were defined as level 2, 3 and 4 (between brackets the units and temporal scale of each measurement)

vegetation, and regeneration are assessed. Each tree is assessed for the presence of nests or similar features.

Trees and neighbours level: this level concerns the tree and its imediate competitors, thus, the issue of competition, mutualism and growth capacity is relevant. A description of the management is recorded, mainly type, intensity, state, the relative position of trees with their neighbors, the origin (coppice or seed), topographic variables like slope, geomorphology and orientation, signs of grazing, water, erosion, drainage, endangerous flora, fauna, buildings, high religious area or etnic valued area are some of the data collected.

Taking advantage of the cluster spatial arrangement, coarse woody debris (lying trees pieces with intersection diameter >10 cm) and fine woody debris (pieces with diameter <10 cm) are sampled by applying line intersect sampling, using an imaginary line connecting the subplot centers.

As well as woody debris, standing dead trees and stumps are also measured, using the same plots and rules applied to living trees. Dead trees are important for the nutrient cycle and they relate to habitat or shelter provision for the fauna and microfauna.

Biomass is also relevant to the amount of fuel or nutrient stored in the forest, but also allows for $CO_{2\text{-eq}}$ estimations in several pools.

Stand level: the cluster is used as an indicator of landscape dynamics with a focus on soil, which is sampled in plot 1 of the cluster. Among soil variables, color, pH, depth, depth of humus and litter, texture, structure, humidity condition, presence of worm, roots and micorrizes, compactation, fertility and erosion are recorded. Furthermore, a general description is added reflecting signs related to the degree of human intervention, degradation status and biotic, abiotic, cultural-ethnic and social drivers dominating the sample plot. Regeneration is also depicted for the cluster as a proxy of the forest sucessional stage. Lichens, shrubs and some herbaceous are collected mainly as potential site quality indicators.

At landscape level, biodiversity as life support for the ecosystem is monitored by collecting data on: plants, mammals, arthropods, reptile, birds and fungus based on a hexagonal unit of 269,000 ha, containing close to 50–70 clusters previously stratified according to Holling stages. Trap cameras and field sound and ultrasound recorder are installed in the field to record mainly species abundance. Reptiles and arthropods are sampled in line sampling. The goal for this level is to collect evidence on forests species or species together with non Plantae reigns species, in order to get a thorough understanding of management effects on these forest dependant species.

13.1.4 Data Processing, Reporting and Use of Results

The NFEI was not designed to assess land use changes and land classification. This task is performed, using a wall to wall approach officially undertaken by the Chilean Forest Service (Corporacion Nacional Forestal, CONAF). Thus, the NFEI takes the estimated CONAF areas as a base for its volume and biomass approximations to country level.

The volume and consequently biomass are processed using the following steps:

1. Field data collection
   At this stage, the data are stored in the field data logger which includes a set of validation rules controlling data consistency and quality.
2. Upload to database
   This stage consists of loading the field data from the data logger to the NFEI database. At this step, a second validation of consistency is performed by applying database engine specific stored procedures. The database engine utilised by the NFEI corresponds to an SQL Server over a normalised data model.
3. Tree processing
   Individual tree calculation is the core element in processing statistics. Firstly, a visual and graphical inspection of data is performed. Then, several procedures for the detection of unusual tree variable relationships are applied, e.g. the subplot relation diameter at breast height versus height, analysis of consistency between diameters at different heights, checking for errors in attribute classification. Once the data quality is approved, several volume and biomass functions available by species are applied to the several selected trees in every concentric plot of the cluster.
4. Plot and cluster processing
   The cluster of the three 500 m^2 plots, constitutes the sample unit. Thus, the aggregated results from the cluster plots are the statistical valid results for inventory precision estimation.

5. Tables and maps
   The usual tables with several entries like forest types, administrative arrangements like regions, provinces or communes, and combinations among them are produced as results. Additionally, by applying *k-nn* algorithm on samples aided by satellite images (Tomppo 1990), a set of national thematic maps are generated for volume/ha, basal area/ha, number of trees/ha, above ground live biomass/ha, above ground dead biomass/ha, carbon/ha, growth/ha, among others.
   No drain estimation is performed given that only first cycle data are available. The second cycle will commence in 2015.

13.2 Land Use and Forest Resources

13.2.1 Land Use Classification and Designation

The classification of lands established by CONAF during 1993–1997 applied a Montpellier approach known as “Carta de Ocupación de Tierras” (COT) to produce a forest map at a resolution of 6.25 ha, including a forest type delineation.

According to national definition, a forest is a portion of land with a minimal area of 5000 m^2 with a potential height of trees larger than 2 m, and crown cover larger than 25 %. FRA Classes like and Trees Outside the Forest (TOF) are not measured. The results of this national classification expressed as FAO classes (FAO 2010) are presented in Table 13.1.

Table 13.1 Land use areas for national classes and FAO classes (1000 ha)

National classes	Forests	Other wooded land	Other land	Water (inland)
Urban			230.5	
Agriculture			3674.1	
Pasture			5858.3	
Shrubs-pasture		2515.5		
Shrubs		8632.6		
Shrubs-trees		1667.3		
Shrubs-arid		1824.0		
Arid vegetation		63.6		
Shrubs-plantation		45.2		
Forests	16,231.0			
Wetland			4496.2	
Bare land			24,621.8	
Glacier and snow			4505.9	
Water inland				1229.2
Non recognised			399.7	

Table 13.2 Forest area by primary management objective

Management objective	Description	Area (1000 ha)
Production	Devoted to wood production and similar like fibre, bioenergy and non wood forest products[a]	7485
Protection	Soil protection and riparian areas	4714
Conservation	Mainly biodiversity protection	2320
Multiples uses	Several uses on production	1712
		16,231

[a]This is a potential productive resources from natural forests, given more than 90 % of industrial production in the country come from forest plantations

In relation primary management objective of the forests, Table 13.2 details the forest area by FAO management objective classification. Recently a law to promote natural forest management was enacted. Its effects on natural forests has yet to materialise. While management and cutting regulations are in place, few management plans are proposed for approval to the authorities.

13.2.2 Wood Resources

The growing stock associated with natural forests and its increment are calculated from the sample units defined as a cluster of three 500 m^2 plots. Available volume and biomass functions consider only trees with dbh > 8 cm. Table 13.3 depicts national definitions and threshold considered for calculation.

An estimate of drain is still not reliable given the lack of data on natural losses from the field. Currently, cutting removals and household fuelwood consumption statistics are available. However, the fuelwood statistics underestimate the true extent of felling as at least 70 % of trade in fuelwood is not accounted for. It is expected the drain will be reported after the end of second cycle of NFEI. The resulting assessment on natural forest from data processing is detailed in Table 13.4 by Chilean administrative regions.

The total 2014 stock of forest in the country rise to 3.4 billion m^3 in a total area of natural forests of 13.4 million ha. Every year the forest growing stock increases

Table 13.3 Detailed related growing stock national definitions

Variable	Definition
Standing stock	Volume of trees with dbh > 8 cm including bark and full stem, excluding above ground piece of the stump
Increment	Volume of trees with dbh > 8 cm over bark taken by bore extraction
Drain	Drain is defined as the sum of cutting removals, household fuelwood consumption, natural losses and waste estimation. In this respect currently, NFEI is still not able to provide reliable estimate of drain

Table 13.4 Current estimates of the natural forest area, volume, growing stock and growth by region

Region	Forest area (1000 ha)	Growing stock (m^3/ha)	Growing stock (1000 m^3)	Increment (1000 m^3/y)
Coquimbo	3.5	28.79	101.1	–
Valparaíso	95.4	21.16	2019.9	–
Metropolitana	93.5	28.21	2638.7	–
O'Higgins	118.0	36.43	4299.1	–
Maule	370.3	161.54	59,823.1	1527.8
Bio Bio	786.2	172.62	135,715.2	6965.4
Araucanía	908.5	290.6	264,010.4	5689.2
Los Ríos	850.0	357.43	303,815.5	5389.3
Los Lagos	2758.8	265.36	732,100.5	6782.5
Aysén	4814.0	266.32	1,282,082.0	24,118.7
Magallanes	2625.5	248.17	651,571.8	7181.0
Total	13,424.0		3,438,171.3	57,654.2

by 57.6 million m^3. The current lack of drain estimates do not allow the calculation of forest balance to be assessed until the second cycle of the inventory be completed. The distribution of growing stock by forest type and administrative region is provided in Table 13.5.

Table 13.5 Distribution of growing stock by forest type and administrative region (million m^3)

Forest type	Region						
	Maule	Bio Bio	Araucanía	Los Ríos	Los Lagos	Aysén	Magallanes
Fitzroya cupressoide					39.14		
Nothofagus dombeyi Nothofagus alpina, Laurelia phillippiana			37.31	135.67	537.65		
Quillaja saponaria, Peumus boldo	7.18						
Nothofagus dombeyi, Nothofagus alpina, Nothofagus obliqua	23.33	88.17	79.62	51.8	37.83		
Nothofagus glauca, Nothofagus obliqua	26.92						
Other forest types		25.95	27.64	51.56		5.44	
Araucaria araucana		7.64	119.46				
Austrocedrus chilensis		3.29					
Other forest types		0.75		64.78	114.22	1124.45	
Nothofagus pumilio		9.88				104.2	651.57

13.3 Asessment of Wood Resources

13.3.1 Wood Supply and Wood Quality

Nothofagus dombeyi, *Nothofagus alpina*, *Nothofagus oblique*, evergreen and *Nothofagus pumilio* forest types are among the most relevant forest types for future productive use. Natural forests in Chile are currently not the cornerstone of industry, which mainly supported plantations of *Pine* and *Eucalyptus* species. There are important barriers and issues to be solved before these forest types become a productive alternative satisfying the internal and international market, including:

1. Irregular status of land tenure. By law any landowner must show legal status of their property and once demonstrated, permission to cut and management are provided. Unfortunately, a large amount of natural forest landowners have no tenure, which consequently results in illegal logging, degradation and unsustainable practices.
2. Forest location. The majority of forest are geographically located in areas with very poor accessibility. It is not economically viable to transport this timber to any plant or industrial facility. Another element to this is the geomorphology of forest areas, steepy areas dominated by Andean Range limits harvesting operations.
3. Irregular forest structure. The current forest structure is highly irregular, showing an age and size structure not suitable to sustain a stable wood product flux through a certain time horizon, usually 20–30 years.
4. Forest is being degraded. Every year more than 9.0 million m^3 is cut illegally for the fuelwood market, as this activity is not regulated by a management plan the forest is shown to be degraded, according to field observations.
5. Interest rate too high. An interest rate of 8 % is required to borrow funds for forest related projects, which is far from the 3 % return from economic activity in natural forests. In order to sustain such a rate, forest products need to be valued by management and focus in high quality wood products.
6. Cattle grazing. Cattle grazing whithin the forest results in strong soil compactation, destroys regeneration and opens the understory to borer insects. Insects destroy the first log of the tree causing a number of galleries declassifying the log. As a result, only 9 % of volume/ha classify as high quality, 21 % is lost volume because of damage and disease, and the remaining volume is medium to low valued material.

13.3.2 Change Assessment

The NFEI is treated as a continuous forest inventory, where two successive inventories are combined to assess change through time. In general two alternatives

Table 13.6 NFEI continuous forest inventory cycle

Zone id	Year 1	Year 2	Year 3	Year 4
Zone 1	Remeasure	Project_{t+1}	Project_{t+1}	Project_{t+1}
Zone 2	Project_{t+1}	Remeasure	Project_{t+2}	Project_{t+2}
Zone 3	Project_{t+2}	Project_{t+2}	Remeasure	Project_{t+3}
Zone 4	Project_{t+3}	Project_{t+3}	Project_{t+3}	Remeasure

are available, (i) using permanent sample plots or (ii) using temporal sample plot. In this case, the NFEI apply permanent sample plots with partial replacement. The whole country is divided in four zones which are assessed over a 4 year period. Continuous estimates are coming from remeasurement 25 % of the available sample unit belonging to the respective zone and, measured during the first cycle. As a means to maintain an updated inventory for the whole country, a projection of growing stock based on sample units is performed in those zones where no remeasurement is performed. The inventory cycle is detailed in Table 13.6. As Table 13.6 shows, the cycle of remeasurement and projection of growing stock, facilitates the annual updating for the whole country. Remeasurement, provides data on the trends of growing stock at the level of a sample unit, but also, provides data about the quality of projection by modeling. It also allows for correction algorithm to be generated which are used to improve estimates (Kangas 1991; Dixon and Howitt 1979).

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Chapter 14
China

WeiSheng Zeng

14.1 The Chinese National Forest Inventory

14.1.1 History and Objectives

Large-scale forest surveys began in China, from 1950 to 1962, when the forest census was undertaken. This survey aimed to assess the state of forests in the whole country after the new People's Republic of China was set up in 1949. In 1962, the former Agriculture and Forestry Ministry (AFM) mandated the provincial forestry departments to compile forest data from various inventories, such as reconnaissance inventories and forest management inventories conducted during 1950–1962. These provincial data were summed to provide national results. This was the first time that forest data were gathered, compiled and reported at national level. From this forest census, the general forest status in China was revealed, although the scope of inventory only involved the main forest regions and the state forest bureaus, representing about 3 million km^2 (Xiao 2005; Lei et al. 2009; Lin et al. 2013).

In 1973, the AFM conducted two pilot forest inventories in the Jiwen Forest Bureau of Daxinganling and the Huitong County of Hunan Province respectively. Using past experience and study results of the two pilot inventories, the first national forest inventory (NFI1) was conducted at a county-level during 1973–1976, which is usually referred to as the "4th Five-Year Plan Inventory" (Xiao 2005). Except for some regions where a sub-department survey method was used, the sampling survey method was applied in most regions, however not unified for the entire country. The primary emphasis of NFI1 was on the assessment of the current status of the forests.

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Thereafter, the importance of monitoring forest change resulted in the establishment of a permanent sampling grid in each province for continuous forest inventory (CFI) during the 2nd NFI 1977–1981. All subsequent NFIs were primarily based on the CFI system. The first re-measurement of the permanent plots was done in the 3rd NFI 1984–1988. From this inventory, not only the current state of forest resources was obtained, but also the development trends. Since the 4th NFI 1989–1993, four newly established regional forest monitoring centres were responsible for technical instructions, quality checks, statistical compilations, and output reporting at regional level. In the 5th NFI 1994–1998, the United Nations Development Programme (UNDP) and Crisis Prevention and Recovery (CPR) 91/151 project "Establishment of National Forest Monitoring System" was completed and an integrated pilot study on new technology applications was conducted in the Jiangxi Province using remote sensing (RS) data, geographic information systems (GIS), and advanced database and modelling techniques. The pilot laid a foundation for the application of new techniques such as RS and GIS in the NFI and for the optimisation and improvement of the CFI system.

In the 6th NFI 1999–2003, RS technology was widely applied. Several provinces in the western China, such as Tibet, Xinjiang, Gansu, Qinghai and Sichuan, conducted their first complete inventories. Nationally, a total of 415,000 ground plots were measured, and 2.84 million RS plots were interpreted. The sampling area covered the total land area of 31 provinces of the country except Taiwan, Hong Kong and Macao. It was the first complete inventory of the mainland China. In the 7th NFI 2004–2008, several new ecological variables on forest health, ecological functions and biodiversity were integrated in the inventory and a national evaluation of forest ecological services was implemented for the first time (State Forestry Administration 2004, 2009). The assessment of these ecological services was continued and tree biomass equations for main tree species were developed in the most recent 8th NFI 2009–2013 (State Forestry Administration 2014a; Zeng 2014). The NFI results are used for macro decision-making and by forestry administration, as well as for the provision of regional, national, and international forest statistics.

14.1.2 Sampling Methods and Periodicity

The NFI is the largest forest monitoring program in China and covers all land, including forest land and non-forest land. The inventory has a 5-year cycle, with about 20 % of the provinces implementing an inventory each year. The sampling schemes of the 31 provinces (not including Taiwan, Hong Kong and Macao) are adapted to the geographic characteristics and structure of the forest resources. Since China's NFI system has been implemented for more than 40 years, some of the provinces improved their sampling designs according to the national specifications for continuous forest inventory. At present, most of the provinces employ a systematic sampling design, and all the sample plots are permanent. A few of the provinces divide the territory into strata according to eco-geographic regions. Each stratum is considered as an independent sub-population in which systematic sampling is applied (Xiao 2005; Lin et al. 2013).

The sample size in each province depends on the variability of the sample units, and the desired sampling precision and confidence level. Among the 31 provinces in China, the smallest sample size is less than 3 thousand plots, and the largest sample size is more than 10 thousand plots. The permanent plots are located systematically on two-dimensional grids, with the grid spacing varying considerably between provinces. The smallest spacing of plots is 1 × 2 km, the largest 8 × 8 km.

At present, the sample plots are fixed-area plots in all 31 provinces. Only one province (Guangxi) used to apply variable-area plot, i.e. point sampling or angle count sampling (also known as Bitterlich or variable radius plot sampling), which was converted into fixed-area plot in 2005 (Cen et al. 2007). The plot sizes vary between 0.06 and 0.10 ha, but most of them have a size of 0.0667 ha (1 Chinese mu). Plot shape includes three types: square, rectangular, and circular. The square plot is usually used, and rectangular plot is used in only a few provinces. In Tibet, a circular plot is used. The sampling design of NFI for 31 provinces in China is detailed in Table 14.1.

14.1.3 Data Collection

Besides the basic data such as the allocation of sample plot (administrative region, geographical coordinates), the list of field staff and inspection team, the dates of surveying and checking, the NFI collects data on three categories: stand-level variables, tree-level variables and auxiliary information.

Stand-level variables describe the plot attributes and include the following variables:

- Landform
- Elevation above sea level
- Slope direction
- Slope position
- Slope gradient
- Surface configuration
- Dune height
- Coated sand thickness
- Erosion gully area ratio
- Bedrock bareness
- Soil group
- Soil texture
- Soil gravel content
- Soil layer thickness
- Humus layer thickness

Table 14.1 Sampling design of the NFI for the 31 provinces in China (State Forestry Administration 2010)

Province	Sub-population	Land area (1000 ha)	Plot number	Grid	Plot shape	Plot size	Year of last inventory
Beijing	/	1641	4074	2 × 2	Square	0.0667	2011
Tianjin	/	1131	2818	2 × 2	Square	0.0667	2012
Hebei	/	18,769	11,709	4 × 4	Square	0.06	2011
Shanxi	/	15,662	9915	4 × 4	Square	0.0667	2010
Inner Mongolia	/	118,300	17,951	8 × 8	Rectangular	0.06 (10 × 60)	2013
Liaoning	/	14,574	4613	4 × 8	Square	0.08	2010
Jilin	/	18,919	8865	4 × 16/3	Square	0.06	2009
Heilongjiang	I	10,054	1571	8 × 8	Square	0.06	2010
	II	6479	1013	8 × 8	Rectangular	0.06 (10 × 60)	2010
	III	28,928	9083	4 × 8	Square	0.06	2010
Shanghai	/	634	3365	2 × 1	Square	0.0667	2009
Jiangsu	/	10,260	8536	4 × 3	Square	0.0667	2010
Zhejiang	/	10,180	4249	4 × 6	Square	0.08	2009
Fujian	/	12,150	5051	4 × 6	Square	0.0667	2013
Jiangxi	/	16,695	2608	8 × 8	Square	0.0667	2011
Shandong	/	15,222	9646	4 × 4	Square	0.0667	2012
Henan	/	16,700	10,358	4 × 4	Square	0.08	2013
Hubei	/	18,590	5820	4 × 8	Square	0.0667	2009
Hunan	/	21,184	6615	4 × 8	Square	0.0667	2009
Guangdong	/	17,677	3685	6 × 8	Square	0.0667	2012
Guangxi	/	23,760	4948	6 × 8	Square	0.0667	2010
Hainan	/	3391	2829	4 × 3	Square	0.0667	2013
Chongqing	/	8234	5133	4 × 4	Square	0.0667	2012
Sichuan	/	48,374	10,007	6 × 8	Square	0.0667	2012

(continued)

Table 14.1 (continued)

Province	Sub-population	Land area (1000 ha)	Plot number	Grid	Plot shape	Plot size	Year of last inventory
Guizhou	/	17,617	5500	4 × 8	Square	0.0667	2010
Yunnan	/	38,264	7891	6 × 8	Square	0.0667	2012
Tibet	/	122,844	5855	6 × 8	Circular	0.0667	2011
Shaanxi	/	20,598	6440	4 × 8	Square	0.08	2009
Gansu	I	44,973	2817	2 × 3	Square	0.08	2011
	II		4038	3 × 3	Square	0.08	2011
	III		10,846	4 × 8	Square	0.08	2011
Qinghai	I	72,151	76,616	2 × 2	Square	0.08	2013
	II		51,620	4 × 2	Square	0.08	2013
Ningxia	/	5195	12,936	2 × 2	Square	0.06	2010
Xinjiang	I	16,470	16,474	3 × 4	Square	0.08	2011
	II		59,917	6 × 4	Square	0.08	2011

Note (1) The permanent plots in Jilin province were established through intensifying the 4 × 8 km grid by 50 %, that is, there are 3 plots for each 64 km^2; (2) The 5855 plots in Tibet only includes ground plots in the 1st sub-population (30 forestry counties); (3) The plot numbers of Gansu, Qinghai, Ningxia and Xinjiang include some RS-interpretation plots

- Litter layer thickness
- Vegetation type
- Shrub cover
- Shrub height
- Herb cover
- Herb height
- Vegetation cover
- Land type
- Land ownership
- Forest ownership
- Forest classes (ecological/commercial)
- Governance level of ecological forest
- Protection class of ecological forest
- Management class of commercial forest
- Tending measures
- Forest category
- Forest origin
- Dominant tree species
- Mean age (boring or visual estimation)
- Age class
- Production stage of economic forest
- Mean diameter
- Mean height
- Crown cover
- Forest community structure
- Stand storey structure
- Species composition
- Naturalness
- Accessibility
- Forest disaster type
- Forest disaster class
- Forest health class
- Number of 4-side trees (e.g. isolated trees beside croplands, roads, rivers, and villages or residential areas)
- Number of bamboos
- Natural regeneration class
- Size class of land type
- Reason of land type conversion
- Deliberate interference (Y/N).

Tree-level variables describe the sample tree attributes. They include the following variables:

- Tree type (trees in forests; scattered trees in other forest land; isolated trees beside croplands, roads, rivers, and villages or residential areas)

- Species
- Diameter at breast height (the dbh threshold is 5.0 cm measured over bark)
- Tree height (only 3–5 trees per plot with average dbh for calculating the mean height)
- Stand storey
- Azimuth
- Distance.

Auxiliary information includes forest damages, vegetation status, natural regeneration, artificial afforestation, and changes of plot attributes such as land type, forest category, origin, dominant species, age class, and vegetation type.

Detailed information about the data collected by the China's NFI and the variables assessed are available from the technical specifications on national continuous forest inventory (State Forestry Administration 2014a).

14.1.4 Data Processing, Reporting, and Use of Results

Field assessments and measurements constitute the input variables for the estimation algorithms applied by the China's NFI. Basically, area-related estimates and volume-related estimates can be distinguished.

The estimation of area has two components, the land and forest category related data collected on sample plots and the area of the province. The area represented by one sample plot is calculated by dividing the total land area by the total number of sample plots located in the respective category. The area of each province, municipality, or autonomous region is obtained from the official statistics and is assumed to be error-free. The area estimate of a given category is equal to the sum of plots located in the category multiplied by the area represented by the plot.

The estimation of the volume of standing stock, increment, and drain is of particular interest for forest land. The estimation procedure includes several steps. After field data collection, the data undergo quality control procedures. Volume is then calculated for each sample tree. Different equations are applied depending on the species of the sample tree. For each plot the represented volume per hectare is calculated as the sum of per hectare values represented by individual trees. These per hectare estimates are aggregated to a mean volume per hectare for forest and multiplied by the area of forest to obtain the total volume of standing stock and growing stock. Mean volumes per hectare and total volumes are also estimated for different categories, such as the ownership, the origin, forest types, and age classes (State Forestry Administration 2011).

Change estimates are obtained from the assessments of two consecutive NFIs. The volume increment of sample trees is calculated as the difference between the volume at the second and the first occasion. Sample trees that have exceeded the dbh-threshold of 5.0 cm between the two NFIs are included in the increment estimation. The drain is assessed by recording the sample trees that have been harvested or that have disappeared naturally since the previous field assessment. The drain is defined as the volume at the moment of the first assessment (State Forestry Administration 2011).

China's NFI provides estimates at two regional scales, the national level, and the 31 provinces. The estimates include total forest area, forest cover or percentage, growing stock, increment and harvest. The NFI is used as basis for decision-making in forestry and environmental policy, forest management, forest products industries, and for evaluating the consequences of the decisions taken. It also provides country reports for international organisations such as the United Nations Food and Agriculture Organization (FAO) Forest Resources Assessment process, and sustainable forest management report for Montréal process. Therefore, users of the NFI data include forestry and environmental policy makers, forest managers, forest industry decision makers, research scientists, and international organisations (Tomppo et al. 2010).

14.2 Land Use and Forest Resorces

14.2.1 Classification of Land and Forests

14.2.1.1 General Land Classification

The land classification system used in China's NFI follows a hierarchical system of land types (Table 14.2). At the highest level the land area is divided into forest land and non-forest land. To qualify as forest, a piece of land requires a minimum area of 667 m^2, a minimum width of 10 m, and a minimum crown cover of tree species of 20 %. Forest land contains the classes of arboreal forest, bamboo forest, open forest land, shrub land, and other forest land. Non-forest land is distinguished into cropland, grazing land, inland water, built-up land and other land as described in Table 14.2. The details of the land classification system applied by China's NFI are described in the Technical Specifications on National Continuous Forest Inventory (State Forestry Administration 2004, 2014a).

The areas of forest and non-forest land classes according to the China's NFI are given in Table 14.2. The forest definition in China's NFI includes special shrubs, which overlaps with the Other Wooded Land (OWL) definition of FAO (2004). The forest definition in China contains also some areas of land that are considered as Other Land with Tree Cover (OLwTC) by FAO (2004). This is as a result of the smaller minimum area and smaller minimum width, and higher minimum crown cover in the national definition compared to the FAO definition. The non-forest categories correspond to OLwTC depending on the crown cover.

Table 14.2 Land use classes according to the national definition with area estimates (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Class name		Description	Area (1000 ha)	Corresponding to FRA classes (FAO 2004)
Forest land	Arboreal forest	Forest land with a minimum area of 667 m^2, a minimum width of 10 m, and a minimum crown cover of tree species of 20 %	177,470	Forest, intersection with OLwTC
	Bamboo forest	Forest land composed of bamboos with a minimum dbh of 2 cm	6006	Forest
	Open forest land	Forest land with a crown cover of tree species of 10–19 %	4007	Forest
	Shrub land	Forest land with a minimum crown cover of shrub species of 30 %, including two sub-classes: special shrubs[a] and general shrubs	65,729	Intersection with OWL
	Other forest land	Unclosed afforestation land, nursery land, clear-cut land, burned forest land, and planned forest land	59,378	Forest, intersection with OL
Non-forest land	Cropland		169,707	OL
	Grazing land		245,988	OL
	Inland water	Lakes, rivers, and other water bodies	33,126	Inland water bodies
	Built-up land	Industry and commerce, mining, traffic and transport, tourist facilities, dwellings and parking sites, gardens and parks	31,441	OL
	Other land	Unused and unproductive non-forest land	167,148	OL
Total land area			960,000	

Note The total forest area 2,128,000 ha in Taiwan, Hong Kong and Macao is included in “arboreal forest”, and the other land area is included in “other land”

[a]Special shrubs are defined as shrub lands which provide mainly non-wood forest products and fruits, or lands above the timber line, or in areas with less than 400 mm precipitation or in karst and dry-hot valley areas

14.2.1.2 Forest Classifications by Use

According to the definition in China’s NFI, forests include three forest types: arboreal forests, bamboo forests, and special shrubs. Forests are further classified according to the Forest Law into five categories: protective forest, special-use forest, timber forest, fuelwood forest, and economic forest as described in Table 14.3. The first two categories are called ecological forests, and the latter three categories are called commercial forests. The area of protective and economic forests includes also special shrubs.

Table 14.3 Classes within forest and their areas (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Forest classes	Description	Area (1,000,000 ha)
Protective	Provides protective functions and benefits	99.67
Special-use	Serves species conservation, environmental protection, defence, recreation, experiment, etc.	16.31
Timber	Serves timber production and wood supply	67.24
Fuelwood	Serves fuelwood supply	1.77
Economic	Provides non-wood forest products and fruits	20.56
Total forest area (not including the forest area in Taiwan, Hong Kong and Macao)		205.55

Table 14.4 Forest area according to the national forest definition by ownership categories (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Ownership category	Area (1,000,000 ha)	Area (%)
State forests	73.77	38.59
Collective forests	117.40	61.41
Total forest area	191.17	100

Note The forest area does not include special shrubs except economic shrubs

14.2.1.3 Classification by Ownership Categories

The China's NFI distinguishes two main categories of forest ownership: state forests, and collective forests. Over half (61 %) of the forest area belongs to category of collective community forests (Table 14.4).

14.2.1.4 Forest Management and Cutting Systems

The forests in China are managed in ecological and commercial management systems. For ecological forests, the management target is to strengthen protection function and ecological benefits; and for commercial forests, the target is to increase timber production, fuelwood supply, and non-wood forest products. Also, the forests in China are managed in natural and planted management systems. Since the Natural Forest Protection Program was implemented in major forest regions in 1998, good results have achieved in protecting natural forests in China. The results of recent NFIs have showed that the proportion of natural forests with harvesting operations has decreased while harvest levels in plantations has increased. At present, a new policy is taken into consideration under which all natural forests in China will be protected and commercial cutting in natural forests will be prohibited in the near future.

The forest cutting quota system in China is an important part of cutting management. Provincial forest cutting quotas are made by the State Forestry Administration and approved by the State Council for execution every 5 years. According to the forest cutting quota during the period of “12th five-year plan” (2011–2015), the maximum annual cut volume of the whole country was 271 million m^3. The cut volume could be distinguished by the type of harvesting. About 52 % of cut volume was for final cutting. Tending cutting accounted for about 26 % of cut volume. Regeneration cutting accounted for about 6 %, and other cutting contributed about 16 % of the total harvest. Also the cut volume was classified by forest category and origin. About 80 % of the cutting quota was in commercial forests, and about 70 % was in plantations (State Forestry Administration 2011).

14.2.1.5 Legal and Other Restrictions for Wood Use

The decision to harvest trees is made by the forest owner but all operations must comply with the related regulations, such as Regulations on National Ecological Forests (2013) and Regulations on Forest Harvesting and Regeneration (1987). In 1st grade national ecological forest stands that are located in world natural heritage site, international important wetland, national nature reserve, national forest park, and other areas with special ecological importance or protective function, management activities are generally not allowed and cuts are forbidden. In 2nd grade national ecological forest stands, only selection cuts are allowed in regeneration cutting, and cutting intensity can’t exceed a certain level, for example, the cut volume percentage should be less than 15 %, and the canopy cover of remaining trees should be more than 60 %. In pre-mature forest stands clear-cuts are prohibited and also tending activities are not allowed to exceed a certain intensity level. Clear-cuts must not exceed a certain area (5 ha) and a new stand has to be established either by natural regeneration with artificial measures or planting before the end of the next year.

An important point with regard to the availability of wood resources is the accessibility, particularly in mountainous regions. According to the results of 8th NFI, about 13 % of the stocking volume of pre-mature, mature, and post-mature timber forests is inaccessible. Long logging distances and steep slopes increase the hauling costs for wood. Cable crane logging is necessary in forest areas that cannot be accessed by machinery like harvesters, forwarders or tractors because of steep slopes. These logging technologies are more expensive than conventional harvesters or forest tractors and may not be economically feasible in every case.

14.2.1.6 Further Classification of Forests

In addition to the previously described classifications of the forest area further stratifications are used in national statistics and reporting. Commonly used stratification variables are origin, age group, and tree species. The stratifications of the forest area are based on the field assessment of the forest plot. Forests are classified by origin into two types: natural forests and plantations. Natural forests account for 64 % of the total forest area (Table 14.5).

The arboreal forests are classified into five groups by age: young, middle-aged, pre-mature, mature, and post-mature forests. The arboreal forest area and percentages by age groups are given in Table 14.6.

In China there are more than two thousand tree species. According to the dominant tree species or species groups, the top 10 are *Quercus* spp., *Betula* spp., *Cunninghamia lanceolata, Larix* spp., *Pinus massoniana, Populus* spp., *Pinus yunnanensis, Eucalyptus* spp., *Picea* spp., and *Cupressus* spp. The top 10 species or groups account for more than half of the arboreal forest area (Table 14.7).

Table 14.5 Forest area according to the national forest definition by origin categories (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Origin category	Area (1,000,000 ha)	Area (%)
Natural forests	121.84	63.73
Plantations	69.33	36.27
Total forests	191.17	100

Note The forest area does not include special shrubs except economic shrubs

Table 14.6 Arboreal forest area according to the national definition by age group (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Age group	Area (1,000,000 ha)	Area (%)
Young	53.32	32.39
Middle-aged	53.11	32.27
Pre-mature	25.83	15.69
Mature	21.76	13.22
Post-mature	10.58	6.43
Total arboreal forests	164.60	100

Note The arboreal forest area does not include economic forests 10.73 million ha

Table 14.7 Arboreal forest area according to the national definition by species (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Tree species (groups)	Area (1,000,000 ha)	Area (%)
Quercus spp.	16.72	10.15
Betula spp.	11.26	6.84
Cunninghamia lanceolata	10.96	6.66
Larix spp.	10.69	6.50
Pinus massoniana	10.01	6.08
Populus spp.	9.97	6.06
Pinus yunnanensis	4.55	2.76
Eucalyptus spp.	4.46	2.71
Picea spp.	4.21	2.56
Cupressus spp.	3.66	2.22
Total of top 10	86.49	52.54

14.2.2 Wood Resources and Their Use

14.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock, increment and drain are based on the sample tree measurements at the plots on arboreal forest land. They are calculated as volume of stem wood over bark. Stem wood according to the China's NFI includes the whole trunk from the ground or collar of root to the top. The minimum dbh is 5.0 cm measured over bark. Trees below this threshold are not included in regular NFI estimates. The volume of standing stock only includes the volume of growing stock, not including volume of standing dead wood. Increment and drain are calculated as mean annual estimates for the period between two consecutive NFIs, which are based on the permanent sample plots (State Forestry Administration 2011). The national definitions for standing stock, increment and drain are compiled in Table 14.8.

According to the 8th NFI, the arboreal forest has a standing volume of 14,479 million m^3 of stem wood over bark (not including Taiwan, Hong Kong, and Macao). Between the inventories 2004/2008 and 2009/2013, about 680 million m^3 of volume increment have been produced each year and almost 441 million m^3 drained annually (333 million m^3 harvested, and 108 million m^3 dead). Thus, the drain between 2004/2008 and 2009/2013 is about 65 % of the increment in the same time period. The top 10 tree species or species groups in growing stock are *Quercus* spp., *Abies* spp., *Larix* spp., *Picea* spp., *Betula* spp., *C. lanceolata, Populus* spp., *P. massoniana, P. yunnanensis,* and *P. densata*. The top 10 species or groups account for about 55 % of the standing stock of arboreal forests. For the increment and drain this order of tree species is different: *Populus* spp. and *C. lanceolata* contribute the highest shares of increment, followed by *P. massoniana* and *Quercus* spp.; while *C. lanceolata* contribute the highest shares of drain, followed by *P. massoniana* and *Populus* spp. Table 14.9 gives the estimates of standing stock, increment and drain by top 10 tree species or groups. Increment and drain are average annual values for the period 2004/2008–2009/2013.

Table 14.8 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with dbh ≥ 5.0 cm over bark, including the bole (wood and bark), and stem top, and the above-ground part of the stump, not including volume of standing dead trees
Increment	Volume increment of surviving trees with dbh ≥ 5.0 cm over bark plus the volume of ingrown trees and half of the estimated growth of harvested or dead trees between two consecutive NFIs
Drain	Volume of trees with dbh ≥ 5.0 cm over bark at the first measurement that were found to be harvested or dead in the subsequent NFI plus half of estimated growth between measurements, including two categories: cut volume and dead or mortality volume

Table 14.9 The volume of standing stock, increment, and drain on arboreal forest land (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Tree species (groups)	Standing stock (1,000,000 m^3)	Annual increment (1,000,000 m^3/year)	Annual drain (1,000,000 m^3/year)
Quercus spp.	1294	46	25
Abies spp.	1166	11	13
Larix spp.	1001	35	20
Picea spp.	999	13	8
Betula spp.	918	28	13
Cunninghamia lanceolata	726	74	67
Populus spp.	624	76	42
Pinus massoniana	591	56	46
P. yunnanensis	502	18	11
P. densata	350	4	2
Total of top 10	8171	361	247

14.2.2.2 Tree Species and Their Commercial Use

Cunninghamia lanceolata and *P. massoniana* are the most economically important tree species in China, especially in the southern region. In northern China, *Populus* spp. is the most economically important tree species. According to the "Report 2012 of Forestry Development in China" (State Forestry Administration 2012a), 91 % of the timber products in China's forests is round wood, and 9 % is fuelwood. Certain broadleaved species are used for special purposes if they feature high wood quality or unique properties. In the recent years the use of pulpwood for paper production has increased considerably. The stock of *Eucalyptus* spp. plantations was about 19 million m^3 in NFI6, 46 million m^3 in NFI7, and 160 million m^3 in NFI8.

14.3 Assessment of Wood Resources

14.3.1 Forest Available for Wood Supply

14.3.1.1 Assessment of Restrictions

The field assessments of the China's NFI include all sample plots in the sampling grid, with the exception of plots in inaccessible terrain which are assessed using satellite imagery. The existence of legal restrictions is not assessed in the field.

With regard to other restrictions and in particular to harvesting possibilities, China's NFI assesses several relevant variables. The slope is decisive for the use of harvesting and logging technologies. In driveable terrain, technologies like harvester, forwarder, and tractor can be employed, whereas in steep areas cable cranes and cable harvesters have to be used. Another crucial variable is the accessibility for pre-mature, mature, and post-mature timber forests. Three classes are divided according to the conditions of harvesting, skidding, and transporting. The information can be used for assessment of forest resources available for wood supply. From the results of 8th NFI, the majority (87 %) of growing stock in pre-mature, mature, and post-mature timber forests is available for wood supply.

14.3.1.2 Estimation

In the study on the forest resources timber supply capacity analysis in China (Zhang and Gao 2014) the legal restrictions due to nature conservation and ecological protection were taken into account by limiting harvests according to the related regulations on forest harvesting, forest tending, and ecological forest conservation. The study results showed that the reasonable harvest volume was between 274 and 317 million m^3 per year, and the area of pre-mature, mature and post-mature timber forests was 19.2 million ha, which occupied about one-third of total timber forest area and was available for wood supply.

The utilisation of wood resources also depends on the harvesting costs. In locations with difficult accessibility the harvesting costs may render harvesting uneconomic as the costs are not covered by the revenue obtained from the harvested product. To estimate the available wood resources under given economic conditions the harvesting costs (including machine costs and labour costs) are calculated and compared to the revenue achievable under the current wood price situation.

14.3.2 Wood Quality

14.3.2.1 Stem Quality and Assortments

The basic quality classes for round wood are veneer logs, sawn timber and industrial round wood like pulpwood. Apart from these categories other assortments may be specified for particular purposes, such as mine timber and instrument or resonance wood. Veneer logs are of very good quality and require a minimum length of 2 m and a minimum diameter of 30–40 cm depending on the veneering technology. The quality classes of sawn timber contain different grades specified with butt rot, minimum diameter and minimum lengths of the log. The specifications of the quality grades are different for logs from coniferous and broadleaved trees.

Table 14.10 Stem quality classes as assessed by the China's NFI

Stem quality class	Description
1-Timber tree	Timber length is more than 40 % of total length of the tree
2-Semi-timber tree	Timber length is more than 2 m for coniferous tree or 1 m for broadleaved tree, but less than 40 % of total length of the tree
3-Fuelwood tree	Timber length is less than 2 m for coniferous tree or 1 m for broadleaved tree

14.3.2.2 Assessment and Measurement

Diameter classes are related to the stem quality. During field data collection, all sample trees in pre-mature, mature, and post-mature forests are classified by dbh into 4 classes: 5.0–12.9 cm, 13.0–24.9 cm, 25.0–36.9 cm, and ≥37.0 cm. Before the 7th NFI, three classes of stem quality are distinguished in the field. The three stem quality classes are described in Table 14.10. However, in the 7th and 8th NFI, the assessment of stem quality classes was discontinued.

In addition, several other variables are assessed on individual sample trees that are relevant with regard to stem quality. These include the tree status dead or alive, information whether a tree is forked or not, and some other stand- and site-specific variables like the type of forest and the elevation above sea level.

14.3.3 Assessment of Change

14.3.3.1 Assessment and Measurement

The estimation of increment and drain in the China's NFI is based on the field measurements on permanent plots at two consecutive points in time. Sample trees can be distinguished into trees present only at the first occasion, trees present at the first and second occasion, and trees present only at the second occasion. Sample trees that have been present at the first occasion and that are no longer present on the plots at the second occasion are recorded in the field assessments and the type of drain (cut or mortality) is determined. Sample trees present at the first and second occasion on the plots are recorded to determine the growth of survivour trees. Sample trees present only at the second occasion are used to estimate the ingrowth part of the increment.

14.3.3.2 Estimation of Increment

The increment estimated by China's NFI is defined as the volume increment of survivour trees between two field assessment periods plus the volume of ingrown trees that exceed the dbh threshold of 5.0 cm between the two points in time (State Forestry Administration 2011). The volume of the sample trees is calculated by applying the one-variable volume equations V = f (dbh), where dbh is the diameter at breast height. The volume functions contain all stem parts above ground level or root collar and include the tree elements bole plus stump, bark and the stem top.

Estimates of change include the increment of trees that die between cycles, are felled or fall over naturally as well as for trees that grow into the sample. Also the increment or volume of trees on land areas converted to forest or changing from forest to other land uses are considered in the increment and drain estimates. The NFI increment estimates are average annual increments for the time period between two field assessments. To obtain increment per hectare and total increment, the increment data of individual sample trees are converted into annual and per hectare values for each sample plot. The plot-level estimates are averaged to obtain the mean increment per year and per hectare and are furthermore multiplied by the forest area to calculate the total increment. National estimates are gross increment and they are calculated by forest and ownership categories, age classes and tree species.

14.3.3.3 Estimation of Drain

The NFI drain estimated by the China's NFI is defined as the volume of trees that were found to be harvested or dead between two field assessment periods. The volume of the sample trees that have disappeared between measurement occasions is calculated using the tree measurements at the first occasion and adding half of estimated growth between measurements. Individual tree volumes are estimated using the previously mentioned volume equations, and species-specific growth is estimated using the observed growth of trees measured at both measurement occasions. The volume of felled trees on land areas converted to other land-uses is included in the drain estimates.

The drain estimates of NFI are average annual volumes of drain for the time period between two measurement periods. Drain per hectare and total drain are obtained by referring to the situation and the number of trees represented by the sample trees at the time of the first assessment. National estimates are calculated by forest and ownership categories, age classes and tree species.

Besides the periodic drain estimates of NFI, annual statistics on the amount of wood harvested in China's forests are compiled in the "Forestry Statistics in China", which is published by the State Forestry Administration (State Forestry Administration 2012b). The statistics given by the "Forestry Statistics in China" are lower compared to the NFI estimates. The differences are mainly due to the fact that the "Forestry Statistics in China" reports only commercial wood volume whereas China's NFI reports all harvested volume, including wood used by the forest owners themselves.

14.3.4 *Other Wooded Land and Trees Outside Forests*

14.3.4.1 Assessments and Measurements

The sampling grid in China's NFI covers all land-use classes and ownership categories of the mainland of China. It is broadly similar to the FAO's Other Wooded Land definition (FAO 2004). All trees that exceed the dbh-threshold of 5.0 cm are measured, including trees growing on non-forest land. The land-use and ownership categories were also determined for plots located outside the forest. Thus, growing stock, increment, and drain of trees outside forests are also available.

14.3.4.2 Estimations

Besides the growing stock, increment and drain of arboreal forests are given in the China's NFI (see Table 14.9), those of trees outside forests are also estimated. For example, from the latest 8th NFI, the growing stock volumes of open forest, scattered trees in other forest land, and isolated trees beside villages (residential areas), roads, rivers, and croplands (so called "4-side trees") are 106, 789, and 401 million m^3 respectively. The total growing stock volume in China is 16,433 million m^3, including forest stock volume of 358 million m^3 in Taiwan, Hong Kong and Macao.

14.4 Conclusion

The availability of wood and biomass resources has become an increasingly important issue in the recent years at both national and regional scales. Therefore reliable data and information about the amount of wood and biomass available on a sustainable level are essential to develop strategies that take into account the multiple forest functions including: economic use, nature conservation and protection, and recreation. China's NFI, as the largest national forest monitoring program, has continuously broadened its thematic scope since its establishment in the 1970s. Through the integration of additional data from various sources like China Forest Ecosystem Research Network, China's NFI has estimated forest biomass carbon storage and assessed the forest ecological services in recent years (Li and Lei 2010; Project Group for Assessment of Forest Ecological Services in China 2010; Zeng 2014). Since the 7th NFI, some variables on forest health and ecological function have been added in monitoring items, and the main objective has started to convert from timber monitoring to ecological monitoring (Yang et al. 2015). Also, some ideas for improving the NFI system in China were presented in recent years (Yan et al. 2011; Zeng 2013). With regard to the estimation of available wood and biomass resources, the consideration of new reporting requirements will provide further methodological developments to satisfy the information needs of decision makers.

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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.

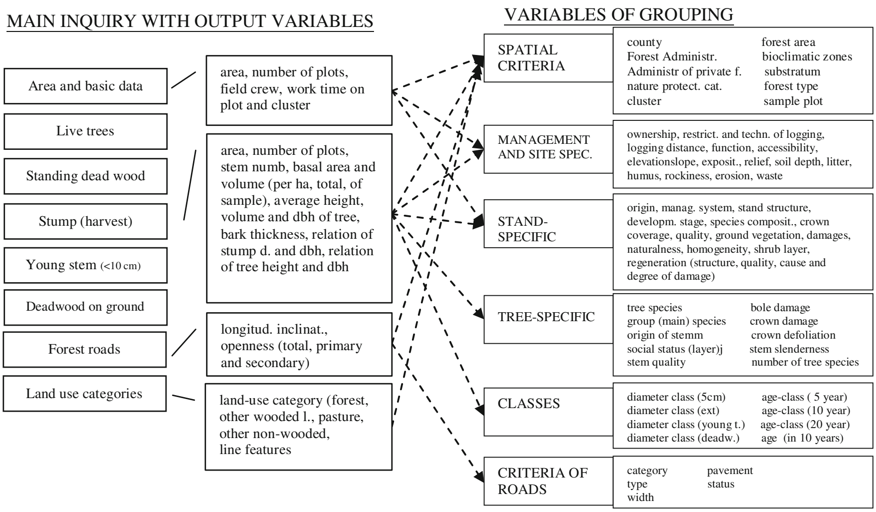

Fig. 15.1 The main structure of inquiry for variables, data processing and reporting of results provided in the ANFORRES computer program

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,

$$\mathrm{iv}_1 = \mathrm{f}(\mathrm{dbh}_1, \mathrm{id}, \mathrm{v}) \tag{15.1}$$

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

$$\mathrm{iv}_2 = \mathrm{f}(\mathrm{dbh}_2, \mathrm{id}, \mathrm{v}) \tag{15.2}$$

(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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Chapter 16
Czech Republic

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16.1 The Czech Republic National Forest Inventory

16.1.1 History and Objectives of the Czech Republic NFI

The first National Forest Inventory (NFI) started in 2001 and was completed in 2004, while the second forest inventory was launched in 2011 and was completed during 2015. In 2016, the third cycle began on a continuous basis with a five year re-measurement period. The main aim of inventory is to provide information for the formulation of national forest policy, which will inform the establishment of forest management goals and allow the evaluation of forestry activities. The inventory will also establish comprehensive information about the state and development of forests in the Czech Republic, which will facilitate the monitoring the sustainable use of forest resources. Inventory data is also used for national and international reporting.

16.1.2 Sampling Methods and Periodicity

The following information describes the first (NFI1) and second (NFI2).

16.1.2.1 NFI1 2001–2004

Basic description of NFI1 (Černý et al. 2010):

- grid size 2 × 2 km, remeasurement period 10 years

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- two circular plots in each grid cell, exact location is known for each plot in grid cell
- the position of the first inventory plot is randomly shifted a maximum of 300 m from the centre of the inventory grid cell; the distance between inventory plots of the same cell is 300 m, and the direction from the first to the second plot is random
- number of plots: approximately 39,000 in total of which approximately 14,200 were forest
- stratification within a plot: segments according to the specific classes of the land cover; minimum segment size 10 % of the area of inventory plot; no shift of plot center when plot is intersected by the forest edge; plot is established when the plot center is located within the category of forest
- type of plots: permanent (both position of trees and boundary of plot segments are mapped)
- plot size: fixed circle size 500 m^2; for trees with diameter at breast height (*dbh*) *greater or equal to* 12 cm; additional two concentric circles are established at the center of each polygonal segment of the plot; circle with the radius 3 m for the trees with *dbh* between 7 and 11.9 cm, circle with the radius 2 m for the regeneration with height ≥10 cm and dbh lower than 7 cm
- number of trees: approximately 25 per plot
- number of trees with height measurement: first 50 trees of each species per plot
- forest regeneration: tree count by species and height classes.

A more detailed description of methods, sampling design, sample plots, land categories and further details about first inventory 2001–2004 were published in Cerny et al. (2010).

16.1.2.2 NFI2 2011–2015

Two grids of inventory plots were assessed in the second NFI. The first is the sampling grid established in the first inventory 2001–2004. In this grid all inventory plots that were classified as the land category forest were re-measured. Inventory grid plots that were classified by photogrammetry into the category Forest or "Uncertain" (possible occurrence of forest) are also assessed. Repeated assessment in this grid is aimed at estimation of dynamic values like increment, harvest, change of standing stocks, forest area, species composition, etc. This inventory grid is described in Černý et al. (2010). The range of assessed attributes is reduced compared to the new inventory grid described below.

Based on analyses of first inventory grid and all technology used in the first NFI it was decided to change the sampling design. The main reason to change the design is due to a move to a new continuous inventory from 2016 and to incorporate new remote sensing methods in the NFI. The new sampling design allows new inventory technology to be incorporated, while also facilitating the continuous inventory with a re-measurement period of 5 years. The continuous inventory will enable the production of results annually.

On the grid of new plots a comprehensive set of variables on trees and sites were assessed. The new inventory grid has a north—south orientation and is a systematic design with 0.5 × 0.5 km between sample points. This grid is defined within Cartesian coordinates system of the Uniform Trigonometric Cadastral Network (S-JTSK). Inside every 0.5 km^2 one inventory plot is randomly placed. The sampling design used is referred to in the scientific literature as random tessellation stratified sampling or two step tessellation stratified sampling. Further repeated inventories will be solely based on the new 0.5 × 0.5 km grid.

NFI2 inventory grids

By randomly sampling from the primary 0.5 × 0.5 km grid, four higher level sampling grids were derived (Adolt et al. 2013). The NFI2 inventory grid comprises five sampling frames, which have different data collection and measurement details:

0.5 × 0.5 km (315,249 plots)—On inventory plots in the primary grid the photogrammetry assessment of land category is undertaken. Fundamental stand characteristics are also assessed, such as growth phase, species composition and canopy closure;
1 × 1 km (78,856 plots)—in comparison to the grid 0.5 × 0.5 km, a photogrammetry assessment of a transect is completed to monitor landscape characteristics like Trees outside Forest (TOF), forest edges, roads, streams, Intergovernmental Panel on Climate Changes (IPCC) land use categories, etc.;
2 × 2 km (19,727 plots)—in comparison with the previous 1 km grid field measurement is added. Field measurement is carried out on all plots classified by photogrammetry as category Forest, Other Wooded Land (OWL) or Uncertain (possible occurrence of Forest or OWL category). These inventory plots are called "Basic survey plots". Basic inventory details are assessed, such as field tree measurement, site and stand description;
4 × 4 km (4920 plots)—in comparison with previous 2 km grid the field measurement includes an expended set of assessed variables. Additionally, site variables are monitored, including the collection of soil samples from a soil soil pit, tree health condition assessment, evidence of deadwood with minimal diameter over 2 cm. These inventory plots are called "Extended survey plots";
16 × 16 km (307 plots)—in comparison with previous grid land category and IPCC land use category is assessed in the field on all plots in this grid. The aim of this survey is to estimate systematical error in estimation of area land and IPCC land use categories caused by restriction of field measurement on plots in category Forest, OWL and Uncertain according to photogrammetric interpretation of inventory plots. Measurement serves too for validation of quality of photogrammetric interpretation.

The NFI field data are collected on inventory plot at four main levels: site, stand, tree and transect. Figure 16.1 describes the plot design and summarises the information collected on the plot.

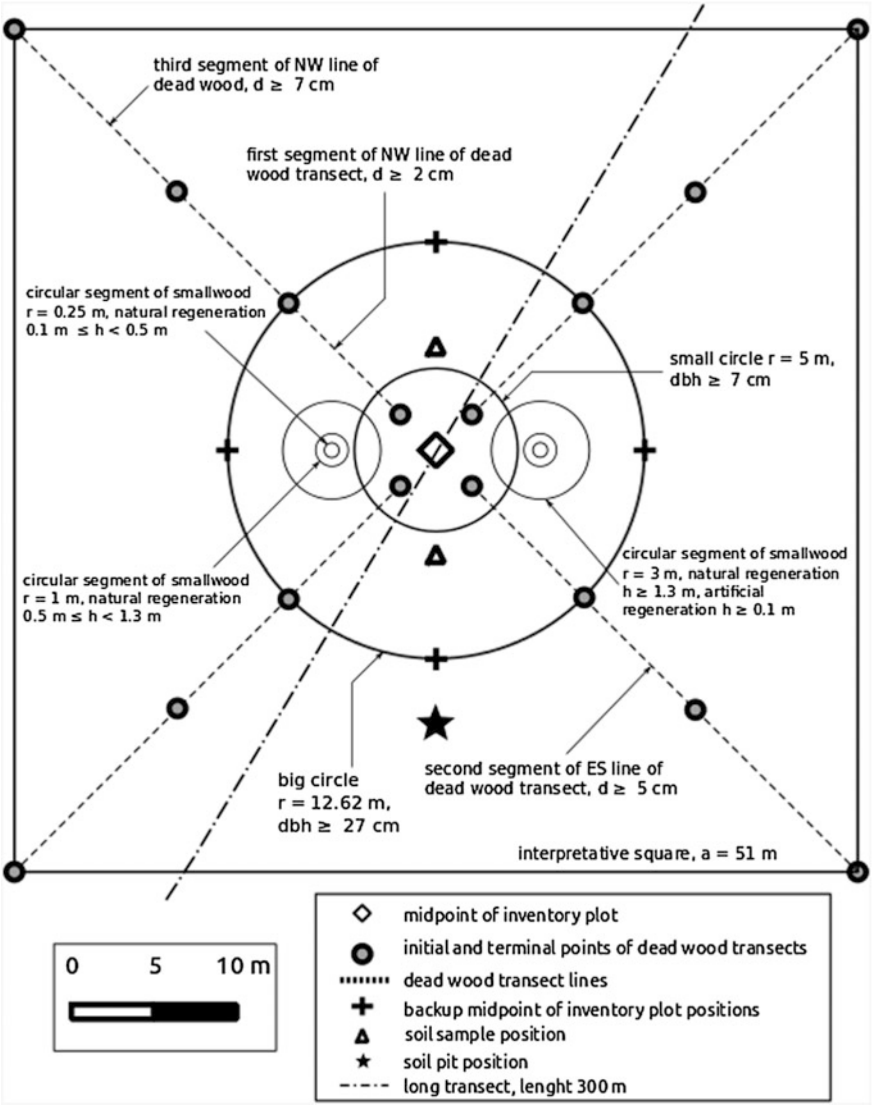

Fig. 16.1 Extended survey inventory plot (Adolt et al. 2013)

16.1.3 Data Collection

Site level variables describe site and soil condition on the 12.62 m radius circle inside the inventory plot. At site level variables include: accessibility, land category, IPCC land use category, type of ownership, altitude, forest vegetation zone, description of soil condition in a soil pit, physical and chemical analyzes of soil sample, inclination, exposition, forest type, phytocoenology, skidding distance, type of relief, occurrence of soil erosion, occurrence of lichens, forest category according to its prevailing function of forest.

Stand level variables describe stand characteristics and land category on the 51 × 51 m^2 inventory plot. The inventory plot can be divided into the segments according to the specific land category, type of forest land, accessibility and stand characteristics (age, species composition). On each segment variables assessed include: stand structure, naturalness of stand, species composition and type of mixture, growth phase of main stand layer, origin of stand (artificial or nature), form of stand (high forest, sprout forest). Trees with a height greater than 10 cm and a with a dbh 6.9 cm (regeneration) are assessed on the two circular sub-plots.

Tree level information is collected on two concentric circles: sample stems with threshold ≥7 cm on small circle (radius of circle 5 m) and stems with threshold ≥27 cm on the larger circle with radius 12.62 m. As well as the basic information such as dbh and height, upper stem diameter and crown projections are also assessed. Other parameters are assessed to describe the stem quality such as forking and stem damage.

Transect level In NFI2 two types of transects are used, a long transect and deadwood transects. The long transect has length 300 m and is randomly oriented. The midpoint of the transect is placed at the inventory plot center. On the long transect the following three types of objects:

- Point objects (detected on strip with width 50 m): rubbish, rare tree species, tourist facilities and facilities for game management;
- Line objects: forest roads, watercourses, forest edges and soil erosion;
- Area objects: spring areas, swamps, occurrence of invasive species, garbage dumps.

16.1.4 Data Processing, Reporting and Use of Results

The complete methodology for the evaluation of the second inventory data is currently being prepared and will be published during 2016. A description of the data processing from the first inventory 2001–2004 is given in Černý et al. (2010).

Forest Management Plans (FMP) are used in combination with the NFI as a source of forest information for both national and international in the Czech

Republic. Following the completion of the second NFI it will be possible to provide dynamic forest data, such as increment, felling, land use changes, etc. However in the interim FMP are used to supply these dynamic estimates. The NFI supplies data on some important aspects that are not available in FMP, such as volume of dead wood, area of OWL, Other Land with Tree Cover (OLwTC) or Forest Available for Wood Supply (FAWS).

16.2 Land Use and Forest Resources

16.2.1 Classification of Land and Forest

16.2.1.1 General Land Classification

The first NFI divided land into two main categories Forest and Non-forest. Forest includes two subcategories; Forest stands and Non-stocked forest land. These categories and subcategories are defined by national definition and are not compatible with FAO definitions for land categories. The category Forest land comprises forest land pursuant to the Forestry Act 289/1995 Coll., (Sec. 3, par. 1a) and Decree No. 84/1996 Coll., of the Ministry of Agriculture, where the forest land is divided into timber land and non stocked forest land. This category includes also land that resembles forests and is not defined in the aforementioned legislation, e.g. forest stands on agricultural land (Tomppo et al. 2010).

Forest stands: Land with forest stands with boundaries with other land, made up by connecting lines of trees higher than 1.3 m and situated not further than 12 m from each other, should these trees be shorter than 1.3 m, then it is the connecting line of trees situated not further than 5 m from each other that is considered to be the forest boundary. A piece of land with a forest stand at least 10 m wide and of an area of at least 400 m^2 must be located behind these boundary lines. A forest stand is considered to be a community of tree species with canopy closure of at least 20 % (Tomppo et al. 2010).

Nonstocked forest land: Forest rides wider than 4 m, unpaved forest roads wider than 4 m, paved forest roads not wider than 4 m, forest depots, small water areas and other land without tree cover on forest land according Forestry Act 289/1995. The total Czech Republic land area by the land category is presented in Table 16.1.

Table 16.1 Total Czech Republic land area by the land category (NFI1 2001–2004)

Land category	Area (1000 ha)	Area (%)
Forest	2752	35
Forest—forest stand	2705	98
Forest—nonstocked forest	46.68	2
Non-forest	5135	65
Total	7887	100

In the second NFI the COST E43 definitions (Tomppo et al. 2010) have been used for Forest, Other Wooded Land, Other Land with Tree Cover and Other Land. The IPCC land use classification has also been implemented. The land category Forest and OWL is further classified into three categories:

- Forest land includes tree stands, unpaved forest roads and watercourses not wider than 4 m, clear-cuts and stand gap not wider than 20 m;
- Non-stocked forest land includes unpaved forest roads and forest rides with width of 4–20 m, watercourses with width of 4–8 m, temporary unpaved forest depots;
- Other forest land—paved forest roads not wider than 4 m, paved forest depots and other paved plots fulfilling definition of land category Forest, small temporary buildings used for forestry, game or recreational purposes.

16.2.1.2 Forest Classification by Use

Forests that have a forest management plan are also classified into three subcategories according to the prevalent forest function potential:

- Production forest
- Protection forest (Extremely unfavourable sites, High altitude forests and *Pinus mugo* stands)
- Special purpose forest (Water sources, National parks, Suburban forest etc.).

As for the NFI1, Forest land was also classified according to the primary forest function (Table 16.2). One inventory plot can be included in several subcategories of special purpose forest, therefore total in Table 16.2 is above 100 %.

16.2.1.3 Classification by Ownership Categories

In both inventories, the ownership is specified for all inventory plots in the categories Forest and OWL. The national cadaster and official forest statistics ownership categories are used (Table 16.3). Over 60 % of Czech forests are owned by state, 18 % are owned by private owners and 13 % by Municipalities.

Table 16.2 Forest area by the primary forest function (NFI1 2001–2004)

Primary forest function	Area (1000 ha)	Area (%)
Production forest	1790	65.1
Protection forest	77.21	2.8
Special purpose forest	1111	40.4
Total	2979	108.3

Table 16.3 Forest area by ownership category (NFI1 2001–2004)

Ownership category	Area (1000 ha)	Area (%)
State forests—managed by Forests of the CR	1407	51.1
– managed by Military forests and farms	136.0	4.9
– managed by National Parks	95.02	3.5
– other	41.22	1.5
Forests owned by—municipalities	353.3	12.8
– churches	3.677	0.1
– legal persons and cooperatives	80.50	2.9
Private forests	505.4	18.4
Owner unknown	129.6	4.8
Total	2751	100

16.2.1.4 Forest Management and Cutting System

According to NFI1 data, Czech forests are dominated by even-aged forest stands with a uniform structure (83.4 %). This high proportion of uniform forests was caused by management based on clearcuts that was first practiced more than 200 years ago and is used with different intensity to the present day. Vast calamities in the 19th and 20th century (wind, snow, pests) and the subsequent establishment of even-aged forests stands played also an important role (Štěrba and Jankovská 2007). Forests managed with the of shelterwood silvicultural system which have two or three stand stories cover 11 % of forest area. Only 4 % of forests cover forest stands that have a rich structure.

Forest stands in NFI1 were classified according to silvicultural system, which is based on the origin of stands. High forests (forest of seed origin—planting, natural regeneration) cover 96 % of forest area. Low forests (coppice forest—vegetative regeneration) cover only 0.7 % of forest area. The combination of the two previous systems is called coppice with standard forest and covers 1.9 % of the forest area. On the remaining 1.4 % of the forest area, the silvicultural system was not evaluated.

16.2.1.5 Legal and Other Restrictions for Wood Use

Forest owners must manage forests in accordance with Forest Act no. 289/1995 and the FMP. The Forest act specifies limits regarding to timber harvest. Final cutting is allowed only in forest stands older than 80 years. In stands less than 80 years old it is not permitted to decrease density of stocking under limit 70 % of full stocking. The maximum area of clear-cut is one hectare but on natural pine and floodplain sites the area limit is increased on two hectares. Other restrictions are included in the FMP. Each FMP includes binding provisions on the maximum aggregate volume of felled timber per ten years, minimum share of soil cultivation and restocking species for stand regeneration, minimum area of tending activities in stand of under 40 years of age. Further legal restrictions may be present in forests in National parks and other protected or protective forests. All protected areas have special management guidelines which may exclude or restrict harvest. Non-legal wood use restriction depends on site conditions especially on accessibility, site productivity and profitability of harvest.

16.2.2 Wood Resources and Their Use

16.2.2.1 Standing Stock, Increment and Harvest

Standing stock according to the NFI includes volume of living and dead standing trees with dbh ≥ 7 cm over bark. Volume of tree includes stem and branches volume with top diameter ≥7 cm over bark. However standing stock, increment and harvest is calculated and reported as a volume without bark. Standing stock estimates are based on sample tree measurement on the inventory plots.

Total standing stock of Czech forests varies according NFI and Forest Management Plans. Total standing stock according to NFI1 is 900 million m^3 and in 2003 it was estimated to be 650 million m^3 using FMP data. Also mean standing stock per hectare varies from 251 m^3/ha according FMP 2003 to 333 m^3/ha according NFI1. Volume of standing dead wood according NFI is 13 million m^3, it is 4.8 % from total standing stock. Highest standing stock is contributed by Norway spruce 57 % and Pine 13.5 % followed by broadleaves species Beech 7.4 % and Oak 5.8 % (Table 16.4).

It is not possible to estimate increment and drain using NFI data as the second inventory data is not yet available. In this report the current annual increment according Forest Management Plans is presented. Current annual volume increment is computed by using growing stockaccording FMP and current annual increment according Mensuration and Growth tables of the main tree species of the Czech Republic (Cerný et al. 1996). The estimation of annual harvest is calculated on the basis of questionnaires filled by sample of forest owners. Calculation is provided every year by Czech Statistical Office. Current annual increment and harvest estimates are presented in Table 16.5.

16.2.2.2 Tree Species and Their Commercial Use

The main tree species in Czech are Norway Spruce, Pine, Larch, Beech and Oak, representing 80 % of the forest area and 88 % of total standing stock. All species except of *Pinus mugo* are commonly used in wood industry or as firewood. The total timber supplied in 2013 was 15.3 million m^3 from which 13.2 million m^3 (86 %) was coniferous timber and 2.1 million m^3 (14 %) broadleaves timber. In 2013, the total roundwood supplies amounted to 8.6 million m^3 (coniferous timber

Table 16.4 Standing stock and reduced area of group of species on forest stand area (NFI1 2001–2004)

Group of tree species	Reduced area 1000 ha[a]	Area (%)	Standing stock Million m^3	Standing stock (%)
Norway spruce (*Picea abies*)	1138	47.7	514.1	57.1
Silver fir *Abies alba*	23.67	1.0	11.53	1.3
Pine spp. (*Pinus spp.*)	332.7	13.9	121.1	13.5
Larch spp. (*Larix spp.*)	91.83	3.8	38.96	4.3
Mountaine pine (*Pinus mugo*)	2.140	0.1	0.073	0.0
Douglas fir (*Pseudotsuga menziesii*)	5.335	0.2	2.213	0.2
Grand fir (*Abies grandis*)	1.232	0.1	0.145	0.0
Introduced Spruce species	8.741	0.4	0.156	0.0
Other coniferous species	0.406	0	0.172	0
Oak (*Quercus spp.*)	176.5	7.4	52.08	5.8
Red oak (*Quercus rubra*)	5.586	0.2	1.449	0.2
European beech (*Fagus sylvatica*)	172.9	7.2	66.52	7.4
European hornbeam (*Carpinus betulus*)	45.35	1.9	7.575	0.8
Maple spp. (*Acer spp.*)	53.30	2.2	12.186	1.4
Ash spp (*Fraxinus spp.*)	40.82	1.7	11.88	1.3
Elm spp (*Ulmus spp.*)	2.853	0.1	0.543	0.1
Black locust (*Robinia pseudoacacia*)	13.44	0.6	3.637	0.4
Birch spp. (*Betula spp.*)	101.5	4.2	16.22	1.8
Alder spp (*Alnus spp.*)	50.39	2.1	15.80	1.8
Linden spp. (*Tilia spp.*)	38.25	1.6	10.20	1.1
Common aspen (*Populus tremola*)	17.90	0.7	3.564	0.4
Poplar spp. (*Populus spp.*)	6.678	0.3	3.290	0.4
Villow spp. (*Salix spp.*)	14.03	0.6	2.941	0.3
Other broad-leaves species	43.70	1.8	3.691	0.4
Total coniferous	1605	67.2	688.5	23.5
Total broad leaves	783.2	32.8	211.6	76.5
Total	2387	100	900.0	100

[a]Reduced area derived from canopy closure—area covered by tree canopies of one stand layer

8 million m^3, broadleaves timber 0.78 million m^3). The volume of coniferous pulpwood supplied was 4.03 million m^3 and 0.46 million m^3 of broadleaves. Firewood accounted for 2.18 million m^3 of timber. Production of timber chips in 2013 was 1.9 million m^3 and is not included in total volume of timber supplies.

Table 16.5 Current annual increment and harvest (Ministerstvo zemědělství 2011, 2012, 2013, 2014)

Attribute	1990	2000	2010	2011	2012	2013
Total current annual increment, million m^3	17	19.8	21.2	21.4	21.6	21.7
Total current annual increment per ha of timber land m^3/ha	6.6	7.7	8.2	8.3	8.3	8.4
Harvest of conifers in milion m^3	12.2	12.9	15.1	13.3	13.1	13.2
Harvest of broadleaves in million m^3	1.2	1.6	1.7	2.0	2.0	2.1
Total harvest in million m^3	13.3	14.4	16.7	15.4	15.1	15.3
Harvest per ha of forest land m^3/ha	5.1	5.5	6.3	5.8	5.7	5.8

16.3 Assessment of Wood Resources

16.3.1 Forest Available for Wood Supply

In the Czech NFI there is no national classification for Forest available for wood supply (FAWS) which is applied in the field. However, FAWS can be estimated by using auxiliary information from other sources, such as: FMP, Regional Plans of Forest development, Forest Typology Classifications and others. All forests under Forest Management Plans (98 % of forests) are classified according its primary function. This classification included all possible legal and site restriction regarding to the forest management. For forests outside of the FMP process additional information is available from the NFI survey. By combining all of this data it is possible to asses FAWS on all inventory plots. In the second inventory the area of FAWS will be estimated using parameters of inventory plots and additional data sources. This methodology is consistent with the State of Europe's Forest (SoEF) definition and estimates will be prepared in 2015.

In Table 16.6 an overview of forests categories according prevalent primary function is presented. Five sub-categories are excluded from wood production function. The total area of land excluded from FAWS is 354,881 ha (12.9 % of forest land). Three subcategories of protection forests (extremely unfavorable sites, high altitude forest and *Pinus mugo* stands) have a share of 2.8 % on forest area. Two subcategories of special purposes forests (national parks and reservations, first zones of protected landscape area) have a share 10.1 %.

16.3.2 Wood Quality

16.3.2.1 Stem Quality and Assortments

Stem quality is assessed on all permanent inventory plots in the land categories Forest and OWL on sample stems with threshold ≥7 cm on small circle (radius of

Table 16.6 Forest area by primary function (NFI1 2001–2004)

Category	Area (1000 ha)	Area (%)
Production forest	1791	65.1
Protection forest—extremely unfavourable sites	54.95	2
Protection forest—high-altitude forest	17.03	0.6
Protection forests—dwine pine stands	5.225	0.2
Special purpose forest—water sources	17.61	0.6
Special purpose forest—mineral water sources	71.79	2.6
Special purpose forest—national parks and reservations	120.9	4.4
Special purpose forest—forest in the first zones of protected landscape area	156.7	5.7
Special purpose forest—spa forests	1.742	0.1
Special purpose forest—suburban forests	33.47	1.2
Special purpose forest—forest research	30.96	1.1
Special purpose forest—forest with increased protective function of soil, landscape, water	208.2	7.6
Special purpose forest—protection of biodiversity	293.7	10.7
Special purpose forest—game enclosure, pheasantry	50.31	1.8
Special purpose forest—other public interest	125.4	4.6
Total (one stand can be classified in two or more special purpose forest subcategories)	2979	108.2

circle 5 m) and stems with threshold ≥27 cm on circle with radius 12.62 m. The Czech NFI uses a combination of two approaches for assessing stem quality. Firstly, a set of parameters are directly assessed on all stems or sample stems. Secondly, sample stems are classified into four quality classes: A, B, C and D.

Parameters used in the determination of stem quality on stems of tree directly detected or measured:

- Species
- dbh
- Standing dead tree
- Fork tree over 1.3 m
- Occurrence of break stem
- Occurrence of uprooted trees,
- Age of stem
- Height of stem
- Height of crown
- Height of continual stem (end of continual stem is place where the stem is forking in two stems or branches)
- Diameter of stem in height 7 m
- Height of roundwood (over this height, there is no roundwood)

- Height at which "pulpwood defect" occurs (due to the presence of a defect on a stem of quality roundwood, this part of stem cannot be used as roundwood. This pulpwood defect must be on roundwood at least 3 m long)
- Stem damage by game
- Stem damage by harvest, stones and other types
- Occurrence of rot
- Crown projection.

16.3.2.2 Assessment and Measurement

Quality Classes

During field measurement every sample stem is classified into one of four quality classes. All defects and knots on the stem are assessed to a height of 5 m on the stem. This assessment procedure is in accordance with national rules for grading wood. This classification together with the measured stem parameters serves for the estimation of assortments on standing stems using models. The four quality classes are:

- **Quality A**—no visible defects that excludes the stem from national wood grading classes I and II. Quality I and II—wood suitable for producing veneer and specialist purposes like resonance wood.
- **Quality B**—no visible defects that excludes the stem from quality roundwood but there are defects that excludes the stem from national wood grading classes I and II. Quality III—construction sawn timber and other sawn timber.
- **Quality C**—no visible defects that exclude the stem from quality roundwood but there are defects that excludes part of stem from roundwood into quality pulpwood or firewood. Minimal length of roundwood part must be 3 m. Combination of national wood grading classes Quality III and IV (wood for producing of groundwood pulp) or V (wood for producing of pulpwood and plywood), VI (firewood, chips).
- **Quality D**—Defects are present that exclude all of the stem from quality roundwood into national wood grading classes IV (wood for producing of groundwood pulp), V (wood for producing of pulpwood and plywood) or VI (firewood, chips).

A detailed description of how the tree parameters are used to define the quality classes is outlined in Table 16.7.

16.3.2.3 Estimation and Model

During data processing, the individual quality class information assigned in the field is used to model the share of assortments of standing stems. These models

Table 16.7 Use of tree parameters in defining quality classes

Bole quality		A	B	C	D
Min. DBH overbark (cm)	Spruce, pine larch	28	16	16	7
	Beech	33	23	23	7
	birch	28	23	23	7
Max DBH overbark (cm)	Spruce, pine larch	70	–	–	<16
	Beech	70	–	–	<23
	birch	70	–	–	<23
Mechanical damage[a]		Not allowed	Allowed up to 1/8 of circumference at breast height	Allowed	Allowed
Game damage (peeling)[a]		Not allowed	Allowed up to 1/8 of circumference at breast height	Allowed	Allowed
Knot above 8 cm in size[b]		Not allowed	Not allowed	Allowed	Allowed
Rotten knot (dead wood or rot, dead branches)		Not allowed	Allowed	Allowed	Allowed
Healthy knot (live branches only)		Not allowed	Allowed	Allowed	Allowed
Rotten knot (dead wood in its interior, dead branches)		Not allowed	Not allowed	Allowed	Allowed
Twisted, more than 2 cm/m (in fact any visible marks of twist)		Not allowed	Allowed	Allowed	Allowed
Damage by insects		Not allowed	Not allowed	Allowed	Allowed
Compressed wood (any visible marks)		Not allowed	Allowed	Allowed	Allowed
Flattening (elliptic cross section) above 20 %		Not allowed	Allowed	Allowed	Allowed
Other damage		Not allowed	Allowed, provided saw processing still possible	Allowed (all damage)	Allowed (all damage)

[a]In the case of more damage, the circumference shares are summed

[b]This damage is assessed differently for coniferous and broadleaved species. In coniferous forests, healthy as well as rotten knots >8 cm are taken into account. For broadleaved species only rotten knots are limiting for the A and B classes

Notes Knots are defined by inner parts of wood belonging to the corresponding branch. Surrounding wood bulges belong to the bole (not the branch). The size of elliptical knots is measured as the size of its minimum semiaxis. The measured size is rounded down to 1 cm precision, in the case of veneer (category A) to 0.5 cm precision. In the case of broadleaf species healthy knots up to 1 cm are not taken into account or considered as damage. For veneer assortments (category A), the basal part of the bole must be free of knots up to 2 m in height, with an allowance for broadleaved species with knots below 1 cm

Table 16.8 Real assortments share according stem quality class—*Picea abies* (Felled tree project)

Stem quality class	Number of felled trees	% Veneer	% Roundwood	% Pulpwood
A	22	15.7	72.4	11.9
B	293	1.1	88.3	10.6
C	143	0	73.8	26.2
D	290	0	28.2	71.8

were developed by cutting and detailing the assortments of 5000 stems. Using data from the cut trees a model was generated to estimate the share of assortments on standing trees classified into definitive quality class. A model was parameterised for seven main species *Picea abies*, *Pinus silvestris*, *Larix decidua*, *Fagus sylvatica*, *Quercus robur*, *Quercus petraea* and *Betula spp.* These seven species account for 90 % total standing stocks. As an example of stem quality results, Table 16.8 details the real share of assortments measured on felled trees (*Picea abies*). Its estimation of assortments volume is working in two main steps:

(1) Each tree has quality class A, B, C, D class from the field, which is based on assessing first 5 m of stem
(2) The model then assigns the whole tree volume into the three assortments veneer, roundwood and pulpwood defined in national grading system using other qualitative and quantitative tree parameters.

16.3.3 Assessment of Change

Currently, data processing for the second NFI is underway and the methodology for change estimation has not been finalised. Notwithstanding this all necessary attributes on inventory plot, trees and stumps are being collected. Change estimation will be based on the repeated measurement of trees on permanent plots established in the first NFI 2001–2004. During field measurement in the second NFI, the following attributes are recorded to facilitate change estimation at plot and tree level:

Plot level

Land Category—according to COST E43 (Tomppo et al. 2010), *Reason of change of land category in comparison with previous inventory*—Afforestation, deforestation, change of forest definition, misidentified category in previous NFI.

Plot status in comparison with previous inventory—this attribute describes the status of the plot for repeated field identification. Three status categories were included:

- inventory plot center found
- inventory plot center not found—plot must be reestablished
- plot center is newly established—new plots on category forest, in previous NFI non-forest plot.

Stem level

Dbh—measured on all stems on plots over registration dbh threshold (≥7 cm). *Stem height*—measured on sub-sample stems for height measurement, average number of sub-sample tree per plot is five.

Identification of stem—this attribute describes if the stem was correctly recorded in previous inventory. Three identification classes were recorded:

- without mistake
- tree omitted in previous inventory—stem was not recorded in the previous inventory in spite of the tree clearly fulfilling the registration threshold in the previous inventory and is inside inventory plot
- tree recorded by mistake in the previous inventory—stem could not have fulfilled the registration threshold in the previous inventory or is located outside of the inventory plot (or sub circle).

Standing dead or living stem—Describes if the stem is dead or alive,

- *Stem status*—Describes stem status in comparison with its status in the previous inventory: survivor stem
- ingrowth—stem achieved registration threshold
- mortality of survivor stem
- mortality of ingrowth stem
- harvested stem
- ingrowth harvested—stem achieved registration threshold and after was harvested.

Stump level

The following information is recorded for stumps:

- *Stump status*—assessment of stump status into four classes: stem is not stump—standing live or dead stem
- old stump—harvested dead stem from previous inventory (in previous inventory status—dead stem)
- new stump following harvest
- new stump following stem break—break height must be under height 1.3 m, over this height is stem classified as standing.

Height and circumference of stump—serves for estimation of stem volume at the actual time of harvest using models based on data from the harvested tree in the first NFI and the current stump dimensions. This approach will be used for the estimation of volume of stems with status—ingrowth harvested and harvested.

16.3.4 Other Wooded Land and Trees Outside Forests

16.3.4.1 Assessment and Measurement

In the first inventory 2001–2004 the only national categorisation of land included two categories; Forest and Non-forest. The primary national forest definition uses legislative parameters from Forest Management Plans and Land Cadaster and legal land use is more significant than real land use. Also different stands and land use parameters were used, so the national forest definition is not comparable to FRA or COST E 43 definition. There are no results for OWL, OLwTC and TOF from first inventory.

In the methodology for the second inventory (2011–2015) land categorisation and definitions according to COST E43 (Tomppo et al. 2010) were implemented, instead of the national categorisation. After the second NFI it will be possible to provide results structured by this international categorisation. Also, the definition of TOF according FRA 2005 (FAO 2004) has been implemented in the second inventory methodology.

The NFI assess land categories using a photogrammetric methods based on the 0.5 × 0.5 km sample grid designed for the second inventory. Assessment of TOF uses a photogrammetric transect on the 1 × 1 km grid.

Other wooded land

The field assessment is performed only in the new inventory grid designed for the second NFI. On OWL a reduced set of variables are collected in comparison to Forest plots. In the field, data necessary for estimation of variables for international reports is collected. The inventory will provide the following outputs for OWL:

- area
- standing stocks
- tree species composition
- volume of stumps
- volume of lying dead wood
- share of timber assortments
- occurrence of trees over 10 cm height in regeneration.

Other Land with Tree Cover and Other Land

OLwTC and Other land plots are excluded from field measurement. Only area of these categories will be estimated using photogrammetry.

Tress outside the Forest

Data relating to the TOF category are collected exclusively by photogrammetric methods on 1 × 1 km plots. The standing stock of wood resources are not estimated on TOF. Four types of objects are assessed using line intersect sampling: line object, strip objects, small area objects and point objects. Line, belt and small area objects are counted on the line transect, which has a length of 500 m and randomly orientated. The centre point of the transect is positioned at the center of inventory plot. Line, strip and area objects intersected by line transect are registered. Point objects are monitored on the strip transect which has a width of 40 m. The axis of this transect is the same as the line transect described above. On transects the following type of objects are assessed:

Line objects—boundary between land and land use categories, characteristics of forest edges.

Strip objects—landscape elements are recorded on the category OL and simultaneously in the LULUCF category settlements:

- linear stand of trees—trees along roads and watercourses
- windbreaks
- linear stands of shrubs
- boundaries around agricultural parcels, which can be covered by trees or shrubs.

Small area objects—landscape elements are recorded on the category OL and simultaneously in the LULUCF category settlements:

- small stands of shrubs and trees
- small water body
- small rock outcrop.

Points objects—recorded are landscape elements on category OL and simultaneously out of LULUCF category settlements:

- individual tree over height 5 m
- small groups of trees over 5 m (area under 20 m^2).

16.3.4.2 Estimations

Estimates of wood resources from these categories will not be available until 2016, when the second NFI data processing is completed.

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Chapter 17
Denmark

Thomas Nord-Larsen and Vivian Kvist Johannsen

17.1 The Danish National Forest Inventory

17.1.1 History and Objectives

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

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

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

17.1.2 Sampling Methods and Periodicity

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

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

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

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

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

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

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

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

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

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

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

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

17.1.3 Data Collection

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

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

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

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

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

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

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

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

17.1.4 Data Processing, Reporting and Use of Results

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

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

When estimates of forest area are required for different geographical subdivisions of the country (regions, natural-geographic zones, protected areas, owner types, species cover etc.), the forested plots or parts hereof are assigned to the different strata. The fraction of the forested plot area covered by each stratum is estimated as its share of the total forest covered plot area. Subsequently, the forest area covered by each stratum is estimated as its share of the forested plot area times the estimated forest area. The procedures are described in greater detail in Johannsen et al. (2013a, b).

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

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

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

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

The Danish NFI provides estimates at different regional scales, the national level (NUTS1), the five basic regions (NUTS2), the 11 smaller regions (NUTS3) and the 99 municipalities. The estimates include among others forest area, growing stock, carbon pools, increment, number of harvested stems, stem damages, regeneration, and dead wood (see for example Johannsen et al. 2013a, b). The results of the Danish NFI are used as basis for decision-making in forest and environment policy, forest management, forest products industries, and for evaluating the consequences of the decisions taken. Reporting obligations of many international processes and organisations are fulfilled using the data and results of the Danish NFI. Reporting processes include: the Forest Resources Assessment (FAO 2010) of the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 of the Kyoto Protocol (Nielsen et al. 2013), the indicators and criteria for sustainable forest management for Forest Europe (2011), and on the conservation status of natural habitat types under the Habitats Directive (Council of the European Communities 1992).

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

17.2 Land Use and Forest Resources

17.2.1 Classification of Land and Forests

17.2.1.1 General Land Classification

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

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

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

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

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

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

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

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

17.2.1.2 Forest Classifications by Use

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

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

17.2.1.3 Classification by Ownership Categories

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

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

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

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

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

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

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

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

17.2.1.4 Forest Management and Cutting Systems

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

17.2.1.5 Legal and Other Restrictions for Wood Use

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

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

17.2.1.6 Further Classification of Forests

In addition to the previously described classifications of the forest area further stratifications are used in national statistics and reporting. Commonly used stratification variables are tree species and age classes. The stratifications of the forest area are based on the field measurements of trees and assessment of plot variables.

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

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

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

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

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

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

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

17.3 Assessment of Wood Resources

17.3.1 Wood Resources and Their Use

17.3.1.1 Standing Stock, Increment and Drain

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

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

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

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

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

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

17.3.1.2 Tree Species and Their Commercial Use

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

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

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

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

17.4 Assessment of Wood Resources

17.4.1 Forest Available for Wood Supply

17.4.1.1 Assessment of Restrictions

The field assessments of the Danish NFI include all forest covered sample plots in the sampling grid, with the exception of inaccessible plots (commonly due to flooding, wind throws, and roads) which are assessed using aerial photographs. The existence of legal restrictions are not assessed in the field, but rather obtained from a post-stratification approach by intersecting sample plot locations with a GIS database that contains the areas with restricted harvest. Any restriction available as a geo-referenced GIS-layer can be considered in assessing the forest area available for wood supply.

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

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

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

17.4.2 Wood Quality

17.4.2.1 Stem Quality and Assortments

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

17.4.3 Assessment of Change

17.4.3.1 Assessment and Measurement

The estimation of increment and drain in the Danish NFI is based on the field measurements on permanent plots at two consecutive points in time. Sample trees can be distinguished into trees present only at the first occasion, trees present at the first and second occasion, and trees present only at the second occasion. Sample trees present at the first occasion and that are no longer present on the plot at the second occasion are recorded in the field assessments and the type of harvesting (harvested, dead, wind thrown or missing) is determined. On a subsample of the recorded trees, additional variables are measured including total tree height, height to the living crown base and possible forking height.

17.4.3.2 Estimation of Increment

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

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

Estimates of change include increment of trees that between cycles die, are felled or fall over naturally as well as for trees that grow into the sample. Also the increment or volume of trees on land areas converted to forest or changing from forest to other land uses are included in increment estimates. The increment estimates of the Danish NFI are commonly reported as average annual increments for the time period between two field assessments. Scaling-up from the sample trees to increments per hectare and total increment, is completed by using the number of trees represented by the sample trees at the time of the first measurement. National estimates are gross increment and they are calculated for forest management classes, ownership categories and tree species. Also gross increment in units of biomass can be calculated, but are not part of the standard estimation procedures. These biomass increment estimates may include other tree parts apart from the stem, like increment in branches and needles, and increment of the below-ground parts. The biomass estimates for these tree elements are obtained by applying species specific biomass models (Skovsgaard et al. 2011; Skovsgaard and Nord-Larsen 2012; Nord-Larsen and Nielsen 2014).

17.4.3.3 Estimation of Drain

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

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

The drain estimates of the Danish NFI are average annual volumes of drain for the time period between two measurement periods. Drain per hectare and total drain are obtained by referring to the situation and the number of trees represented by the sample trees at the time of the first assessment. National estimates are calculated for forest management classes, ownership categories, tree species and types of fellings. Drain can also be calculated in units of biomass. These estimates may include other tree parts like branches and needles, and the stump and root biomass of felled trees, although these figures are not part of standard estimation procedures.

Besides the yearly drain estimates provided by the Danish NFI, annual statistics on harvested wood based on questionnaire surveys are provided by Statistics Denmark. These statistics are based on three methods of data collection and include a sampling survey in selected forest properties having forest areas between 2 and 20 ha and a full census in forest properties larger than 100 ha.

17.4.4 Other Wooded Land and Trees Outside Forests

17.4.4.1 Assessment, Measurement and Estimation

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

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Chapter 18
Ecuador

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18.1 The Ecuadorian National Forest Inventory

18.1.1 History and Objectives

Ecuador's National Forest Inventory (NFI) is the main component of its National Forest Assessment (NFA) which emerged in 2009 as an initiative led by the Ministry of Environment of Ecuador (MAE). The NFA received technical support from the Food and Agriculture Organization of the United Nations (FAO), through the Sustainable Forest Management in the Face of Climate Change project and financial support from the Government of Finland. The NFA was devised to generate the information required to plan for the sustainable management, harvest and conservation of Ecuador's native forest resources (Aguirre et al. 2010). This methodological and technical process was Ecuador's first experience with forest planning at a national scale.

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There have been past efforts, from the 1960s to the 1980s, to assess Ecuador's timber resources. Those assessments, although compiled nationally, were undertaken at the regional and local levels. They focused on particular objectives, but without standardised methodologies.

The last three important forest inventories completed in Ecuador occurred in the 1960s, 1970s and 1980s. The first one focused on the northwestern Ecuador in the province of Esmeraldas; the second one focused on the forests of southern of the country; and the third one and last forest inventory focused on the central portion of the Ecuadorian Amazon. The main objectives of these subnational forest inventories were related to timber harvesting, floristic composition, monitoring of plant diversity and interpretation of satellite images and aerial photographs of the sampling areas.

The promoters of these first steps related to forest inventories in Ecuador included institutions such as: UN agencies, national and international NGO's, Center for Integrated Natural Resource Remote Sensing (CLIRSEN) and the National Forestry Directorate (DNF) which at that time belonged to the Ministry for Agriculture, Livestock, Aquaculture and Fishing (MAGAP) (Aguirre et al. 2010).

Subsequently, the need to have robust and current national information about forest resources was recognised It was seen as an essential tool to facilitate the development of the forest sector nationally. In May 2006, the DNF planned the NFA with three main components: (1) NFI, (2) Carbon density maps and (3) socio-economic components.

In this context and under the mandate of MAE, the NFA was initiated as a multipurpose tool with the capacity to: (i) provide data and information for decision-making and policy development for sustainable forest management, (ii) respond to requirements for access to international carbon markets, (iii) facilitate periodic long-term monitoring and (iv) offer flexibility and adaptability for future information needs (Aguirre et al. 2010). These requirements were framed within one of the main goals of the Forest Governance of Ecuador related to the "Generation of Forestry Information" (MAE 2011).

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The NFA is the first effort in Ecuador that defines primary inputs of information related to native forests that considers multipurpose objectives and long term planning. Also, it was the only one done at the national scale with standardised methodologies. Its results provide baseline forest information and identifies new questions related to native forests research and management. The structure of the NFA allows periodic updating of information.

18.1.2 Sampling Methods and Periodicity

The NFI uses a stratified random sampling scheme, based on a 1 × 1 km grid of points within forest type strata. At each grid point, a cluster with three subplots was established. A pilot forest inventory was conducted and 40 sampling units (SU) were completed, distributed across two strata: Andean Dry Forest (20 SU) and Pluviseasonal Dry Forest (20 SU). Subsequent analyses facilitated the estimation of the approximate number of plots to be inventoried in each stratum.

Stratified random sampling was defined as the sampling scheme in which the population was divided into strata and where a simple random sample of *n*th size within each *h*th stratum was selected (Balzarini et al. 2008). A maximum sampling error of 10 % (IPCC 1997) was deemed acceptable for the NFI.

NFI SU were clusters of temporary plots where each one consisted of three subplots arranged in an L-shape, with an area measuring 60 × 60 m and 60 × 40 m depending on the strata (Fig. 18.1). Nested plots were established

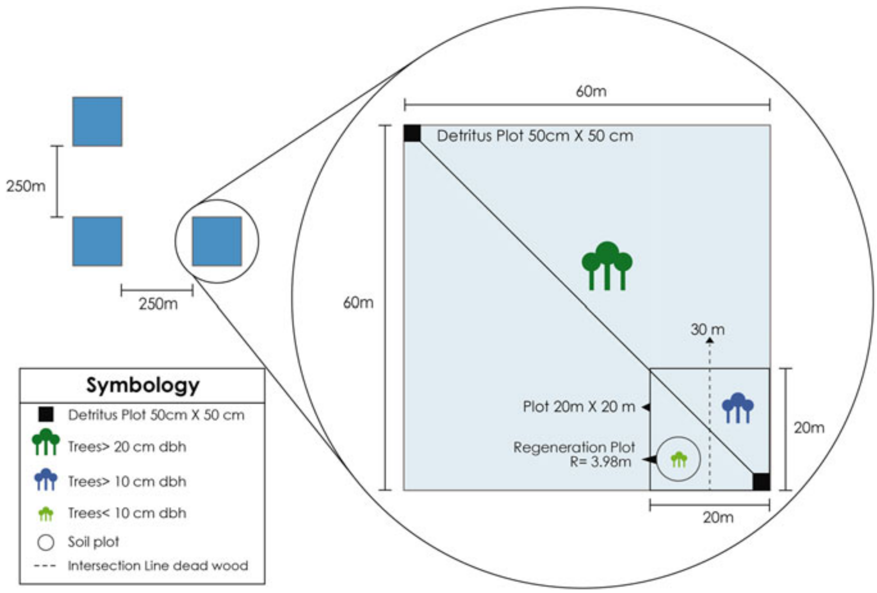

Fig. 18.1 NFI sampling and plot design

within the subplots to measure and capture information from three of the five carbon pools recommended by the IPCC (1997): litter, dead wood, soil and understory. Seven of the strata used square plots (Fig. 18.1) and the Mangrove and Morete Palms strata used rectangular plots.

18.1.3 Data Collection

In the field, precision instruments were used to take measurements. For full details refer to the NFI Field Manuals (MAE 2012). The variables measured in the NFI were:

- Dead wood: Downed wood with diameter ≥10 cm
- Litter and non-living detritus: Organic matter fallen on soil, less than 10 cm and more than 2 mm in diameter
- Soil sample: Color, texture, structure, stoniness, carbon content, bulk density, organic horizon depth
- Living biomass: Living biomass <5 cm dbh. Understory in plantations; shrubs and fruit trees; herbs, crops and cultivated and natural pastures; destructively sampled in the 2 × 2 m plot
- Tree measurements: Living trees, standing dead trees, and stumps. Location, tree species, diameter at breast height (dbh) for trees ≥10 cm dbh in all forest types and ≥5 cm in the Andean High Mountain Evergreen Forest stratum, total height (HT), commercial height (HC), plant health, crown cover, phenology, ethnobotanical uses, and stump decomposition state.

18.1.3.1 Field Work and Quality Control

The information gathering began with the formation of tasks teams for field work. Prior to entering the field, interviews were carried out with key informants such as MAE regional staff, parish leaders, community leaders, indigenous territory leaders, farm owners and local contacts. Support from local contacts helped arrange field access, and necessary permits were managed with the owners of the places where the plots would be established.

The quality of information obtained both in the field and office was monitored and controlled. Quality control took place during field data acquisition after field data collection the data was cleaned prior to the processing and analysis.

In the field, each field team was evaluated by a supervisory sub-team composed of a MAE-FAO technician, a dendrologist, a consultant responsible for the field brigade, and local guides who accompanied the team during data collection.

The sample size for field supervision was determined when the consultant team ended the field work, and consisted of 10 % of the established plots. All information collected in the 10 NFI forms was verified. Qualification criteria was defined to verify the quality of the data collected, representing the different scenarios considered in the methodology, as well as those found at the time the information was collected in clusters.

Further reviews were undertaken in the office by a supervision matrix to correct data such as typing errors. The information generated by the NFI was stored in a database created in the Open Foris Collect software (MAE 2013a). The supervisory process the NFI used is explained in more detail in the Manual of Supervision and Quality Control carried out by MAE-FAO (2014).

Corrections were carried out by numerical logical validators, geographic data verification and the standardisation of criteria such as the correction of inconsistencies of categorical variables registered for each individual. Measurement data was checked to identify out of range values. These values were identified with graphic techniques such as scatter plots of dbh and total height; and outliers were identified through variable standardizing, identifying those values that exceeded the 3.5 standard deviation from the overall mean. The debugged databases were examined with the OFC system and the professional version of the Infostat program (Balzarini et al. 2008).

18.1.4 Data Processing, Reporting and Use of Results

The biomass of standing living trees was calculated in different ways to compare the final results and choose the method that best fits the national needs. The volumetric method used a specific density for each species, an average for genus, average for families, and a weighted average for all other unidentified individuals. Volumetric calculations were also used to categorise the plots as harvestable or non-harvestable, according to the provisions of the three forest regulations of Ecuador.

Furthermore, stratum-specific allometric equations were assigned according to the classification of forests by Chave et al. (2005). The allometric equations selected fit the climatic characteristics of each stratum in the NFA.

With these equations, the amount of carbon in the biomass of living trees with a dbh >10 cm was calculated. First, the dry biomass of each individual tree registered on the plots was estimated using allometric equations. The sum of the biomass of all individuals in each plot was calculated to provide plot biomass estimates. Subsequently, the average biomass per cluster was calculated, and then the mean of the biomass per forest strata. Selected equations required dbh (in cm) and specific wood density (ρ in g/cm^3) as variables. Specific wood density was obtained from FAO's global database of wood densities (Zanne et al. 2009). For calculating root biomass, the value of aerial biomass obtained using the Chave et al. (2005) allometric equations was multiplied by a factor of 0.24 for tropical forest (Cairns et al. 1997).

The NFI results constitute a primary source of information for MAE in the context of forest management and related natural resources. Among the multiple applications given to the NFI outputs, the Ecuadorian report through MAE to the United Nations Framework Convention on Climate Change stands out, as well as the country's Forest Reference Emission Level for Deforestation (FREL) in the context of results-based payments for the REDD+ mechanism, and Ecuador's updating of its forests information for the Global Forest Resources Assessment 2015.

On the other hand in the national context the NFI results have promoted adjustments to the Forest Regulation to improve its management. Various programs and projects of the Ministry of Environment as well as external institutional stakeholders have used this information to strengthen their technical documentation, planning and decisions.

The NFI has generated extensive research among the academia; undergrad, postgrad and doctoral students, as well as forest researchers in the country and the region have shown interest to derive more detailed data and with a higher scientific level.

The possibility of using NFI results in future cycles of measurement, linked with the National Forest Monitoring System of Ecuador, are very broad and ambitious. With certainty, its periodicity will make more information available and will clarify any existing doubts that preliminary results generated.

18.2 Land Use Classification

18.2.1 Classification of Lands and Forests

The National Forest Inventory (NFI) classified land use and forest types based on the criteria required by the Intergovernmental Panel on Climate Change (IPCC). The classification system represents cover and type of land use to estimate carbon stocks and emissions associated with human activities, and uses defined criteria and descriptions of each type of use (IPCC 2006). This classification is based on four characteristics described below:

- Hierarchical: the national forest area is divided into separate scales, defined according to the following criteria:
  - Level 1, IPCC global classification classes
  - Level 2, classification of forest land by biogeographic and physiographic criteria, and for crops according to temporality
  - Level 3, classes according to forest strata with different carbon stock
  - Level 4, classes according to forest exploitation/management (productive/nonproductive).
- Independent: classes are independent of the meanings used according to data collection resources, i.e. satellite images, aerial photos, field data or combinations.

Table 18.1 Area of native Ecuadorian forests strata considered in the NFI

Forest type strata	Area (1000 ha)	Area (%[a])
1-Dry andean forest	174.913	1
2-Pluviseasonal dry forest	720.298	4
3-Andean montane evergreen forest	2030.671	17
4-Andean foothills evergreen forest	533.558	10
5-Andean high mountain evergreen forest	1302.435	4
6-Amazon lowland evergreen forest	6756.679	55
7-Choco lowland evergreen forest	936.978	4
8-Mangrove	151.377	1
9-Morete palms forest	431.458	4
Total forest area	13,038.367	100

[a]The values correspond to percentage area relative to the total area of native forests in Ecuador (MAE 2016c)

- Categorical: classes must be clearly defined; possible errors due to data recording must be identified.
- Flexible: can be used in combination with auxiliary information to form new classes that allow grouping of specific levels of another classification (e.g. FAO Forest Resources Assessment).

Although IPCC guidelines suggest dividing the country into managed and unmanaged areas, Ecuador decided the total land area would be considered as managed.

Using pilot sampling, the historic maps of deforestation for 1990, 2000, and 2008; and preliminary results of the vegetation map of Ecuador, the stratification of native forests was performed based on the methodology for identifying threatened ecosystems in South America (Jarvis et al. 2010). The NFI defined nine strata in which the forests of Ecuador (Table 18.1) were divided to meet IPCC level III. These strata were defined on the basis of the area occupied by these units and the internal variation of biomass and carbon content (MAE 2012).

18.2.2 Characteristics and Conditions of Ecuador's Native Forests

The Republic of Ecuador has an area of 24,898,396 ha (Senplades 2010). The total native forest area in 2008 was 13,038.367 ha. In the 1990s and 2000s several national and international sources identified Ecuador amongst the countries with highest deforestation rates in Latin America. Nowadays the native forest has 12,753.387 ha that represents the 51 % of the continental area of the country (Fig. 18.2). The rate of native forest loss has been reduced to half: from 93,000 ha per year in the 1990s (approximately) to 47,000 ha per year in between 2008 and

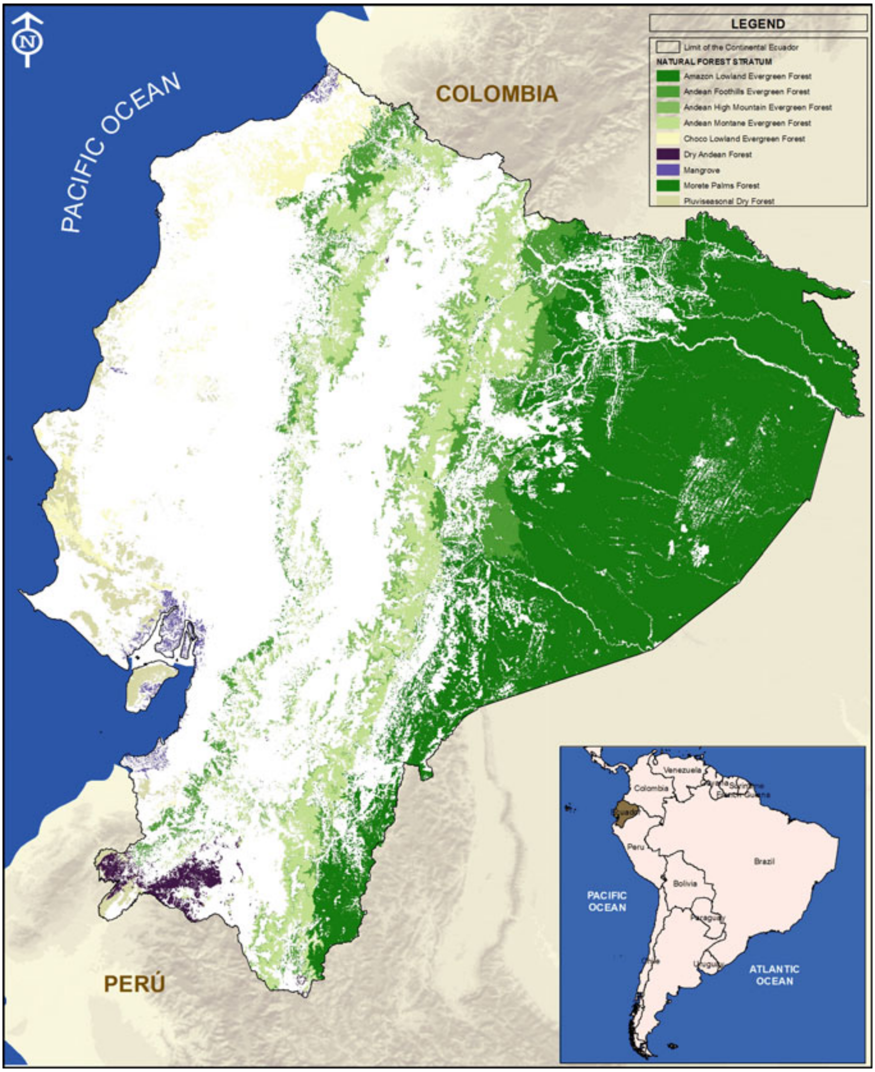

Fig. 18.2 Ecuador's native forest stratum (MAE 2015)

2014 (MAE 2015). This was achieved with sustained efforts by the government and the civil society using initiatives such as the NFA itself, and others programs like Socio Bosque, Forest Control and Wood Traceability System currently in construction (FAO 2015).

MAE's Historic Deforestation Map project updated the land use/land cover map for the continental Ecuador to 2014. In this project the forest was defined as a plant community of at least 1 ha, with trees 5 m in height and a minimum canopy cover of 30 %. This definition differs from FAO's in the inclusion of bamboo and palm-covered areas and the exclusion of agricultural production systems and trees growing in parks and urban gardens. The report shows that the total forest cover area is approximately 50 % of the total land area, equivalent to 13,038,367 ha. The majority of this is Amazonian lowland evergreen forest (MAE 2016a, in press).

The main change in land use in the country is from native forests to agricultural areas, including the establishment of palm oil plantations, especially in the province of Esmeraldas (MAE 2016a, in press). Most of these forests (6.8 million ha), located mostly in the Amazon region in northwestern Ecuador (Bertzky et al. 2011), are in the possession of indigenous peoples and nationalities, the Afro-Ecuadorian people and the State. Private owners (farmers, settlers and processors or loggers) have a relatively small area of natural forest (Añazco et al. 2010). Likewise, most of the forest plantations belong to private owners.

The Map of Ecosystems of the Continental Ecuador (MAE 2013b) recorded 91 ecosystems in the Ecuadorian mainland, reflecting the large floristic diversity of the country (Senplades 2013). Of those ecosystems, 65 are forests, 11 shrubby and 15 herbaceous ecosystems (MAE 2013b). Up to 31 % of Ecuador's total area is under conservation (Patrimony of State Natural Areas (PANE) and the Socio Bosque Program); from this percentage, 87 % is under forest cover, 12 % corresponds to heath and 1 % to shrub and herbaceous vegetation (MAE 2013b).

Ecuadorian laws dictate rules for the use of timber resources of natural wet, Andean and dry forests; cultivated forests: forest plantations, planted trees, trees of natural regeneration in crops; pioneer formations; trees in agroforestry systems; and non-timber forest products (MAE Ministerial Agreement 039 and 040).

Ecuador is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and participates in the creation of international policies on climate change, which also guide national mitigation policy development. The forest sector is also involved in the Reducing Emissions from Deforestation and Forest Degradation (REDD+) process through initiatives at the national level. In this process, the NFA is an important contributor to building the system for measuring, reporting and verification (MRV) of mitigation measures to climate change, especially in the context of REDD+ strategies.

18.2.3 Carbon Stock and Its Relation with Forest Tree Structure

A total of 102,647 individual trees were measured in the forest inventory, corresponding to 1639 plots and 711 clusters. Living trees accounted for more than 92 % of the total, whereas the percentages of stumps and dead trees without leaves were almost insignificant (Table 18.2). The stratum with largest sample effort is the Amazon Lowland Evergreen Forest with 174 clusters.

Total above and belowground carbon storage within living and dead biomass above and below ground in Ecuador averages between 37.04 MgC/ha in Andean

Table 18.2 Distribution of individual trees recorded in the forest inventory, according to their status

Tree status	Number of individuals	Individuals (%)
Living	94,773	92.32
Stump	282	0.27
Dead without leaves	744	0.72
Dead without branches	6848	6.67

Dry Forests, to 160.40 MgC/ha in Amazon Lowland Evergreen Forests (excluding soil organic carbon). Andean forests in humid and very humid areas range from 105 to 123 MgC/ha, while other forests in very humid areas range between 76 and 87 MgC/ha. Chave et al. (2005) suggested that bioclimatic classification may not be useful in Ecuador to evaluate variations in carbon at the national scale (Table 18.3).

As expected, living trees accumulate the majority of the carbon (more than 57 %), while the dead biomass and the root biomass are the second most important component in terms of carbon reservoirs, followed by the understory and detritus biomass (Table 18.3). Several reviews (Nogueira et al. 2008; Cummings et al. 2002; Nascimento and Laurance 2002; Russel 1983) show similar proportions for Amazonian forests outside of Ecuador.

The total above ground biomass could actually be higher than the values being reported for Ecuador because lianas and vines were not measured by the NFI. Tropical forest studies suggest that the carbon storage in this component could represent 4.5 % of the total carbon in a forest (Putz 1983).

In terms of tree size, the 10–60 dbh diameter class represents more than 90 % of the total trees, and stores approximately 74 % of the living biomass. Trees with dbh ≥ 60 cm represented less than 5 % of the total trees, suggesting very large trees are a rare occurrence in these forest, and thus showing that carbon stock in the diametric class of trees with dbh ≥ 60 cm is low (Table 18.4).

A strong correlation between tree biomass and tree diameter of dbh ≥ 10 cm ($R^2 = 0.88$, $p < 0.0001$) was found, but the relationship is weak in the case of tree biomass and height (MAE 2016b, in press). It is known that basal area is a good predictor of the carbon biomass in trees, according to reports of primary forests in Australia, Mexico, and Brazil (Cummings et al. 2002; Nightingale et al. 2008; Torres and Lovett 2013), and isolated trees in pasture lands and secondary forests in Costa Rica (Chacón and Harvey 2013; Cifuentes 2008).

The fact that there is a weak relation between tree biomass and tree height should be researched in the future, because studies have demonstrated that, at least for Andean forests, the biomass of trees tends to decrease with elevation (Leuschner et al. 2013; Girardin et al. 2013; Moser et al. 2011). Challenges in accurately measuring tree height in the field may be precluding our ability to find a similar relationship.

Table 18.3 Carbon stock (Ton/ha) in biomass in the 9 forest type strata and by pool

Forest type	Forest type according to Ecuadorian NFA	Living trees	Under-story	Palms	Dead trees with branches (without leaves)	Dead trees (without branches and leaves)	Stump	Fallen wood	Detritus (leaf litter)	Root, living trees	Root, dead tree, stumps	Total (Mg C/ha)
Dry	Andean dry	28.80	1.59	0.00	0.22	0.35	0.01	5.55	4.22	6.91	0.26	47.91
Dry	Pluviseasonal dry (BSP)	25.00	1.49	0.00	0.08	0.32	0.01	2.07	1.86	6.00	0.21	37.04
Humid	Andean montane evergreen (BSVAM)	80.89	4.06	0.10	0.68	5.10	0.02	7.67	2.42	19.41	2.76	123.10
Very humid	Andean foothills evergreen (BSVAPM)	72.94	3.24	0.01	0.54	3.66	0.01	20.73	2.16	17.51	1.97	122.77
Humid	Andean high mountain evergreen (BSVCA)	61.22	7.62	0.07	0.46	3.56	0.01	12.88	2.69	14.69	1.90	105.10
Humid	Amazon lowland evergreen (BSVTBA)	108.12	3.24	0.49	0.39	3.79	0.02	13.32	3.07	25.95	2.02	160.40
Very humid	Choco lowland evegreen (BSVTB)	52.41	3.02	0.05	0.39	1.77	0.12	9.36	2.32	12.58	1.32	83.34
Mangrove	Mangrove (M)	50.12	19.18	0.00	0.23	0.70	0.00	3.96		12.03	0.41	86.63
Very humid	Morete palms (Mo)	49.44	1.16	1.42	0.15	1.01	0.08	6.62	3.47	11.87	0.59	75.80

Table 18.4 Percentage of trees and carbon biomass according to the diametric classes present in the nine strata analysed

Forest type	dbh 10–59.9				dbh ≥ 60			
	Trees		Carbon		Trees		Carbon	
	Number/ha	%	Ton/ha	%	#/ha	%	Ton/ha	%
Andean dry	305	99.2	24.46	84.9	3	0.8	4.34	15.1
Pluviseasonal dry	213	98.6	19.475	77.9	2	1.4	5.52	22.1
Andean montane evergreen	341	98.3	62.585	77.4	6	1.7	18.30	22.6
Andean foothills evergreen	433	98.2	55.495	76.1	8	1.8	17.45	23.9
Andean high mountain evergreen	166	97.6	48.225	78.8	4	2.4	13.00	21.2
Amazon lowland evergreen	415	98.0	79.76	73.8	9	2.0	28.37	26.2
Choco lowland evergreen	319	98.2	39.315	75.0	6	1.8	13.10	25.0
Mangrove	298	99.7	47.675	95.1	1	0.4	2.44	4.9
Morete palms	166	94.6	29.58	59.8	9	5.4	19.87	40.2

18.2.4 Forest Management and Harvesting Systems

Ecuador's Forest Law established forestry regulations that determine administrative and technical aspects regarding the use of timber and non-timber forest products, to ensure the permanency of forest goods and services for medium and long term (MAE 2010).

The Constitution of the Republic of Ecuador states that the Central Government holds the exclusive competence over the forests resources. As a result, the management of forest resources in Ecuador is the responsibility of the MAE. Thus, it authorises timber harvesting upon submission through the approval of formal plans and programs (Table 18.5). These plans are elaborated and carried out almost always by a Forest Engineer, supported by MAE.

In December 2009, MAE detailed the administrative procedures for authorising the sustainable exploitation of timber resources that may originate in: (1) natural forests (Humid, Andean, Dry), (2) planted forests, (3) agroforestry systems (planted trees and natural trees regenerated inside crops), and (4) secondary forests. For non-timber products, harvest plans and programs should be approved according to each case (MAE 2010). Wood products derived from such exploitation (logs, planks, boards, laths and others) are the exclusive property of the owner or

Table 18.5 Classification of forest harvesting and cutting programs by forest type

Natural forests	Forest plantations	Agroforestry systems	Pioneer forests
PAFSu: sustainable Forest harvesting program PAFSi: simplified forest harvesting program PCZCL: cutting program in zones of legal conversion	PCPF: cutting program for forest plantations PCAP: cutting program for planted trees	PCRNC: cutting program for naturally regenerated trees PCAR: cutting program for relict trees	PCFP: cutting program for pioneer forests Cutting forms for pigue (*Piptocoma discolor*) Cutting forms for balsa (*Ochroma pyramidale*)

possessor of the forest, who can market or trade them as he or she sees fit (Orozco et al. 2014).

The NFI is a key tool that has to be applied in the future, with periodically updated data, and new measurement cycles. It should also be included in a complete forest monitoring system. This will enable changes in forest policy to be evaluated. While the NFI establishes the baseline information on timber resources, it also further describes the characteristics of this resource. For forest management and harvest, for example, it is necessary to have data regarding survival, growth and recruitment. Without this information it is difficult to make conclusions about harvest volumes in continuous cutting cycles. In addition, we have to take into account the high biodiversity of forests in Ecuador and the political, economic and social scenarios.

It is very important to consider biodiversity in the management of forests resources, and there are regulations to ensure its protection. Currently, these regulations are being reviewed, to integrate them with the principles of sustainable forest management. The generation of applied forestry research and the strengthening of capacities for monitoring forest management are important technical inputs needed to generate the national forestry regulations and to improve the NFI.

In recent years, Ecuador has made significant efforts to develop policies and strategies to enhance forest governance. These efforts include incentives to reduce deforestation, control forest harvest levels and mobilisation of wood products, and disseminate information about forest regulations. Also, funding has been provided to preserve forests, promote re-vegetation and regeneration of degraded lands, increase reforestation with commercial objectives, and provide resources for training and investigation (Orozco et al. 2014). Particularly, it is important to recognise the efforts made to simplify forestry regulations, as well as launch a verification system for forest legality associated with the Forest Law, containing different controls for all phases of the wood value chain.

There are still unresolved challenges to ensure sustainable forest management (SFM), which are linked to reduced institutional, politic and scientific gaps in forest planning. Also, it is necessary to adapt the forestry regulations to meet the needs of small land owners and native people, who represent a large section of users of exploitable forest resources in the country (Mejia and Pacheco 2013).

The land zonification of the Ecuadorian forests is the key to SFM. The identification of forest areas in production, protection or recovery zones, as well as the defining of priority zones, will allow for sustainable land and forest use planning (MAE and ITTO 2011). In this context, future efforts of the NFI will be guided towards generating inputs of technical information to support this process.

Currently, Ecuadorian Forestry Regulations consider three types of forests: Dry, Humid and Andean. However, data from the NFI show the 9 forest strata that represent more effectively the national forest biodiversity. More efficient monitoring activities and effective policy decisions is recommended, to achieve an adjustment of regulations with a forest stratification made to ensure synchrony between forest units and policies.

For the new NFI cycle, the sample size has to be calculated not only taking into account the size of the strata or the precision level for carbon estimation, but the required precision for important parameters of forestry management and conservation like, i.e. forest productivity, density and structure, recruiting and growth, species diversity, ecosystem services, forest degradation, disturbance and forest dynamics, trees outside forests, non-timber forest products, wildlife, others.

18.2.5 Availability of Forest Resources

Forest resources can be classified into commercial and non-commercial volume. The commercial volume is the volume of the species contained in the national forestry regulations, as well as the volume of species that are not contained in the regulations but with individuals with a diameter greater than the minimum cutting diameter. The non-commercial volume is the volume of all species contained in the regulations. Those individuals with a diameter below the minimum cutting diameter in those areas that are not included in the regulations.

The highest total commercial volume per hectare is found in the Amazon Lowland Evergreen and Andean Foothills strata, while the lowest is found in the Dry Forest, Andean Dry forest and Andean High Mountain Evergreen strata. The Mangrove stratum is the exception, demonstrating a commercial volume lower than 7 m^3/ha (Table 18.6). The Morete Palms stratum has the highest total volume (commercial and non-commercial); however most of it cannot be considered commercial. Most likely, the high volume value is explained by the dominance of the *Mauritia flexuosa* palm, which in this stratum is mixed with other species, and has a high density and large diameters and heights.

In addition, the commercial volume of species considered as prioritised for each stratum was calculated, taking into account the minimum cutting diameter, as indicated in the forestry regulations (Table 18.7).

In most of the strata, the priority species show volumes higher than 50 % of the commercial volume above the minimum cutting diameter. This result shows that these species are susceptible to a considerable reduction of commercial volume in

Table 18.6 Commercial and non-commercial volume per hectare

Strata	Commercial (m^3/ha)	Non commercial (m^3/ha)	Total (m^3)	Commercial (%)
1-Dry andean forest	39.3	21.6	60.9	64.6
2-Pluviseasonal dry forest	37.8	15.8	53.6	70.6
3-Andean montane evergreen forest	56.2	68.2	124.5	45.2
4-Andean foothills evergreen forest	70.5	134.0	204.5	34.5
5-Andean high mountain evergreen forest	31.2	33.4	64.6	48.3
6-Amazon lowland evergreen forest	70.9	167.9	238.8	29.7
7-Choco lowland evergreen forest	47.7	97.9	145.6	32.7
8-Mangrove	6.8	129.3	136.1	5.0
9-Morete palms forest	71.6	215.1	286.7	25.0

Table 18.7 Commercial volume per strata in each identified category according to forest law

Strata	NE (m^3/ha)	ND (m^3/ha)	NE (Percentage of non specified total)	ED (m^3/ha)	ED (m^3/ha)	EE (Percentage of specified total)
1-Dry andean forest	10.3	8.6	54.5	29.1	13.0	69.1
2-Pluviseasonal dry forest	9.1	3.0	75.2	28.8	12.8	69.2
3-Andean montane evergreen forest	37.0	51.7	41.7	19.3	16.5	53.9
4-Andean foothills evergreen forest	44.8	104.7	30.0	25.7	29.3	46.7
5-Andean high mountain	16.5	22.0	42.9	14.6	11.4	56.2
6-Amazon lowland evergreen forest	34.6	134.7	20.4	36.3	33.2	52.2
7-Choco lowland evergreen forest	28.0	79.7	26.0	19.6	18.3	51.7
8-Mangrove	6.8	128.7	5.0	0.0	0.7	0.0
9-Morete palms forest	34.3	188.7	15.4	37.3	26.4	58.6

ND Non-specified below minimum cutting diameter, *NE* Non-specified above minimum cutting diameter, *EE* Specified above minimum cutting diameter, *ED* Specified below minimum cutting diameter the first cutting cycle (15 years according the current forestry regulations in the country). Care should be given to not overexploit these species and risk their ecological roles or long-term permanence.

18.3 Assessment of Wood Resources

18.3.1 Regulatory Restrictions to Forest Harvesting

The harvest and commercialisation of the wood extracted from natural and planted forests, public or private, is regulated by Law of Forestry and Conservation of Natural Areas and Wildlife, established in Book III of the Unified Forestry Regime Text of the Secondary Legislation of MAE. The law establishes a permanent and direct participation of the State in all forestry activities in Ecuador. The State, through MAE, is responsible for native forest management, forest control, regulation, promotion, wood supply and, above all, the restoration of forest resources used by the society. The restoration of forest resources is carried out mainly through forest plantations and, to a lesser extent, through the management of harvested native forests (Carrión and Chiu 2011).

There are regulations and technical standards issued for the management and sustainable use of forests and their resources, which are referred to as the Forest Normative. They include basic criteria that determine legal restrictions for SFM related to the development and implementation of integrated management plans and logging programs of native forests, like the sustainability of production, maintenance of forest cover, biodiversity conservation and co-responsibility in the management and reduction of negative environmental and social impacts. For example, for the sustainable harvest in forest areas, the Forest Normative (Ministerial Agreement 0125) determine that the harvesting intensity (the trees that will be cut for production) must not exceed 30 % of the basal area inside the managed unit and the intensity of intervention (promote the growth of some tree species by the cut of others) may not exceed 40 % of the basal area.

Aspects such as maintaining a minimum mandatory reserve of forest species of low abundance, as well as using "conditioned" species should be done by demonstrating high enough abundance. Forest enrichment should be carried out in gaps, and cannot exceed 50 trees/ha of native species. Understory elimination is permitted only in the case of silvicultural treatments. In terms of conserving biodiversity, species of exceptional ecological importance have to be identified and protected in the forests. Species that have an abundance of less than one tree per three hectares cannot be harvested.

The Forest Normative allows for the identification of Permanent Protection Zones (PPZ) that restrict forest harvesting in essential habitats that are indispensable for the survival and maintenance of populations of threatened species of fauna and flora. Also, forest harvesting is restricted on river flows (i) with slopes greater than

50° and a width greater than 3 m (ii) areas with slope greater than 70° and (iii) in areas declared as public interest or in areas declared as protection zones by the owners. The riverbanks, water reservoirs and intermittent water holes are also declared as PPZ.

The forests inside the State Patrimony Natural Areas (PANE in Spanish) and other protective forests are represented by the set of wild lands that stand out for their protective, scientific, scenic, educational, touristic and recreational value; because of their flora or fauna, or because its ecosystems contribute to the environmental equilibrium (Forest Law Art. 69). Due to the protective character of these areas, forest harvesting is not permitted. The area of protection is considered natural capital, from which only the flux of environmental services such as hydric cycle regulation, landscape beauty, biodiversity protection, greenhouse gases mitigation, etc. can be harvested.

Forest resource use is also regulated by accessibility, particularly in remote areas and mainly in the Amazon region where there are high slopes; also, areas of social conflict restrict forestry activities. Finally phenology, flowering, pollination, seed dispersal, germination, light and nutrient requirements, forest regeneration, among others ecological considerations sustain the productivity of the site and can limit the amount of timber resources extracted during harvesting operations.

18.3.2 Evaluation of Timber Resources Available for Harvesting

In Ecuador, there are harvesting zones ("units" or "blocks") that are integrated with the State Forests National Patrimony. These zones were incorporated into the national forest regime, and were delimited provisionally through the Ministry Agreement 202, specifically in the provinces of Esmeraldas and Napo. However, not all the areas that are under the Ecuadorian forest regime are susceptible to harvesting because it is limited to those "units" or "blocks". Outside those areas, harvesting is subject to a process of forest licensing through formal petition of the owner to the governing body (MAE). All the information is stored at the institutional level in a Forest Management System (SAF), which provides volume, surface and geographic data, and contains cartographic and alpha-numerical information that belongs to the information systems in the MAE.

Currently, not all of the forest resources in the country are available for harvest. The country has more than 4000 tree species, but no more than 200 are suitable for use. Also, in most cases, the population of the exploitable species are being reduced. Therefore there is limited information that can be used to determine sustainable harvest levels. This makes relevant develop methodological protocols designed in a way that includes the sustainable forest management considerations currently defined in Ecuadorian forest law.

On the other hand, the NFA value has been limited to a tool to orient and review management decisions about forests and territories in general by the lack of connection between the way regulations are defined, identifying of development priorities, planning processes and the forest stratification. Under this scenery it is necessary to use the prior definition of priority areas in terms of net productivity, growth, quality, recruiting and replacement of the forest reserves (including the connectivity between natural remnant forest masses). This will allow for territorial zoning which incorporates ecological and productive considerations.

18.4 Conclusion

For the new measurement cycle (2016–2019) the primary goal is to consider the lessons learned from the first NFA on an institutional, technical, methodological, logistical and financial level.

The data acquired in the first NFA facilitated information about management priorities in forest strata or political geographic zones. In most cases, the NFA detected identifiers to evaluate the necessity of developing mechanisms to obtain more detailed and precise data. Thus, forest monitoring in a broader perspective and the future of NFA became a key issue policy development, environmental management and the utilisation and conservation of natural resources, at various scales in Ecuador.

Future challenges for the NFA include the characterisation of high diversity zones, monitoring high conservation value areas and the quantification of human activities on biodiversity, through identifying indicators of biodiversity, forestry, hydrology, soil conservation, watershed management, issues of urban/rural planning, environmental services, generating policies, stewardship of related actors and governance scenarios, One particular aspect to be included is the monitoring of trees outside the forests, to enhance approaches to integrated management of landscapes, and including other types of land uses in forest monitoring. More specific issues for the NFA to address include; the strengthening the forest classification system, reducing uncertainties, automating databases and enhancing biomass and carbon calculations using local factors and conditions. The NFA must incorporate into the country's REDD+ Measuring, Monitoring, Reporting and Verification (MRV) system.

An aspect that requires a particular focus on the NFI is the inclusion of trees outside forests, because this represents significant resources that must be quantified for management and sustainable use, e.g. agroforestry and silvopasture systems, also, urban and rural forestry schemes. Today trees outside forests are the subject of extensive debate; thus, the NFI should gradually incorporate it in the analysis, design and technical measurement protocols.

The NFA must be coordinated with parallel initiatives lead by MAE and related to the analysis of land cover/land use and ecosystem identification. Consolidating remote sensing, field campaigns (National Forest Inventory) and other program elements into the first National Forest Monitoring System of Ecuador (NFMSE) should continue to be promoted and pressed for in the political spheres.

In the case of those forest strata that the NFA identified as being very limited in terms of timber production, the new measurement cycle should incorporate variables emphasising ecosystem services. This would support the generation of conservation and sustainable use strategies in those strata.

In the context of mitigation and climate change, and specifically for REDD+, the NFA should provide the necessary information to calculate emission factors, characterise activity data, and support the establishment of reference levels. Together, these data will help quantify current and estimate future forest emissions and to the actual impact of REDD+ actions.

Furthermore, future NFA processes must also contribute to rural development planning in Ecuador. Forest management should be understood as part of the process of building a culture to regularly review strategies for the forest sector and related sectors.

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Chapter 19
Finland

Kari T. Korhonen

19.1 The Finnish National Forest Inventory

19.1.1 History and Objectives

The first National Forest Inventory (NFI) of Finland was undertaken during the period 1921–1924. Since then, NFI's have been repeated on a cycle of approximately 10 years. From the very beginning, NFI's have been based on statistical sampling. The first four inventories applied a line survey method with plot measurements. Since the 5th NFI (in early 1960s) cluster sampling has been applied. The first inventories were completed in three to four years for the whole country. Since the 1960s NFI's have been done district by district over a longer period of time as part of a permanent structure within the organisation. The new inventory cycle starts immediately after finishing the previous cycle. Starting from the 10th NFI (2004–2008) a five year rolling system, so called panel system has been used, meaning that one fifth of NFI plots are measured each year over the whole country and the whole sample is measured in five years. Traditionally, temporary plots have been used, but in the 9th NFI (1996–2003) one fourth of the plot clusters were established as permanent.

The aim of the NFI is to monitor land use area changes, development of forest resources, increment, silvicultural status of forests, forest health and biodiversity. NFI data and results are used for national and regional forest and environment policy, international reporting (Global Forest Resource Assessment, FOREST

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EUROPE, reporting related to greenhouse gas monitoring, Natura directive reporting), estimation of future production possibilities of timber and forest bioenergy, and research.

19.1.2 Sampling Methods and Periodicity

The NFI covers all of Finland's land area and is primarily based on systematic cluster sampling system. Only in the most northern, sparsely forested, part of Finland (Northern Lapland) stratified sampling is applied. The sampling design varies slightly also in the other parts of Finland. The distance between clusters, shape of the cluster, number of field plots in a cluster, and distance between plots within a cluster varies in different parts of the country according to spatial variation of forests and density of roads. The regional sampling design for the most recent NFI, NFI11 (2009−2013), is detailed in Table 19.1. The sampling design consists of permanent and temporary clusters. The grid of permanent clusters was created in the NFI9 (1996–2003). The grid of temporary plots is created at each cycle.

In the Northern Lapland two-phase stratified sampling design is used. In the first phase, a systematic 7 × 7 km grid of sample point clusters is generated, nine points per cluster as specified in Table 19.1. For each sample point land cover/land use class (forest land or poorly productive forest land, bare land, other than forestry land) is estimated using satellite image based forest map, climatic information and map data. The first phase sample point clusters are stratified into six strata according to the land cover/land use percentages on the cluster. At the second phase a sub-sample of the first phase sample points are selected for field measurement.

Table 19.1 Sampling design of the 11th NFI of Finland

Region	Average distance between clusters	Shape of the cluster	Distance between plots in a cluster	No. field plots
South most Finland	P: 12 × 12 km T: 6 × 6 km	P: L—shaped T: L—shaped	P: 250 m T: 300 m	P: 10 T: 9
Central Finland	P: 14 × 14 km T: 7 × 7 km	P: Open rectangular T: L—shaped	P: 300 m T: 300 m	P: 14 T: 11
Southern North Finland	P: 14 × 14 km T: 7 × 7 km	P: L—shaped T: L—shaped	P: 300 m T: 300 m	P: 11 T: 9
Lapland	10 × 10 km (every 4th cluster is permanent	P: L—shaped T: L—shaped	P: 300 m T: 300 m	P: 11 T: 12
Northern Lapland	Depends on stratum	P: L—shaped T: L—shaped	P: 450 m T: 450 m	P: 9 T: 9

P Permanent clusters, *T* Temporary clusters

Sampling intensity varies between the strata according to the estimated measurement cost and percentage of forest.

19.1.3 Data Collection

The NFI field data consist of three main categories: stand description, tree data, and dead tree data. Stand description variables describe the land use class or forest stand where the field plot is located. If a field plot is divided into several land use classes or forest stands, all land use classes/stands are described.

The stand data content consists of four broad categories:

- Administrative data: owner group, restrictions for forestry, etc.
- Site description: land use class (both national and FAO definitions, FAO 2004), changes in the land use class since 1990, site productivity class, soil type, soil texture, drainage situation, etc.
- Growing stock: crown storeys, development class, age, mean height, mean diameter damage by tree species, etc.
- Accomplished and proposed operational measures: accomplished and proposed cuttings, silvicultural measures, soil scarification, drainage, etc.

For tree measurements, the sample plot is a restricted Bitterlich (relascope) point with a basal area factor 2 and a maximum radius of 12.52 m (basal area factor 1.5 and maximum radius 12.45 m in North Finland). All relascope trees higher than 1.3 m are included. Living and usable dead trees are measured. The tree data consist of:

- tally tree data: diameter, species, quality class, crown class;
- sample tree data: tally tree data and height, diameter at 6 m height, age, diameter increment, height increment, thickness of bark, lengths of timber assortment quality classes, damage, etc.

Dead trees (both standing and lying, including decayed trees that no longer are usable for industry or fuel wood) are measured on a 7 m fixed radius plot. Only trees larger than 10 cm in diameter and longer than 1.3 m area measured. Dead trees are measured only on the permanent plots.

19.1.4 Data Processing, Reporting and Use of the Results

The estimation process consists of three steps:

1. Estimation of volumes by timber assortments for sample trees
2. Generalisation of volumes for tally trees
3. Summary of stratum wise area and volume statistics.

Sample tree volumes are estimated with general volume functions and taper curve models (for timber assortments) using diameter at breast height (d), stem diameter at 6 m height (d6), and height (h) as regressors. Volume estimates are generalised for tally trees with non-parametric nearest neighbour method. In this method, each tally tree gets its volume estimate from sample trees that are most similar to it. Similarity is described using measured variables, such as tree species, breast height diameter, geographic location, site class, etc.

The area represented by a sample point is estimated by dividing the land area by number of sample plot centre points in each Forestry Centre. The land area is taken from the official statistics maintained by National Land Survey of Finland. The area estimate for a domain (area of interest, e.g. forest) is the sum of the areas represented by the sample points. However if a sample plot is divided into several land use classes or stands, only the land use class or stand where the plot centre is located is taken into account in the area estimations.

For each tally tree, the sampling probability on the plot is known. The total volume estimate for a domain is obtained by summing the tree wise volume estimates multiplied by the inverse of the sampling probability, then by dividing this by the number of sample plot centres in the domain and by multiplying by the area estimate of the domain.

Results are usually calculated using the data from five most recent years, in some cases also using data from three most recent years. Selected set of results are published annually in the Luke web site (www.metla.fi/metinfo) and Finnish Statistical Yearbook of Forestry (e.g., Finnish Statistical Yearbook of Forestry 2012). In addition, after each inventory cycle a summary report, and numerous articles on selected themes are published.

The main user of the NFI results is the Ministry of Agriculture and Forestry of Finland: preparation of national forestry programmes, evaluation the success of the programmes, planning of forest policy. The Forest Centre uses the results for planning and following forest policy at regional level. NFI data is the main data source for several international reporting processes: the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 of the Kyoto Protocol, the indicators and criteria for sustainable forest management for FOREST EUROPE (FOREST EUROPE, UNECE and FAO 2011), and on the conservation status of natural habitat types under the Habitats Directive (Council of the European Communities 1992). NFI data are a valuable data source for numerous research projects. NFI data and results are widely used by forest and bioenergy industry for planning of investments.

19.2 Land Use and Forest Resources

19.2.1 Classification of Land and Forests

19.2.1.1 General Land Classification

In the national land use classification system, land is divided into Forestry land, Agriculture land and Built-up land. The Agriculture land category is further divided, mainly for carbon reporting, to 12 sub-categories according to the use of the land and soil type. The Built-up land category is further divided into six main categories by land use. Further classification of Forestry land is described in the following Sub-Chapters. The FAO definitions for land use/cover is used in the NFI but the classification is not reported in national statistics.

19.2.1.2 Forest Classification by Productivity and Use

In the national land use classification system, forestry land includes productive forest land, poorly productive forest land, open land and other forestry land (Tables 19.2 and 19.3). Confusingly, the term forestry land includes also protected areas where all forestry operations are strictly forbidden. Timber is extracted from productive forest land. Due to economic reasons, poorly productive land is not used for forestry, even though legally it would be possible. In the past (mainly from 1920s to 1980s) large areas of poorly productive and even treeless peatland sites have been converted to productive forest.

Table 19.2 Land use/land cover class areas according to the national definition

Class name	Definition	Area (1000 ha)	Corresponding FRA class (FAO 2004)
Productive forest land	No other land use than forestry, productivity at least 1 m^3/ha/year, includes protected areas etc.	20,312	Forest
Poorly productive forest land	No other land use than forestry, productivity at least 0.1–1 m^3/ha/year	2447	Partly forest, partly OWL
Open land	No other land use than forestry, productivity less than 0.1 m^3/ha/year	3218	Mostly OL, partly OWL
Other forestry land	Forest roads, temporary timber storage sites	197	Forest
Arable land	Land used for agriculture, pasture land, including built-up land for agriculture purpose	2695	OL
Built-up land, several sub-categories		1521	OL, OlwT

Table 19.3 Land use/land cover class areas according to the FRA2010 classification

Class name	Area (1000 ha)	National remarks
Forest	22,217	Forest roads etc. are included here even in the national classification they are not regarded as forest
OWL	801	
Other land of which with tree cover	7370 2310	

19.2.1.3 Classification by Ownership Categories

The official forest statistics include the following ownership categories: (1) Non-industrial private forest owners (2) Companies (3) State (4) Others (Municipalities, Parishes, etc.). In some studies, private forest owners are further divided to farmers and others; and companies are divided to forestry companies and others. Nearly two-thirds (61 %) of productive forest land (national definition) are owned by NIPF (non-industrial private forest owners), 25 % by state, 8 % by companies, and 5 % by other ownership categories (Table 19.4).

19.2.1.4 Forest Management and Cutting Systems

The majority of forests in Finland are managed with even-aged management system. A good practice model for forest management is as follows:

1. Establishment with natural regeneration, sowing or planting, according to soil type and owners decision.
2. Early tending for seedling stand.
3. Thinning of a seedling stand.
4. First thinning, second thinning and in some cases even a third thinning during the rotation.
5. Regeneration cutting after reaching maturity according to stand age and/or mean diameter criteria.

More than 60 % of roundwood removals come from regeneration cuttings, less than 40 % from thinnings. Approximately one third of the area cut for regeneration is regenerated naturally and two thirds artificially. Increased demand and subsidies for forest bioenergy has influenced the cutting regimes in some cases: thinning of seedling stands and first thinnings may be replaced by whole-tree harvesting for

Table 19.4 Area of productive forest land by ownership categories

Ownership category	Area (1000 ha)	Area (%)
Non-industrial private	12,406	61.1
Companies	1715	8.4
State	5102	25.1
Others	1088	5.4
Total	20,312	100.0

bioenergy, and stumps and cutting residues may be collected in the final cutting. Cutting residues and branches may be harvested for energy also in thinnings, but only on nutrient rich sites.

Forest owners make the decision on the cuttings, no cuttings are compulsory. After a regeneration cutting, a new forest must be established by natural regeneration, planting or sowing. Thinning cuttings may not exceed the limits set by the thinning regimes, but forest owners decides also whether to do the thinning or not.

Until 2014, practically all economic forests are managed with even-aged cutting systems. At the beginning of 2014, a new forest act was accepted. The new forest law also accepts uneven-aged forest management. At the same time, the minimum age and mean diameter criteria for regeneration cuttings were removed from the legislation.

19.2.1.5 Further Classification of Forests

The further classification of forests in national statistics and NFI reports is usually by main soil type (mineral, peatland), site productivity class, dominant species (Table 19.5) and age (Table 19.6) or development class (Table 19.7). The main

Table 19.5 Forest area (national definition) by dominant species

Species	Area (1000 ha)	Remark
Open	257	
Scots pine (*Pinus sylvestris L.*)	12,956	
Norway spruce (*Picea abies Karst.*)	5038	
Other conifers	27	
Silver birch (*Betula pendula Roth.*)	583	
White birch (*Betula pubescens Ehr.*)	1287	
Other deciduous	164	Mainly aspen and alder
Total	20,312	

Table 19.6 Area of productive forest by age classes

Age class (years)	Area (1000 ha)
Open	257
1–20	3246
21–40	3698
41–60	4080
61–80	3334
81–100	2412
101–120	1197
121–140	633
141–160	457
160+	997
Total	20,312

Table 19.7 Area of productive forest by development classes

Development class	Area (1000 ha)	Remark
Open	257	Temporarily unstocked
Young seedling stands	1369	Mean height <1.3 m
Advanced seedling stands	2209	Mean dbh <8 cm
Young thinning stands	7015	At the age of first thinning, removals below sawlog size
Advanced thinning stands	5916	Thinnings produces sawlog sized timber
Mature forest	3436	Age or mean diameter has reached the minimum for regeneration, criteria depend on location and site
Natural regeneration areas	110	Seedling or shelter trees
Total	20,312	

reason for classifying forest data by main soil type is the fact that peatland forests can in most cases be harvested only at winter time where as harvesting on mineral soils can be done during the summer.

19.2.2 Wood Resources and Their Use

19.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock and increment are based on the tree measurements on the NFI plots. They are calculated as volume of stemwood overbark. Stemwood according to the Finnish NFI includes all stem parts above the stump i.e. the bole with bark and stem top and conforming to the definitions of tree elements by Gschwantner et al. (2009). The minimum dbh is 0 cm. The NFI estimates the volume of standing stock which can be divided into the volume of growing stock and volume of standing dead wood. Estimation of increment is based on diameter and height increment measurements of trees on temporary plots. Increment is calculated as mean annual estimate for the period of five years before the plot measurement. Increment on trees removed or that have died during the five year period is included in the increment estimate.

Estimation of drain is based on cutting statistics (for industrial removals), household surveys (for fuel wood and household use) and NFI permanent plots (for mortality). Recently, permanent plots have been used to estimate also the removals, but the official drain statistics are estimated using the listed data sources.

The national definitions for volume of standing stock, increment and drain are detailed in Table 19.8.

The NFI also produces biomass estimates. The biomass estimates are based on tree level biomass functions for different tree components: stem, living branches, dead branches, foliage, stump, and roots (Repola et al. 2007; Repola 2008, 2009).

Table 19.8 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with h >1.3 m, including the bole (wood and bark), and stem top, and excluding the above-ground part of the stump
Increment	Volume increment of trees with h >1.3 m, includes increment of removed and dead trees
Drain	Volume of harvested and dead trees

The main tree species are pine (*Pinus sylvestris*, 50 % of volume), spruce (*Picea abies*, 30 % of volume) and birch (*Betula penduda*, *B. pubescens*, 16 % of volume) (Table 19.9).

The consumption of domestic roundwood in 2012 was 62.3 million m^3. In addition, consumption of imported roundwood and imported chips was 8.5 million m^3 (Finnish Statistical Yearbook of Forestry 2013). Out of a total consumption of wood (including imported wood) 25.5 million m^3 was pine, 20.7 million m^3 spruce, 12.6 million m^3 deciduous trees, 9.3 million m^3 energy wood and 2.7 million m^3 imported chips. In addition, consumption of forest industry by-products and wood residues was 22.6 million m^3.

Wood-products industries used 24.0 million m^3 roundwood, pulp industries 37.4 million m^3 and energy production 9.3 million m^3.

19.3 Assessment of Wood Resources

19.3.1 Forest Available for Wood Supply

19.3.1.1 Assessment of Restrictions

For each sample plot, variables related to legal restrictions for cuttings are assessed. Firstly, GIS data base on protected areas are used to identify if a plot belongs to any protection programme, nature reserve, special use forests, etc. In the field this assessment is checked and further restrictions may be found. For example, the plot stand may be a specific biotope protected by forest law or nature protection law, or near a lake so that specific management is needed for protection of scenic values. Following specific restrictions mainly affect the availability for wood supply:

(A) Protected areas
Forestry operations are not allowed in areas that are protected for biodiversity. These include nature reserves, national parks and specific protection programmes (such as programme for protection of herb rich forests, old growth forests, esker formations etc.). Few protection programmes allow careful management operations. Land use planning at county and municipal level may cause further restrictions. Borders of legally protected areas are available as a GIS data base and can be taken into account in estimation of cutting

Table 19.9 Volume, increment and drain by tree species, productive and poorly productive forest (2012)

Species	Volume (million m^3)	Increment, (million m^3/year)	Total drain (million m^3)
Scots pine (*Pinus sylvestris L.*)	1157	47.3	28.1
Norway spruce (*Picea abies Karst.*)	703	32.6	22.9
Deciduous	472	24.4	18.9
Total	2332	104.4	69.9

possibilities but municipal level land use planning data are not generally available in digital form at the moment.

(B) Recreation areas
Areas reserved for recreation include areas established by the owner's decision (usually in state or municipality owned forests) and areas where land use planning at municipal or county level has introduced reservation for recreation. These areas are managed mainly for recreation values and forestry operations must be planned accordingly. In most cases, forestry is not profitable in these areas and the aim of operations is to maintain recreation values.

(C) Protected biotopes, key habitats
The forest act defines a number of biotopes that may not be managed or can be managed carefully so that the natural elements are not endangered. These biotopes are identified if they occur in NFI plots and are taken into account in estimating the cutting possibilities, estimations.

(D) Protective functions
The protection of water resources causes limitations to forest operations near settlements. Most of these areas are in GIS data base and can be identified in the NFI plots. Protection for soil (erosion/avalanches) is not an issue in Finland. The protection of forests at high altitudes limits the forest operations that can occur in Northern Finland.

(E) Other restricted areas
This category include military areas and other specific use forests (gene reserves, research forests).

(F) Site characteristics and logging costs
Slope is not an issue for timber production in Finnish conditions. Some forests have poor productivity (due to elevation, poor soil, location, etc.) and forest operations are not economically feasible. The site productivity is taken into account when evaluating the sustainable cutting level with e.g. four percent interest rate is estimated. The location of forests (distance from roads) is taken into account only via average hauling costs (not plot specific).

The level of restriction is assessed in five categories: no effect on management options; all forestry operations forbidden; forestry operations forbidden but

Table 19.10 Restriction classes

Category	Relevance in Finland	Comment
Protected for biodiversity	Highly relevant	Forestry operations mostly not allowed
Recreation areas	Relevant	Forestry operations restricted
Protected biotopes	Highly relevant	Forestry operations not allowed or restricted
Protective functions	Relevant	Forestry operations restricted
Other restricted areas	Relevant	Forestry operations restricted or not allowed
Site/logging costs	Relevant	Forestry operations non-profitable with current prices and technology. Does not include areas where logging is possible only in winter time

management for enhancing the ecological values are allowed; part of protected area but management possible in the plot stand location; near-natural management options allowed (removing of single trees, mild thinnings).

Another variable related to legal restrictions on forest resource use and assessed in the NFI data collection is called "Other values". This variable describes if the plot is located in a specific biotope, near a coast line or houses, or if the site has some other specific values that restricts harvesting operations.

The specific restrictions are described in terms of relevance and the level of restriction in Table 19.10.

19.3.2 Wood Quality

19.3.2.1 Stem Quality and Assortments

Upto the early 1990s timber quality standards were part of the timber price negotiations between timber buying industry and wood producers. Since 1992 the centralised agreements on timber prices and quality criteria have been regarded as illegal agreements restricting markets. Since then there has not been any national quality criteria that all timber buying industry wood follow. Instead, each company may use they own criteria for saw log lengths and quality criteria.

Most timber buyers use a minimum top diameter of 16 cm (over bark) for spruce sawlog and 15 cm for pine sawlog. Some companies buy so called mini sawlog, where the top diameter may be only 10–14 cm, which are naturally priced markedly lower than the price of standard sawlog but higher than the price of pulp wood logs. The minimum length of a saw log is usually 37 dm and maximum length 58 or 61 dm. A step of 3 dm is used for the lengths (37, 40, 43, etc.).

For pine sawlog there are traditionally three different quality classes: branch-free sawlog, logs without dry branches, and logs with dead branches. For spruce sawlogs such quality classes depending on the quality of branches usually does not exist. Usually the maximum allowable branch diameter is 5 cm for living branches and 4 cm for dead branches. No steep curves nor decay are allowed for saw log. Apart from these categories other assortments may be specified for particular purposes, such as poles or house building timber.

Veneer logs (mainly birch) usually have a minimum length of 1.5 m and minimum top diameter of 18 cm. A small amount of hard decayed wood is allowed around the pith.

19.3.2.2 Assessment and Measurement

In the Finnish NFI standard quality criteria for timber assortments are still used. These criteria have remained unchanged since the late 1980s.

Wood quality is assessed in tally tree measurements and more detailed in sample tree measurements. For each tally tree, a tree class is recorded describing broad quality classes. The tree classes are:

Living trees

0. Small tree. Diameter at breast height less than 4.5 cm.
1 Waste tree. Diameter at least 4.5 cm but the stem cannot be used for timber or pulp because of defects (decay, fork, sweep). Trees smaller than timber size, pulp wood quality
2 Good pulp wood tree. Diameter at breast height is at least 4.5 cm but stem is not timber sized. The tree will probably develop to timber if the tree grew on maturity at the site and without competition. Trees can belong to this class no matter the site class or species.
3 Regular pulp wood tree. Tree size as above but due to defects or poor technical quality the tree is not expected to develop to a first class timber tree.
4 Pulp wood tree with defects. Tree size as above but due to defects or poor technical quality the tree is not expected to develop to a timber tree.
5 Good timber tree. There is a saw log of the first quality class, and at least 80 % of the timber sized part of the stem is of timber quality.
6 Good timber tree with defects. There is a saw log of the first quality class but less than 80 % of the timber sized part of the stem is of timber quality.
7 Timber tree. At least 80 % of the timber sized part of the stem is of timber quality. There is no sawlog of the first quality class.
8 Timber tree with defects. Less than 80 % of the timber sized part of the stem is of timber quality. There is no sawlog of the first quality class.
9 Timber sized pulp wood tree. The stem is timber sized but due to defects or poor technical quality no saw log can be sawn from the current stem.

Dead trees

(A) Usable standing dead tree.
(B) Usable fallen dead tree.
(C) Dry, hard dead tree. Special dead timber, minimum diameter 20 cm, either spruce or pine.
(D) Non-usable dead tree. On permanent plots a tree that was either living tally tree or usable dead tree in the previous inventory, now non-usable.

For sample trees (every 7th tally tree) the quality is described by dividing the stem in quality classes and recording the length and reason for each module. The quality classes are:

1. Saw log quality without branches or with very small branches
2. Saw log quality with fresh branches
3. Saw log quality with dry branches
4. Pulp wood quality
5. Pulp wood quality between two saw log quality parts (deciduous trees only)
6. Waste wood, not even pulp wood quality
7. Saw log quality in a forked tree
8. Complementary cut point (usually due to sweeping).

The quality criteria for pine and spruce saw log is presented in Table 19.11. There are three quality classes; 1–3 (Class 1 = branch-free saw log, Class 2 = saw log without dry branches, Class 3 = saw log with dry branches).

19.3.2.3 Estimation and Models

The volume of growing stock by timber assortments (timber, pulp, waste) is estimated for national statistics. At the first step the volumes by timber assortment classes are estimated for the sample trees using measured dimension (dbh, d6, h), lengths of quality parts, taper curve models and a bucking algorithm. Volumes by timber assortments are generalised for the tally trees using non-parametric estimation, and finally summed up for a calculation domain. Saw log dimensions (lengths and top diameter limits) used in the estimation are given in Table 19.12. For pulp wood logs the minimum length is 2 m and minimum diameter 6 cm over-bark.

19.3.3 Assessment of Change

19.3.3.1 Assessment and Measurement

The increment assessed in the Finnish NFI is defined as the gross annual increment, including the increment of survivor trees, harvest trees and dead trees in the past

Table 19.11 Quality criteria for pine and spruce saw log quality classes 1–3

Species	Class 1	Class 2	Class 3
Sweep (cm/m)			
Scots pine (*Pinus sylvestris L.*)	1.0–1.5[a]	1.0–1.5[a]	1.0–1.5[a]
Norway spruce (*Picea abies Karst.*)	1.0–1.5[a]	1.0–1.5[a]	1.0–1.5[a]
Knots, diameter (mm)			
All species	Not allowed	Small	Small
Fresh branches diameter (mm)			
Scots pine (*Pinus sylvestris L.*)	10–15[a]	50–70[a]	50–70[a]
Norway spruce (*Picea abies Karst.*)	10–15[a]	40–60[a]	40–60[a]
Dry branches diameter (mm)			
Scots pine (*Pinus sylvestris L.*)	15	15	40
Norway spruce (*Picea abies Karst.*)	15	15	40
Decayed branches diameter (mm)			
All species	Not allowed	Not allowed	30

[a]Depending on the top diameter of the saw log

Table 19.12 Saw log top diameter and length criteria applied in NFI

	Min. length (dm)	Max. length (dm)	Min. diameter (cm)
Scots pine (*Pinus sylvestris L.*)			
Class 1	31	61	15–20[a]
Class 2 or 3	40	61	15
Norway spruce (*Picea abies Karst.*)			
	40	61	16
Deciduous			
	31	61	18–20[a]

[a]Depending on the length of the saw log

five years. The increment is assessed using temporary plots. Variables related to increment estimation include:

1. Diameter increment. Timber cores are taken with a borer and annual increment is measured from bark to pith. The five latest years increment are summed to get the average for past five years. For sample trees measured before the end of July, the diameter increment of the measurement year is ignored, after that the measurement year is regarded as the most recent increment year.
2. Height increment. For conifers the height increment of past five years is assessed using binoculars with a specific scale of Vertex hypsometer (Vertex measurement is allowed for young, well growing trees, only). For deciduous trees, the crown position is assessed and the 5 year height increment is taken from tables using site, tree age and crown position.
3. Thickness of bark.

Currently, the assessment of drain is mainly based on cutting statistics. Permanent plots, established in 9th NFI, are used for estimating mortality and the amount of cutting residues left in the forest (Ihalainen 2013).

19.3.3.2 Estimation of Increment

Increment of survivor trees
At sample tree level, the measured data for volume increment estimation are: diameter over bark and inside bark; height, diameter under bark five years ago, height five years ago. Using sample tree data from the 7th NFI, a function $r = v/g_i = f(h, \text{species})$ has been estimated, v = stem volume, g_i = stem cross section area below bark at breast height, h = tree height. With this function it is possible to estimate the volume five years ago using the height at that time and stem cross section area (diameter) under bark for the sample trees. The volume increment is estimated as a difference of current volume and volume five years ago. Using these data, the average volume increment percentages are calculated by tree species groups, regions and site classes. The volume estimates of growing stock in these classes are multiplied with the increment percentages to obtain the increment of survivor trees.

Increment of removed trees
The increment of cut and dead trees (during the five year period but before their removal/dying) are included both in the cross and net increment estimates. It is estimated by multiplying the annual drain by the increment percentage of survivor trees and 0.7 (assuming that cut and mortality trees have lower increment percentage). The total gross increment (used in national statistics) is estimated by summing the increment of survivor trees and the increment of drain. The net increment (for some international statistics) is estimated by subtracting the mortality from the gross increment.

19.3.3.3 Estimation of Drain

Cuttings are estimated using official removal statistics collected by Natural Resources Institute Finland (Luke). All the large companies that use timber send statistics on cuttings to Luke on a monthly basis. The timber purchased by small-scale saw mills (less than one percent of the total cuttings) is estimated with a separate study, the latest been from the year 2010. Statistics on cuttings for energy use are based on information on the use of wood for energy, not on cuttings directly. The use of fuel wood in small-scale housing is based on separate studies, the latest from the year 2008.

The statistical data produces information on the amount of harvested wood. The amount of cutting residues left in the forest and mortality is estimated using NFI permanent plot data.

19.3.4 Other Wooded Land and Trees Outside Forests

The Finnish NFI covers all land use classes and ownership categories. Thus, the area of forest, other wooded land, and other land is obtained from the NFI plot data.

In the NFI, trees have traditionally been measured only on productive forest and poorly productive forest. As forest cover in Finland is very high, trees outside forests have only nominal proportion of the total volume of trees. For carbon reporting, measuring living trees on all land use classes started at in the beginning of 11th NFI (2009). The plot type for trees outside forests is the same as in forests. Measurements are the same, but simplified: only species and dbh. In 2012 and 2013, the height for trees outside forests were also measured.

Neither the volume nor biomass of shrubs is estimated in the Finnish NFI.

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Chapter 20
France

Jean-Christophe Hervé

20.1 The French National Forest Inventory

20.1.1 History and Objectives

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

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

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

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

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

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

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

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

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

20.1.2 Sampling Methods and Periodicity

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

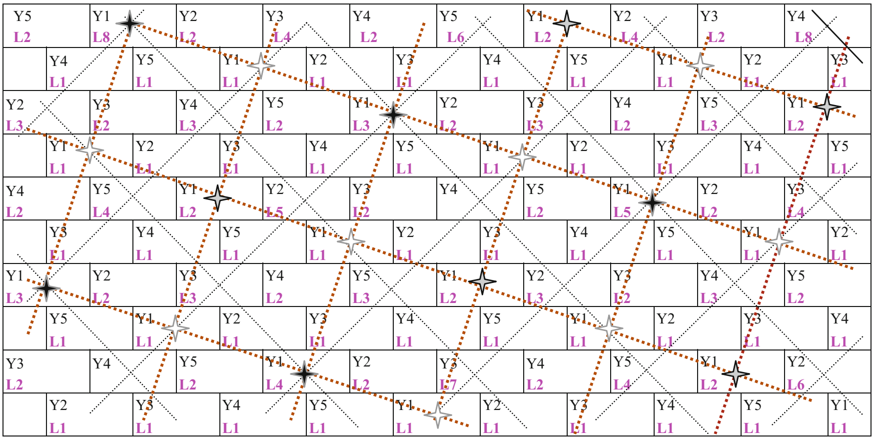

Fig. 20.1 The French NFI permanent sampling grid used to create annual samples (see explanations in the text)

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

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

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

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

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

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

20.1.3 Data Collection

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

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

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

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

- Elevation above sea level
- Slope direction (exposition)
- Slope gradient
- Relief
- Soil moisture
- Soil layer thickness
- Soil group
- Soil movement
- Humus layer thickness
- Humus type
- Soil group
- Assessment of all plant species present on the 7-are plot.

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

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

20.1.4 Data Processing, Reporting and Use of Results

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

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

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

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

The results of the French NFI are used as a basis for decision-making in forest and environment policy, forest management, forest products industries, and for evaluating the consequences of the decisions taken. Reporting obligations of many international processes and organisations are fulfilled using the data and results of the French NFI. Reporting processes include: the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO 2010), the indicators and criteria for sustainable forest management for FOREST EUROPE (FOREST EUROPE, UNECE and FAO 2011) and at the national level (Ministère de l'agriculture 2011).

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

20.2 Land Use and Forest Resources

20.2.1 Classification of Land and Forests

20.2.1.1 General Land Classification

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

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

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

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

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

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

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

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

20.2.1.2 Forest Available for Wood Supply

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

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

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

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

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

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

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

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

20.2.1.3 Classification by Ownership Categories

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

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

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

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

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

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

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

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

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

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

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

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

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

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

20.2.1.5 Forest Management and Cutting Systems

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

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

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

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

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

20.3 Wood Resources and Their Use

20.3.1 Standing Stock, Increment and Drain

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

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

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

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

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

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

20.3.2 Tree Species and Their Harvest

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

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

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

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

(continued)

Table 20.8 (continued)

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

20.4 Assessment of Wood Resources

20.4.1 Forest Available for Wood Supply

20.4.1.1 Assessment of Restrictions

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

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

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

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

20.4.1.2 Estimation

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

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

20.4.2 Wood Quality

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

20.4.3 Assessment of Change

20.4.3.1 Assessment and Measurement

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

Table 20.9 Stem quality classes as assessed by the French NFI

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

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

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

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

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

20.4.3.2 Estimation of Increment

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

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

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

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

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

The final estimate of stem-volume increment is:

$$\text{Vi}(\text{girth}_t) - \text{Vi}(\text{girth}_{t-5})) \times V_t / \text{Vi}(\text{girth}_t) \tag{20.3}$$

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

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

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

20.4.4 Other Wooded Land and Trees Outside Forests

20.4.4.1 Assessment and Measurement

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

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

20.4.4.2 Estimations

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

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Chapter 21
Germany

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21.1 The German National Forest Inventory

21.1.1 History and Objectives

Forest statistics and forest inventories have a long tradition in Germany originating in the nineteenth century (Tomppo et al. 2010). The first German National Forest Inventory (NFI) with a nationwide sample-based data survey based on mathematical and statistical methods was implemented in the old German Laender within the years 1986–1990 (NFI1987). The NFI measures large-scale forest condition and the forest production potential. After reunification the second NFI (NFI 2002) was conducted expanding the methods used in the first NFI to the new German Laender.

In the spring of 2011, the field assessment for the Third National Forest Inventory was started. This NFI is referred to as NFI 2012, with measurements completed in February 2013. NFI 2012 is the first consecutive inventory for the entire Federal Republic since German reunification. A prerequisite in the development of the survey procedure was not to increase the effort associated with data collection. In addition, the comparability with former surveys should be maintained. Therefore, planning the assessment process was modified and extended cautiously. Nevertheless, the most notable innovations and changes are:

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- the collection of forest habitats and their conservation status under the Habitats Directive (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora)
- the reduction of the minimum diameter for the collection of dead wood from 20 to 10 cm
- the exact location of sample points determined by GPS
- the exclusion of the forest-road assessment from the survey.

Additionally, the Laender of Saxony-Anhalt and Thuringia have condensed their network compared to the Second National Forest Inventory. Thus, the sample size is expected to increase about 9 % and there are now nearly 60,000 sample plots in forests with more than 420,000 sample trees for the whole of Germany.

21.1.2 Sampling Methods and Periodicity

The legal foundation of the German NFI changed with the "Second Act to amend the Federal Forest Act", passed by the German Bundestag on 17.6.2010. Thus the amended § 41a of the Federal Forest Act changed the framework for the National Forest Inventory. While it previously stated that the inventory should be repeated "as needed", there is now a cycle defined by ten years. In addition, the carbon stock data could be collected when necessary in the years between.

The NFI uses a stratified systematic one-phase cluster sampling with regionally different sampling intensities (sampling strata). The reference grid of the random sample is designed to fulfil the precision requirements at a national level. In order to increase the informative value, some German Laender regionally applied a denser sampling grid, so that in the end the sampling intensity over 22 % of the area has been doubled and on another 32 % quadrupled (Fig. 21.1).

Each cluster consists of four plots arranged in a square with side lengths of 150 m. Along borders the cluster size could decrease. Only plots in the forest are sampled. The sample plots are marked using permanent concealed markers. In every plot within the forest, the data recorded varies depending on the survey units e.g. sample plot circles, angle count sampling (Fig. 21.2).

21.1.3 Data Collection

Two types of data were recorded. Firstly, the general point data like, cluster number, plot number, sampling strata, German Land, district, municipality, forest region, accessibility, forest/non forest, forest classification, ownership, slope, altitude, natural altitudinal zones, land use changes, etc.

Secondly, the tree data differentiated by: (a) data for structural and biotope attributes like naturalness of the tree species composition or to derive forest habitats

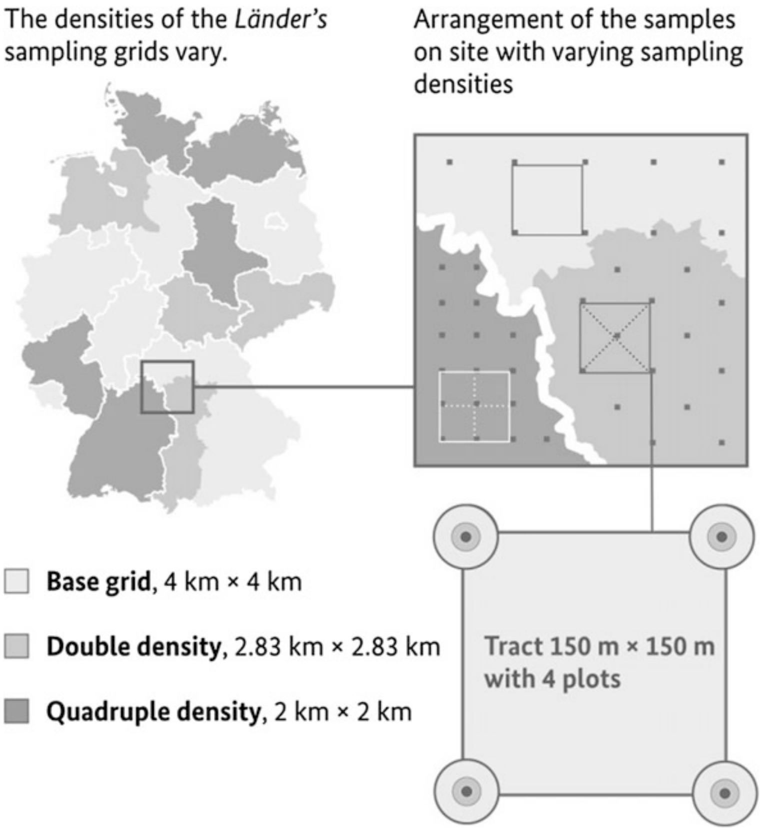

Fig. 21.1 NFI sampling grid (Federal Ministry of Food and Agriculture 2015)

and their conservation status and (b) data to estimate volume, volume change and so on.

To describe the stand, data from the angle count sampling with basal area factor 1 or 2 and from the 10 m radius circle were used. The 1 and 2 m circles were used to derive estimates of regeneration; abundance, stem number, species composition and biomass.

The typical forest parameters of volume, growth and drain were estimated based on the angle count sampling with a basal area factor 4. The following parameters were assessed: tree number, tree species, azimuth, horizontal distance, canopy class, diameter at breast height (dbh), social position according to Kraft, damage, special habitat tree attributes and pruning. The age of the trees is taken from the preliminary data of the cluster established before the actual survey. If the preliminary details of the cluster contain a false age or no age at all, the annual growth rings on stumps or the number of branch whorls are counted. Alternatively, the age is estimated on the basis of the local growth dynamics.

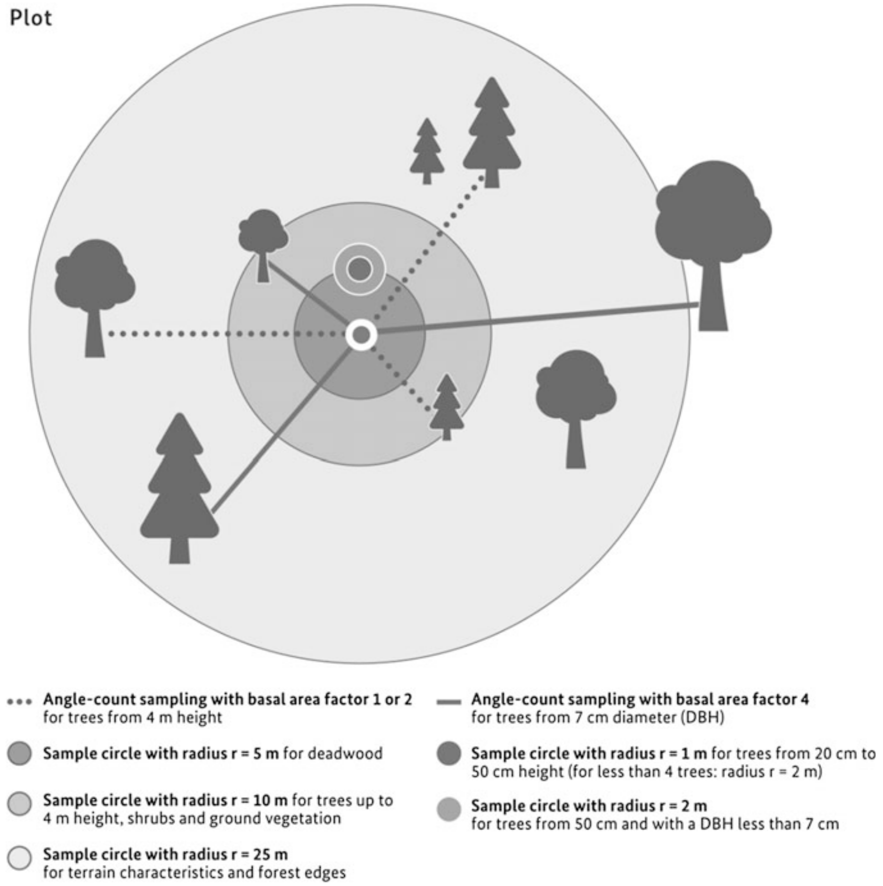

Fig. 21.2 Surveys at the sample point (Federal Ministry of Food and Agriculture 2015)

The dbh is measured on all trees included in the angle count sampling (ACS). On a sub-sample of approximately 1/3 of all ACS-trees the height and the diameter at 30 % of the total tree height (d_{03}) is measured. For the other trees both parameters are modelled depending on tree species groups.

The amount of dead wood for three different tree species groups, seven types of deadwood (lying, standing, root stock, etc.) and 4 degrees of decomposition was derived from circle with 5 m radius.

To avoid biases of the tree inclusion probability for those trees in the near of forest edges, border effects must be eliminated Therefore, all border lines of forest/non forest edges and of stand edges are measured within a maximum distance of 25 m radius by accessing two polar coordinates for each border lines.

A more detailed description can be found in the field guide (BMELV 2011).

21.1.4 Data Processing, Reporting and Use of Results

During and after the field assessments all data must pass two validation checks. Data with warnings must be checked again; and data with errors must be corrected. Validation checks are implemented at four stages. Checks within the field software on tree, plot and cluster level, defined check routines done by Land inventory administration and defined check routines done by the federal inventory administration.

Before the evaluation process can start, a lot of routines must be developed, fitted and programmed to derive attributes not assessed in the field. Three stages have to be distinguished: object level attributes for one time point, object level attributes for two time points and plot level attributes for one time point and their changes between two time points.

Object attributes (trees, dead wood pieces, forest borders) to derive for one time point are:

- represented number of stems per hectare including forest edge correction
- stand area of each tree
- modelled tree heights using unit height-diameter curves
- upper diameters at 30 % tree height (d_{03}) using single tree regression models f(tree species, dbh, height) according to Sloboda et al. (1993)
- volume as f(tree species, dbh, d_{03}, height)
- above ground biomass of living trees, f(tree species, dbh, d_{03}, height)
- below ground biomass of living trees, f(tree species, dbh)
- volume of dead wood pieces, f(tree species, length, lower and upper diameter)
- biomass of dead wood pieces, f(tree species, length, lower and upper diameter, degrees of decomposition)
- forest edge length, exposition of forest edge.

If new models were used, i.e. for biomass, the attribute must be derived again with the new model for the same tree attribute from the last occasions.

Object attributes derived from two time points are: growth of diameter, height, volume and biomass. The basic attributes dbh and height for new selected angle count sampling trees (in-growth, on-growth and non-growth trees) and for cut or mortality trees were modelled using a differential equation according to Sloboda (1971).

For plots the following attributes were derived: forest type, naturalness of the tree species composition, forest habitat and classifications for height zones, exposition, slope, etc.

For each plot the variable of interest (biomass, volume, etc.) per hectare is calculated as the sum of hectare values represented by individual trees. These estimates per hectare are aggregated to a mean per hectare forest and non-forest.

The total estimate is derived by multiplying the mean with the total area of Germany. Dividing the mean by a proportion or one total by another total respectively results in a ratio estimator, i.e. the growing stock per hectare forest. Means, totals and ratios can be estimated for nearly all possible combination of classification variables: Germany, Laender, tree species, age classes, forest classification, ownership, forest habitats, classes of naturalness, natural altitudinal zones, etc.

For change estimations data from two consecutive NFI assessments are used. All changes in forest area and wood resources are assessed on permanent plots. Every change in wood resources are related to the population of trees with a dbh ≥ 7 cm. Volume estimates below this threshold are provided for FAO reporting. For LULUCF and Kyoto reporting biomass estimates are also derived from the regeneration data. Changes in forest area and wood resources are estimated in the same way as described above for means, totals and ratios, but calculating the difference first.

Experience gained from the Second National Forest Inventory and the Inventory Study 2008 (Oehmichen et al. 2011), the collected data is of interest for many stakeholders on national and sub-national level. In particular, forestry and environment policy stakeholders, the forestry and timber industry as well as the forest science needs the data for the analysis of the current situation and the future management of our forests.

The international reporting requirements are the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 and 3.4 of the Kyoto Protocol, the Decision 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, the indicators and criteria for sustainable forest management for FOREST EUROPE (FOREST EUROPE, UNECE and FAO 2011), and on the conservation status of natural habitat types under the Habitats Directive (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora).

At national and sub-national level the German NFI data are the scientific basis to estimate and to evaluate the current status of forests and their retrospective development. They are used to evaluate forest policy strategies like Forest Strategy 2020 or the silvicultural guidelines of the Laender. In some Laender the NFI data are the only source of information about conditions in private forest ownership. In addition, the NFI data are used for modelling the “future forest development and potential wood outcome” (WEHAM) under different management and policy scenarios for the next 40 years.

21.2 Land Use and Forest Resources

21.2.1 Classification of Land and Forests

21.2.1.1 General Land Classification

In the preparatory phase for each NFI assessment all sample plots were classified in two classes: "definitively non forest" and "possible forest". Therefore the administration of the inventory within each German Land uses available maps and aerial orthophotos. All plots classified as possible forests are visited in the field. The final decision to classify a plot as forest or non forest in the field, is based on the following forest definition:

Forest within the meaning of the NFI is any area of ground covered by forest vegetation, irrespective of the information in the cadastre or similar records. The term forest also refers to cut-over or thinned areas, forest tracks, fire-breaks, temporarily unstocked land and clearings, forest glades, feeding grounds for game, landings, forest aisles, further areas linked to and serving the forest including areas with recreation facilities, overgrown heaths and moorland, overgrown former pastures, alpine pastures and rough pastures, as well as areas of dwarf pines and green alders. Heaths, moorland, pastures, alpine pastures and rough pastures are considered to be overgrown if the natural forest cover has reached an average age of five years and if at least 50 % of the area is covered by forest.
Areas with forest cover in open pasture land or in built-up areas of under 1000 m^2, coppices under 10 m wide, Christmas tree and ornamental brushwood plantations, commercial forest-tree nurseries as well as parkland attached to country houses are not forest within the meaning of the NFI. Watercourses up to 5 m wide do not break the continuity of a forest area.

In 2012 the forest area amounted 11,419,124 ha. All other land uses covers 24,301,656 ha.

If sampling points changed their status from forest to non-forest or vice versa since the last NFI one of the following land use categories will be assessed as "land use category before" or "land use category after" conversion additionally:

Settlement areas:

- industrial, commercial and traffic areas, including vegetation-covered slopes along the traffic areas
- built-up, sealed off areas not assigned to any other category (e.g. housing estate)
- mining sites, landfills, dumps, open areas with no or little vegetation (areas that naturally have these surfaces are in their terminal stage and do not become forest. The existing rare cases are assigned to this category as they often originate from this use of land)
- urban green, other unsealed areas, sport and recreation areas.

Agricultural areas:

- arable land
- permanent crops (vines, fruit stands, hops, tree nurseries not belonging to the forest)
- permanent grassland (pastures, meadows, natural grassland, heaths, transitional stages between forest and shrubs).

Other areas:

- wetlands
- bodies of water.

Errors:

- plot was already clearly non-forest before (missing or wrong designation in NFI 2002)
- plot was already clearly forest before (missing or wrong designation in NFI 2002).

Therefore, the German NFI cannot provide area estimates for all land use classes and their change. Only area estimates of land use change classes to or from forest are possible (Table 21.1).

Table 21.1 Land use change from and to forest between NFI 2002 and NFI 2012

Type of land use after or before	Deforestation (1000 ha)	Afforestation (1000 ha)	Corresponding FRA classes (FAO 2004)
Industrial, commercial and traffic areas	16,337	6468	OL, OlwTc
Built-up, sealed off areas not assigned to any other category	4290	596	OL, OlwTc
Mining sites, landfills, dumps, open areas with no or little vegetation	16,506	27,470	OL, OlwTc
Urban green, other unsealed areas, sport and recreation areas	4188	700	OL, OlwTc
Sum of cultivated areas	41,322	35,236	
Arable land	2992	12,443	OL, OlwTc, intersection with forest
Permanent crops	2292	2296	OL, OlwTc, intersection with forest
Permanent grassland	9874	49,133	OL, OlwTc, intersection with forest
Sum of agricultural land	15,159	63,873	
Wetlands	1395	6271	OL, OlwTc
Bodies of water	399	2494	OL, OlwTc
All types of land use change	58,277	107,874	

For carbon reporting under the UNFCCC (LULUCF) and the Kyoto protocol regulations the land use information from the NFI plots are also used. Hence, the carbon reporting system is independent from the NFI. Herein, the NFI land use information is only one source from an overall of 5 sources used for carbon reporting. But it is important to know, that within the carbon reporting system the same sampling grid is applied to assess LULUCF (Freibauer et al. 2014).

21.2.1.2 General Classification of Forest

The forest classification distinguishes between:

- forest, temporarily unstocked land
- forest, unstocked forest land
- forest, stocked timber-land.

Temporarily unstocked areas are areas of timber-land that are temporarily without forest cover. In 2012 the area of this category amounts 0.4 % of the whole forest area. Unstocked forest land includes forest tracks, forest aisles over 5 m wide, landings, non-commercial forest-tree nurseries belonging to the forest, seed and plant nurseries, food plots and meadows, yard and building areas used for forestry purposes, recreational facilities linked to the forest as well as rocks, boulders, gravel and water located in the forest. Swamps and moors located in the forest are also considered unstocked forest land provided that they are not overgrown. The unstocked forest land covers 3.2 % of the total forest area (Table 21.2).

21.2.1.3 Forest Classifications by Ownership Categories

The official forest statistics include the following ownership categories (Table 21.3):

- state forest (national property)
- state forest (Land property)
- communal forest:
  - municipal forest
  - church forest assigned to communal forest
  - community forest assigned to communal forest
  - cooperative forest assigned to communal forest

Table 21.2 Classification of forests and their area including not accessible forest (NFI 2012)

Classification of forest	Area (1000 ha)	Area (%)
Stocked timber-land	11,012	96.4
Temporarily unstocked land	41	0.4
Unstocked forest land	365	3.2
Forest	11,419	100

Table 21.3 Forest area including not accessible forest according to the national forest definition by ownership categories (NFI 2012)

Ownership category	Area (1000 ha)	Area (%)
State forest (national property)	404	3.6
State forest (land property)	3310	29.0
Communal forest	2220	19.4
Private forest + Treuhand forest	5486	48.0
Forest	11,419	100

  - communal forest under exclusive ownership or under exclusive sponsorship of the Land government
  - communal forest under ownership or under exclusive sponsorship of the national government.

- private forest:
  - private forest (in the narrower sense)
  - church forest assigned to private forest
  - community forest assigned to private forest
  - cooperative forest assigned to private forest
  - private forest under exclusive ownership or under exclusive sponsorship of the Land government
  - Private forest under exclusive ownership or under exclusive sponsorship of the national government
- forest under Treuhandanstalt administration (Treuhand forest).

The use of the subclasses (for instance municipal forests) is optional. This is determined uniformly for each German Land.

In Germany the distribution of forest land ownership is very heterogeneous and forced by historical developments. For example in North Rhine-Westphalia the private forest has a proportion of 67 %, in the neighbouring Rhineland-Palatinate it is only 26 %. Those lands with a high rate of forests in state ownership include Mecklenburg-Western Pomerania and Saarland with more than 40 %. The lowest rate of state forests is counted in North Rhine-Westphalia. The highest rate of communal forest was assessed in Baden-Württemberg, the lowest proportion was estimated in Brandenburg.

21.2.1.4 Classification by Legal and Other Restrictions for Wood Use

Restrictions on use exist if the potential timber use cannot be realised. This includes restrictions on the use of timber both due to legal regulations or other external reasons and internal reasons like fragmented ownership, terrain features etc. Restrictions on use are classified into four classes (Table 21.4):

Table 21.4 Accessible forest area according to the national forest definition by ownership categories (NFI 2012)

Restriction of use	Area (1000 ha)	Area (%)
1/3 of usual harvest is to be expected	204	1.9
2/3 of usual harvest is to be expected	285	2.6
Forest utilisation not allowed or not to be expected	450	4.1
No restrictions of forest utilisation	9948	91.4
With or without usage restriction	10,888	100

- no restriction on the use of timber
- use of timber not authorised or not to be expected
- approx. 1/3 of the usual harvest to be expected
- approx. 2/3 of the usual harvest to be expected.

On more than 500,000 ha external reasons are responsible for the reduced expectation of wood use. Forests amounting to 360,000 ha are protected for nature conservation. Approximately 76,000 ha have restrictions in utilisation due to protective reasons (i.e. water recreation) and 22,000 ha are protected for recreational reasons. The remaining 45,000 ha have other restrictions which are not explicitly described.

Internal reasons for restrictions in utilisation of wood was assessed on 611,000 ha with more than one third due to terrain features and nearly one fifth by own initiative of the owners. Overall, 8.6 % of the whole forest area had restrictions on wood use. Forest utilisation is not allowed or is not to be expected on 4.1 % of the total forest area.

21.2.1.5 Other Classifications

Many other classification attributes are incorporated into the NFI, such as: accessibility, management type and timber harvesting conditions. All classifications that group the whole plot into one of the classes are referred to as real classifications. A very detailed database of NFI results is available in BMEL (2014).

In addition, the forest area by tree species-groups and age classes are not derived by plot or proportions of plots but are calculated using the area per single tree. Therefore, tree species group dependent regression functions are used. Afterwards each single tree area will be modified proportionally in a way that the sum of area of all trees which belongs to the main stand or plenter forest/selection forest (high forest in which trees of different ages and different dimensions are mixed in small aggregations and over a long period of time) meets 10,000 m^2 or 1 ha respectively. All these classifications based on such modified areas per tree are called calculated pure stand classifications (Table 21.5).

The NFI 2012 results show that more than 76 % of forests are mixed forests. More than 2.2 million ha are stocked with mixed coniferous and deciduous tree

Table 21.5 Accessible forest area according to the national definition by species and species groups (NFI 2012)

Species and species groups	Area (1000 ha)	Area (%)
Oak spp. (*Quercus* spp.)	1130	10.4
Beech (*Fagus sylvatica*)	1680	15.4
Other deciduous trees with long life expectancy	770	7.1
Other deciduous trees with short life expectancy	1148	10.5
Spruce (*Picea spp incl. all other coniferous tree species*)	2763	25.4
Fir (*Abies* spp.)	183	1.7
Douglas fir (*Pseudotsuga menziesii*)	218	2.0
Pine (*Pinus* spp.)	2430	22.3
Larch (*Larix* spp.)	307	2.8
Temporarily unstocked area	40	0.4
Total forest (calculated pure stand)	10,888	100.0

Table 21.6 Accessible forest area according to the national definition by age-classes (NFI 2012)

Age class (years)	Area (1000 ha)	Area (%)
1–20	1067	9.8
21–40	1631	15.0
41–60	2228	20.5
61–80	1711	15.7
81–100	1389	12.8
101–120	1089	10.0
121–140	693	6.4
141–160	469	4.3
>160	350	3.2
Missing	260	2.4
Total forest (calculated pure stand)	10,888	100.0

species. More than one third of the trees are between 41 and 80 years (Table 21.6). One reason for this unbalanced age class distributions is due to the replanting after the Second World War. Overall, German forests are becoming older. The area of age classes greater than 100 years grew by 0.8 % per class at minimum since 2002. Also the area of trees older than 160 years was increasing in the last decade by 1 %. Contrastingly the area of the both youngest age classes decrease by more than 2 % each.

21.2.2 *Wood Resources and Their Use*

21.2.2.1 Standing Stock, Increment and Drain

All results of standing stock, increment and drain are estimated from the selected trees within the angle count sampling with basal area factor 4 from one time point (standing stock) or from two consecutive assessments (increment and drain). The volume of standing stock, increment, and drain are presented in Table 21.7. The increment and drain data are average annual values for the period 2002–2012.

Standing timber stock includes every living tree and every tree that probably died less than 12 months ago with a dbh of 7 cm or more and consists of all aboveground parts of the stem including the stump, the bole with bark and all parts of branches greater than 7.0 cm according to the German NFI definition. For trees with a dbh < 7 cm no volume is estimated.

In addition, the standing harvestable volume under bark is calculated and does not include stump, bark, rotten parts and dead or sawn branches. Overall, the standing harvestable volume under bark amounts round about 76.5 % of the standing timber stock. The relationship of standing timber stock and standing harvestable volume under bark depends on the following parameters: tree species group, dbh, d_{03} and tree height.

The annual increment per hectare is estimated to be 11.23 m^3 for the stocked timber-land. Taking into account only the trees of the main stand or plenter forests, the calculated pure stand annual increment per hectare is 10.85 m^3. The highest calculated annual pure stand increment per hectare is assessed for spruce area, fir

Table 21.7 The volume of standing stock, increment, and drain on accessible forest land (NFI 2012)

Tree species and species group	Standing stock (m^3/ha)	Standing stock (1000 m^3)	Increment (1000 m^3/year)	Drain (1000 m^3/year)
Oak	33	361,231	9353	5144
Beech	58	635,258	18,293	13,958
Other deciduous trees with long life expectancy	19	204,369	6596	3061
Other deciduous trees with short life expectancy	20	219,712	7283	5497
All deciduous trees	130	1,420,570	41,526	27,660
Spruce	111	1,206,199	45,671	52,505
Fir	9	93,434	2997	2116
Douglas fir	7	72,731	3864	1646
Pine	71	767,814	24,180	20,006
Larch	9	102,224	3365	2408
All coniferous trees	206	2,242,402	80,076	78,681
All tree species	336	3,662,972	121,602	106,341

area and Douglas fir area with 15.3, 16.3 and 18.9 m^3, respectively. The smallest annual increment is estimated with 6.4 m^3 per hectar for the area of other deciduous trees with short life expectancy, i.e. birch, *Salix* spp. and so on.

21.2.2.2 Tree Species and Their Commercial Use

The German official harvested wood statistics, the so called "Holzeinschlagsstatistik" provides estimates for four wood species groups (Seintsch 2010):

- spruce, fir, douglas fir and other coniferous wood
- pine and larch
- oak
- beech and other deciduous woodland

In 2012, approximately 50 % of the harvested wood comes from tree species group spruce (www.destatis.de). The logging rate has increased in the years 2002 to 2006 up to 55 % (Seintsch 2010), mainly in smaller diameter and age classes. Round wood accounted for 68, 16 % as industrial wood, and 12 % as energy wood. Nearly 25 % of harvested wood belongs to the species-group pine, which was used mainly as round wood (47 %) and industrial wood (37 %). The species-groups beech (23 % of total wood supply) and oak (4 % of total wood supply) had the highest proportion of use for energy purposes with 36 and 34 % respectively followed by industrial wood and round wood.

21.3 Assessment of Wood Resources

21.3.1 Forests Available for Wood Supply

Within the German NFI the non-availability will be assessed as opposed to the availability of wood for supply. The non-availability for wood supply is defined by restrictions caused by external or internal reasons. Restrictions caused by internal reasons include those ones due to the use of timber both due to legal regulations. Restrictions on use exist if the possible uses of timber cannot be realised. The reason for such restrictions is indicated as external, internal or both reasons.

External reasons for the restriction on use

- no external restrictions on use
- nature conservation
- protection forest
- recreational forest
- other external reasons.

Where there are several external reasons, the most important reason is selected.

Internal reasons for the restrictions on use

- no internal restrictions on use
- fragmented ownership of uneconomic size (e.g. if the system of land tenure provided for the equal division of land among all qualified heirs)
- stand-alone location
- insufficient accessibility
- site characteristics, wet location
- little expected yield (mean total increment <1 m^3/ha/yr)
- areas protected at owner's discretion (e.g. natural forest reserves)
- other internal reasons

In case of several internal reasons, the most important one is indicated.

21.3.2 Wood Quality

Within the German NFI no assessment of stem quality or timber assortments is conducted.

21.3.3 Assessment of Change

Change estimations are calculated using NFI data assessed consecutively on permanent plots.

Survivor trees
The increment of survivor trees is the difference of the modelled volume between t_2 and t_1. This increment divided by the plot-wise count of years between two consecutive assessments results in the increment per year. The representation factor per hectare is taken from the end of the inventory period.

New trees in ACS (ingrowth, ongrowth and nongrowth trees) on forest remaining forest
For the new trees in the ACS sample only the volume at the end of the period is known. The volume at the beginning of the period is modelled using the same volume model. Therefore the dbh, height and d_{03} at the beginning of the period are modelled by growth functions. Afterwards the difference of both values is calculated as increment; divided by the plot-wise count of years between two consecutive assessments results in the increment per year. The representation factor per hectare is taken from the end of the inventory period.

Increment of drained trees from the ACS on forest remaining forest
For trees, which could be assessed only at the beginning of the period, the dbh, height and d_{03} will be modelled by growth functions up to the mid-point of the period. Then the difference is calculated as increment. The number of trees per hectare from the beginning of the period acts as representation factor per hectare.

New trees in ACS on other land converted to forest land
All new forest plots are assumed to grow into the population in the middle of the period. Thus, the parameters required to estimate the volume for each single tree are modelled back to the half of the inventory period. For trees, which are younger as the half of the inventory period the volume is 0. The representation factor per hectare is taken from the end of the inventory period.

Increment of trees from the ACS on forest converted to other land
For all forest plots that are converted to other land uses the conversion date is set by definition to the middle of the inventory period. All tree parameters are estimated using the same method as was used for drain on those plots that remained as forest.

Drain
The volume of drain is defined as the sum of the volume from the beginning of the inventory period plus the increment up to the half of the inventory period for those trees removed from the ACS on forest remaining forest and forest converted to other land use. To calculate the per hectare representation the basal area factor from the beginning of the period is used.

21.3.4 Other Wooded Land and Trees Outside Forests

Within the German NFI no assessment of “Other wooded land” and “Trees outside forest” is conducted.

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Chapter 22
Greece

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22.1 The Greek National Forest Inventory

22.1.1 History and Objectives

The first forest inventory conducted in Greece was in 1836. Although it was not based on scientific or statistical methods, results were published in 1842 by the consul of Bavaria and Hannover. The area of the entire country at that time was only one third of today's total area (Kontos 1921). Kontos (1929) also published the results of the inventory of 1842 but did not provide any information about the methods used.

The first National Forest Inventory (NFI) in Greece was initiated in 1963 and covered 11,377,000 ha or 86.2 % of the entire country (Ministry of Agriculture 1992). The uncovered areas were primarily agricultural lands which amounted to 1,819,000 ha or 13.8 % of the country area. This inventory was conducted as a joint project between the Hellenic Forest Service and the Food and Agriculture Organization of the United Nations (FAO).

In 1992, the entire NFI was completed, and the results were reported in a handbook titled "Results of the First National Forest Inventory" (in Greek). The results of this inventory indicated that the area occupied by forests was about 19 % of the country with approximately half of the country covered by forest and other wooded land. A characteristic feature of these forests is the uneven-aged structure of the stands with trees belonging to all diameter classes.

After Greece entered the European Union, the main objective for establishing the Greek NFI was to define and report on common forest definitions. The Greek NFI would facilitate scientific research and create results that would be comparable at European level.

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22.1.2 Sampling Methods

Although inventories were conducted in 1836, 1929 and in 1992, only the last one was based on scientific methods, while the rest are only of historic interest.

The source data for the first phase of the inventory was panchromatic black and white aerial photograph at scales of 1:30,000 (mainly), 1:20,000 and 1:42,000 from different years. In each aerial photograph, 25 photo-plots were selected, measured and classified according to their land use, forest types, canopy closure, tree height, slope, and degree of soil erosion. The field plots were located using the azimuth and the distance from characteristic points on the aerial photographs that were easy to recognise. Photo interpretation of 95,220 photo-plots was used as the basis for the stratification into three strata; non-forest, forest without volume and forest with volume. A random process was used to select 2744 field plots from among the photo-plots. In each region the ratio of field plots to photo-plots in each stratum was as follows: 1:35 for the non-forest stratum, 1:50 for the forest without volume stratum, and 1:15 for the forest with volume stratum. The interpretation of a random sample of photo plots was verified in the field. For each field plot, ten trees were measured using a systematic orientation scheme: point No. 1 was 10 m south of the centre of the field plot, and the remaining nine points were determined according to the first point. These ten sample points were separated by a distance of 20 m and covered an area of 0.5 ha. Trees were selected on each sample point using a metric angle corresponding to 10 m^2/ha. For each tree, the measured variables were basal area, diameter at breast height, total height, merchantable height, non-merchantable height, Pressler's height, radial increment and bark thickness. Also, the tree species were identified, and the tree quality, degree of damage, and percentage of the healthy merchantable volume were estimated.

22.1.3 Data Collection

The Greek NFI assesses three main categories of variables: stand, site and sample tree.

The stand data content in broad categories are:

- Administrative data: owner group, restrictions for forestry, etc.
- Site description: land use class (both national and FAO definitions), main forest type, site productivity class, soil type, soil texture, etc.
- Growing stock: crown storey, species composition, crown cover, development class, age, mean height, tree damage, etc.
- Accomplished and Proposed Management Measures: accomplished and proposed cuttings silvicultural measures, soil scarification, draining, etc.

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

- Growth classes
- Age classes
- Share of tree species in age classes
- Dominant height of even-aged conifer stands
- Forest structure: crown coverage, stand structure, development stage, coverage of shrubs in stands
- Stand stability: damages, required tending activities, factors that influence game
- Actual woodland community
- Natural woodland community
- Regeneration
- Stand layers and their coverage
- Occurrence and abundance of woody plant species with attribution to stand layers
- Deadwood.

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

- Elevation above sea level
- Aspect
- Slope gradient
- Relief
- Local climate situation
- Vegetation type
- Soil moisture
- Soil layer thickness
- Soil group
- Humus layer thickness
- Humus type
- Soil group.

The tree data is recorded on three categories of trees:

- standing tree data: diameter, species, quality class, crown class.
- sampled tree data: height, diameter at 6 m height, age, diameter increment, height increment, thickness of bark, etc.
- dead tree data, only on permanent plots.

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

- Species
- Diameter at breast height
- Tree height
- Height to the living crown base
- Crown radius and type of crown base
- Stem quality

- Reserved tree and trees with advanced growth
- Dead standing tree
- Forked tree
- Growth class
- Age class
- Tree class
- Crown class
- Stem damage
- Proposed removal in required tending activities
- Distorted trees.

22.1.4 Data Processing, Reporting and Use of Results

Areas were estimated by counting plots within strata from the total network of photo-plots on 1:50,000 maps using the following equation:

$$Area(\text{ha}) = Ai = A\sum\frac{M}{Mi} \tag{22.1}$$

where

Mi is the number of photo-plots in the survey area by stratum (Ai)
M is the number of photo-plots in the survey area and A the total land area.

Volumes were estimated using the general volume formula,

$$V = \sum\frac{U \times \pi \times (0.5 \times dbh)^2}{\pi \times R^2 \times N} \times H \times F \times A \tag{22.2}$$

where

U is the area of the land unit (m^2)
$\pi = 3.14$
dbh is the diameter at breast height (m)
H is the tree height (m)
F is the form factor for the tree
R is the maximum distance from the point to the tree (m)
N is total number of field plots in the area surveyed.

Based on the general formula, the following variables were estimated: net volume per hectare including branches, net volume per hectare of the main stem inside bark, net volume per hectare of merchantable stem and net volume per hectare of sawn timber volume.

The NFI data consists of two main categories: stand description and measured tree data. Stand description variables describe the forest stand where the field plot is located. If a field plot is divided into several stands, all stands are described. For tree measurements, the sample plot has a maximum radius of 12.65 m. which always gives us a surface of almost 500 m^2 ($\pi r^2 = 3.14 \times 12.65^2 = 502.5$ m^2) (Dafis 1990).

The results of the first NFI in 1992 have been taken into account in formulating forest and environmental policy, forest management, and for evaluating the consequences of the decisions taken.

Reporting processes include: the Forest Resources Assessment (FRA) of the Food and Agriculture of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 of the Kyoto Protocol, the indicators and criteria for sustainable forest management for FOREST EUROPE (Ministry of Agriculture 2000; FOREST EUROPE, UNECE and FAO 2011), and on the conservation status of natural habitat types under the Habitats Directive (Council of the European Communities 1992).

22.2 Land Use and Forest Resources

22.2.1 Classification of Land and Forests

22.2.1.1 General Land Classification

In 1992, when the entire NFI was completed, the results of this inventory indicated that the area occupied by forests was approximately 19 % of the country with approximately half of the country covered by forest and other wooded land (Table 22.1) (Meliadis et al. 2009). Land use is divided in eight categories.

Table 22.1 Land use classes according to the national definition by area (NFI 1992)

Class name	Area (1000 ha)	Area (%)
Forest land	2512	19.0
Partially forest	3200	4.6
Phryganic land	277	2.1
Alpine areas	440	3.3
Grasslands	1756	13.3
Water (ponds, swamp)	273	2.1
Barren land	734	5.6
Agricultural land	3964	30.0
Total	13,156	100.0

In Greece forest land is defined as:

1. Land with 10 % crown cover with minimum height of trees of 5 m at maturity (in situ); areas of approximately 0.5 ha or strips with widths of 30 m (with tree canopy cover of 10 %); areas not used for any purpose other than production of wood
2. Areas from which the trees were harvested
3. Reforested areas
4. Maquis shrubland.

Other wooded land is defined as:

Land which has some forest characteristics but is not forest as defined above. It includes open woodland and shrub, shrub and brushland, whether or not used for pasture or range.

22.2.1.2 Forest Classifications by Use

The land classification system used in the Greek NFI follows a system of land management types (Table 22.2). At the highest level the land area is divided into forest and non-forest by applying the national forest definition.

22.2.1.3 Classification by Ownership Categories

In the national land use classification system, forest land includes productive forest land, forest land used for recreation, protective forest land (i.e. slopes over 50 %) and multifunctional forest land. Most forest land belongs to the state (Table 22.3) (Meliadis et al. 2009), contrary to the situation today in most of the other European Union countries.

Table 22.2 Classes within forest land and their areas according to the NFI (1992)

Class name	Area (1000 ha)	Description
Productive forest		Forests available for wood supply, and with yield
– High forest	872	
– Coppice forest	1206	
– Coppice forest with standards	434	
Total productive forest lands	2512	
Protective forest		Forest and other forest lands that are managed mainly for soil protection
– Forests and other wooded lands	6513	

Table 22.3 Forest area according to the national forest definition by ownership categories (NFI 1992)

Ownership	Area (1000 ha)	Area (%)
State	1643	65.5
Community	302	12.0
Monastery	110	4.4
Charity institution	11	0.4
Co-operative	246	9.7
Private	200	8
Total	2512	100

22.2.1.4 Forest Management and Cutting Systems

The main silvicultural systems used are:

- Coppice system (Oak (*Quercus* spp.), Chestnut (*Castanea sativa*))
- Shelterwood successive cutting system
- Edge shelterwood cuttings in strips
- Selective cuttings in groups and gaps
- Selective cuttings of single trees in all age classes of the forests.

More specifically, Greek forests consist of a large percentage of even-aged stands which are managed in the following manner:

- Establishment stage: Establishment with natural regeneration, sowing or planting, according to soil type and owners decision
- Seedling Stage: Early tending for seedling stand, no harvesting
- Sampling stage: Thinning of a seedling stand, no harvesting
- Stem stage: Two thinnings during the rotation
- Final cutting stage: Shelterwood or coppice felling to encourage regeneration.

The exact timing of these operations depend on the development stage of the tree species (Table 22.4). For example, Shade trees (Beech, Fir, Spruce) reach the Seedling stage up to 10 years, Sampling stage 10–20 years, Stem stage 20–30 years (40) while the Light trees (Pines and Oaks) reach the Pole stage at 15–20 years (Dafis 1990).

Table 22.4 Age phases and development stages according to dbh (Dafis 1990)

Age phase	Development stages	dbh (cm)
Young	Seedlings	<4
	Samplings	4–8
	Thin poles	8–10
Full growth	Thin poles	11–20
	Thick stems	21–30
Mature	Medium stems	31–50
Mature or early old growth	Thick stems	>51

22.2.1.5 Legal and Other Restrictions for Wood Use

The main body for protecting and managing the country's state forest as well as for supervising and keeping under control the private forest is the Forest Service. This body operates under the name General Secretariat of Forest and Natural Environment (GSF & NE) and constitutes an integral part of the Ministry. Also, within the framework of GSF & NE there are other institutions such as the Revisional Council for the Property of Forest, the Forest Technical Councils, the Forest Property Council and the Regional Councils and Committees (Law 300/1981). The legal restrictions impact on timber supply are summarised in Table 22.5.

Legal restrictions are designated for the following five reasons:

1. Protected areas
   Forest operations are not allowed on areas protected for biodiversity conservation. These include nature reserves, national parks and specific protection areas (such as areas for protection of herb rich forests, old growth forests, shore, etc.). In a small number of protected areas low impact management operations are permitted. Land use planning at country and municipal level may contain further restrictions. Borders of official protection areas are available in GIS database and can be taken into account in estimating statistics e.g. cutting possibilities.
2. Recreation areas
   Areas reserved for recreation including areas established by the owners decision (state forests) or land use planning at municipal or country level. These areas are managed primarily for recreation values and forestry operations must be planned accordingly. In most cases forestry is not profitable in these areas, with the aim of operations to maintain recreation values.
3. Protected biotopes, key habitats
   The forest act defines a number of biotopes that may not be managed or can be managed sensitively so that the natural elements are not endangered. These biotopes are identified if they occur in NFI plots and are identified using National, European Legislation and Natura 2000 designations.
4. Other restricted areas (e.g. monastic, military)
   This category includes military areas and other forests of specific use e.g. gene reserves or research forests.

Table 22.5 Relevance of law restrictions in Greece

Category	Relevance	Comment
Legal restrictions protected for biodiversity	Highly relevant	Forestry operations mostly not allowed
Legal restrictions protected habitats	Highly relevant	Forestry operations not allowed or restricted
Legal restrictions recreation areas	Relevant	Forestry operations restricted
Legal restrictions protective functions	Relevant	Forestry operations restricted
Legal restrictions other restricted areas	Relevant	Forestry operations restricted or not allowed

5. Environmental and biodiversity conservation.
6. Protection of water resources causes limitations to forestry operations near settlement. Most of these areas are in a GIS database and can be identified in the NFI plots. Protection of forests in the high altitudes causes limitations to forestry in Greece.

Management (silviculture) and harvesting technology restrictions and logging costs also impact of the availability of wood. Due to the morphology of most of the mountainous areas, where steep slopes exist harvesting machines cannot be used. Regardless of the severity of the slope, the harvesting is conducted using mules, except in the case of plantations. The location of forests (distance from roads) is taken into account only via average hauling costs.

22.2.1.6 Further Classification of Forests

The further classification of forests in national statistics is usually by main soil type (mineral or peatland), site productivity class, dominant species, development class or age class (Table 22.6).

Table 22.6 Productive forest area according to the national definition by species (NFI 1992)

Tree species	Area (1000 ha)	Area (%)
A. Conifers		
Fir (*Abies borisii regis* & *Abies chephalonica*)	543.3	16.17
Aleppo pine (*Pinus halepensis*) and Calabrian pine (*Pinus brutia*)	567.7	16.9
Austrian pine (*Pinus nigra*)	281.7	8.39
Scots pine (*Pinus sylvestris*)	21	0.62
Bosnian pine (*Pinus leucodermis*)	8.3	0.25
Stone pine (*Pinus pinea*)	0.1	0.003
Norway spruce (*Picea abies*)	2.8	0.08
Other conifers	5.2	0.15
Conifer total	1430.1	42.57
B. Broadleaves		
Beech (*Fagus* sp.)	336.6	10.02
Sweet chestnut (*Castanea sativa*)	33.1	0.99
Oak (*Quercus humilis*)	1471.8	43.82
Oriental plane (*Platanus orientalis*)	86.6	2.58
Other broadleaves	0.8	0.02
Total broadleaves	1928.9	57.43
Total productive forest land	3359	100

22.2.2 *Wood Resources and Their Use*

22.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock, increment and drain are based on the sample tree measurements on the plots. They are calculated as volume of stemwood overbark. Stemwood according to the Greek NFI includes all stem parts above the stump. The minimum dbh is 5.0 cm measured over bark (Table 22.7). Trees below this threshold are not included. Due to the lack of periodical NFIs, increment and drain are only available in management studies for specific forest areas which are repeated every ten years. The volume of standing stock and increment, on productive forest land of the main forest species is presented in Table 22.8.

Table 22.7 Definitions for volume of standing stock, increment and drain

Variable	Definition
Standing stock	Volume of trees with dbh ≥ 5.0 cm over bark, including the bole (wood and bark), and stem top, and excluding the above-ground part of the stump
Increment	Volume increment of surviving trees with dbh ≥ 5.0 cm over bark plus the volume of ingrown trees into the small circular plot between two consecutive NFIs
Drain	Volume of living trees with dbh ≥ 5.0 cm over bark at the first measurement that were found to be harvested in the subsequent NFI

Table 22.8 The volume of standing stock and increment, on productive forest land of the main forest species (NFI 1992)

Tree species	Standing stock (overbark volume 1000 m^3)	Net annual increment (overbark volume 1000 m^3)
Conifers		
Fir	47,406	798
Aleppo Pine	14,986	1090
Black Pine	15,269	
Scotch Pine	2574	
Broadleaves		
Beech	30,437	931
Oak	26,537	695
Total	137,209	3514

22.2.2.2 Tree Species and Their Commercial Use

The main tree species are Aleppo pine and Calabrian pine, Oak and Beech. The main use of conifers is for round or structural wood and fuel wood, while the broadleaves are used for firewood (Oak and beech), round wood (Beech and Sweet chestnut) (Tables 22.9 and 22.10). The annual increment estimates are based on field measurements. The quantity of industrial volume in the Greek forest estate is presented in Table 22.11.

The categories of industrial wood are described as follows:

- Merchantable volume: Net volume of trees with dbh > 5 cm, between the stump height and the point where the stem top is 5 cm or the point where there is distortion
- Saw timber volume: Net volume of trees with dbh > 30 cm, between the stump height and the point where the top is 20 cm or the point where there is a distortion

Table 22.9 Total forest growing stock per hectare of all the forest species

Species group	Growing stock (overbark volume 1000 m^3)	Area (1000 ha)	Growing stock/ha (volume m^3/ha)
Conifers	85,012	1430	59.4
Broadleaves	66,776	1929	34.6
Total	151,788	3,359	94.0

Table 22.10 Growing stock increment of all forests

	Annual increment (volume 1000 m^3)	Increment percentage of stock (%)	Annual increment per hectare (m^3/ha)
Conifers	1918	2.26	1.34
Broadleaves	1895	2.84	0.98
Total	3813	5.11	2.32

Table 22.11 Quantity of industrial forest volume based (NFI 1992; Meliadis et al. 2009)

Industrial volume category	Volume estimate (million m^3)
Total volume of industrial forests	152
Merchantable volume	138
Sawn timber volume	139
Stem top volume	14
Desirable trees	60
Acceptable trees	59
Poor trees	21
Rejected trees	12

- Stem top volume: Net volume of trees with dbh > 5 cm between the top of the merchantable wood and the upper edge of the tree
- Desirable trees: Trees with merchantable value; trees that adapt well to a forest environment; trees that have no distortion or other damages, good shape and health
- Acceptable trees: Trees with merchantable value; trees that adapt well to a forest environment; trees whose merchantable wood has not been distorted more than 50 %, and have quite good shape and health
- Poor trees: Trees with less merchantable value; whose merchantable wood has been distorted more than 50 %
- Rejected trees: Trees with no merchantable value.

22.3 Assessment of Wood Resources

22.3.1 Forest Available for Wood Supply

22.3.1.1 Assessment of Restrictions

With regard to other restrictions and in particular to harvesting possibilities the Greek NFI assesses several relevant variables. The slope is decisive for the use of harvesting. In cases where there are steep slopes, harvesting machines cannot be used. On steep slopes, the harvesting is completed using lumberjacks and mules for transport. Another crucial factor is the distance to the nearest forest road. In field assessments the distance to the next skidding road and the distance to the nearest forest road were assessed for sample plot locations. These assessments are complemented by the analysis of aerial photographs and the determination of the shortest distance to the nearest forest road.

22.3.1.2 Estimations

The legal restrictions associated with nature protection and conservation were taken into account by excluding areas where harvest is prohibited such as national parks, and Natura 2000 areas where harvesting is limited.

NFI plots can be classified into one of three categories which is specified in the management plan, forests without any restrictions for resource use such as industrial forests, forests where cuttings are not allowed and forests where cuttings are partly limited.

22.3.2 *Wood Quality*

22.3.2.1 Stem Quality and Assortments

The quality of the stem is evaluated in different ways according to the local economical factors and the specifications for each tree species. In Greece three stem quality categories are used; valuable, normal and faulty. These categories are based on quality standards and wood defects which are relevant and can be incorporated in the following groups:

- Quality traits of the stem form
- Quality traits of the wood quality.

These quality traits describe “good quality wood” and include the following:

- Health, meaning the absence of the damages caused by fungus and insects
- Lack of knot
- Lack of cracks
- Rings of the same thickness
- Straightness of line wood fibers
- Presence of well formed heart or complete lack according to the silvicultural species.

22.3.2.2 Assessments and Measurements

The same quality classes are used for conifers and broadleaves. In Greece three categories of classification are used (Table 22.12).

Table 22.12 Stem quality classes as assessed by the Greek NFI

Stem quality class	Description
Valuable wood	At least 50 % of stem wood at maturity is valuable wood according to the quality standards and belongs to the IUFRO category a and aa[a]
Normal wood	At least 50 % of stem wood responds to the normal standards and belongs to the IUFRO category η[a]
Faulty wood	Less than 50 % of stem wood responds to the normal standards and belongs to the IUFRO category f[a]

[a]Leibundgut (1959), Matthews (1989) and Dafis (1990)

22.3.2.3 Estimation and Models

The volume of an individual tree is calculated using species specific volume tables:

- Black pine

$$V_\alpha = 3.9172327 \times 10^{-5} \cdot d^{1.884915} \cdot h^{1.043285} \tag{22.3}$$

$$V_\varepsilon = 0.0217237 + 1.177424 \cdot V_\alpha \tag{22.4}$$

- Oak

$$V_\alpha = 2.5182532 \times 10^{-5} \cdot d^{1.968549} \cdot h^{1.12419} \tag{22.5}$$

$$V_\varepsilon = 0.01631057 + 1.134771 \cdot V_\alpha \tag{22.6}$$

- Calabrian pine

$$V_\alpha = 3.3041044 \times 10^{-5} \cdot d^{1.790332} \cdot h^{1.181907} \tag{22.7}$$

$$V_\varepsilon = 0.01969779 + 1.195396 \cdot V_\alpha \tag{22.8}$$

where

V_α is volume without bark
V_ε is volume with bark
d is the diameter at breast height
h is height.

22.3.3 *Assessment of Change*

22.3.3.1 Estimation of Increment

Increment was estimated using the general growth formula

$$G = \sum \frac{(H \times F \times A)}{N} \times Pv \tag{22.9}$$

where

G is volume of annual increment for the survey area (m^3)
H is the tree height (m)
F is the form factor for the tree
A is the total land area
N is total number of field plots in the area surveyed
Pv is the annual growth.

Error Estimation

The following errors are estimated for the calculations of forest area, industrial forests and growth:

- Total forest area: ±0.2 %
- Merchantable volume of industrial forests: ±2.6 %
- Growth of industrial forests: ±3.1 %.

22.3.4 Other Wooded Land and Trees Outside Forests

Land which has some forest characteristics but is not forest as defined above, includes open woodland and shrub, shrub and brushland, whether or not used for pasture or range. Other wooded land has very low productivity with tree resources having no economic importance and no forestry operations normally occur on other wooded land. It is estimated that OWL occupies 30 % (3,960,000 ha) of the total land area of Greece.

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Chapter 23
Hungary

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23.1 The National Forest Inventory

23.1.1 History and Objectives

Forest management planning, using a stand wise forest inventory, began in 1879. From this date a lot of progress has been made in developing a methodology for forest inventory. The basis of the current stand-wise inventory (SWI) was initiated in 1970 and the basic methodology of SWI remains unchanged. Forest management plans based for the SWI are prepared in 10 year cycles. Nowadays the planning and regulatory activities are coordinated by the Forest Directorate of the National Food-chain Safety Office (successor of the former State Forest Service). The whole system is supported by a web-based computer system (named ESZIR in Hungarian), complete with mapping tools.

In Hungary a systematic inventory began in 1993 with the Growth Monitoring System (GMS). A 2.8 × 2.8 km grid was used and the survey was accomplished on a five year cycle. This survey was closely related to the SWI including scope and definition applied and basic inventory parameters (surveyed species, age, origin and social status all the trees height and max-min DBH) were assessed or measured.

Based on experiences gained during the previous 15 years while working on the GMS and the results of the COST-E43 co-operation, a new harmonised National Forest Inventory (NFI) was developed and launched in 2010 with a cycle of

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5 years. The aim of the NFI is to survey the forest ecosystem with a special focus on forest resource assessment and the requirement to satisfy information needs on the resources of Hungarian forests.

23.1.2 Sampling Methods and Periodicity

The NFI is based on a systematic 4 × 4 km grid, with a 200 × 200 m square cluster of 4 plots position in the south-west corner of each grid intersection (Fig. 23.1). Each point has a 500 m^2 sampling area with three concentric circles (3; 7; 12.62 m).

Before field work, all the grid plots are classified into two groups based on aerial or satellite photo interpretation: field plots and non-field plots. A plot belongs to the field plot group if it meets the FAO definition of forest or OWL. If there is any uncertainty during the classification process, then the plot will be visited in the field. The other plots are not visited in the field, and as a result there is no information on land use categories for the entire national land area using the NFI.

Over the 5 year period one cluster represents 4 × 4 km = 16 km^2. Each year 20 % of the plots are measured on a regular subset, representing 80 km^2. Due to the grid design the plots assessed annually represent the whole country.

Due to the concentric plot design, if the plot centre is close to the forest boundary but inside the forest the plot is shifted into the forest if possible. On the other side if the plot centre is close to the forest-border but outside the plot will be considered non-forest, even though part of the circle is within the forest. This is ultimately determined in the field using the exact GPS measurement to find the plot centre.

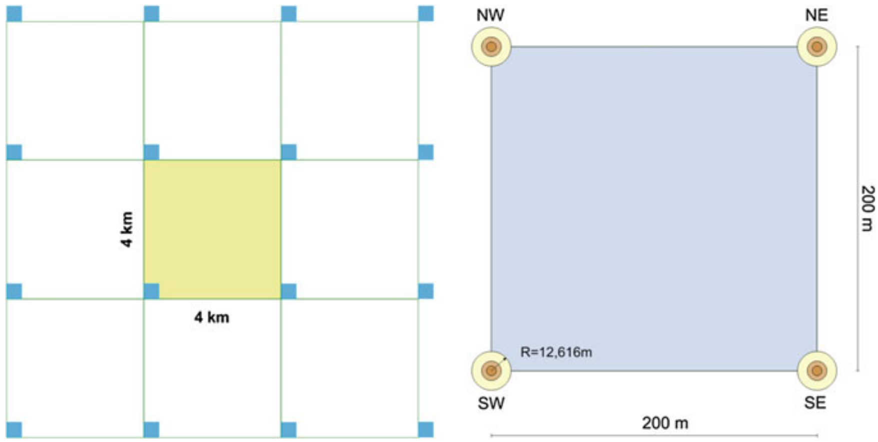

Fig. 23.1 NFI sampling grid and tract design, including plot position

The NFI survey is independent from the scope or result of the SWI. Most of the parameters (including forest area, other wooded land, growing stock, increment, etc.) are collected using the international (FAO/COST-E43) definitions. Adopting the FAO/COST-E43 definitions facilitates the international data submissions (i.e. FRA, EFDAC). Long term there is an opportunity to study the effect of climatic change with special regard to the health condition of the forest.

There is an opportunity to compare data with the SWI results, which acts as a good control for both systems. In the NFI all plots situated within the SWI areas are identified, which facilitates the comparison of SWI forest area and growing stock with the NFI data.

23.1.3 Data Collection

Due the differences in the methods of NFI and SWI, or the short time series of NFI data, there is only SWI data available for certain attributes. To avoid confusion over the data source in the statistics presented in this report, the data source will be stated.

As the data collection is supported by GIS software, there are geographical and descriptive parts of the NFI database. Forest region, county and community can be obtained directly through GIS analysis.

The centre of the plot, co-ordinates of the sampling tree (including living and dead trees), stump, deadwood (lying in the ground) are recorded as geographical information.

The descriptive data recorded in the plot includes the following:

- Administrative data: GPS co-ordinates, community, ID of compartment (if part of SWI), plot status, field worker, date of survey, etc.
- Site description: climatic region, hydrology, altitude, slope, aspect, soil description, potential forest type
- Stand description: forest type, storey, canopy closure and felling type
- Tree data: species, origin, age, social class, health status, diameter, height, crown-height, living status (living or dead), decay status (if dead tree)
- Small tree data: species, height class (0–50 cm; 51–200 cm; 201 cm), damage, average diameter
- Shrub data: species, coverage class, proportion of invasive shrubs (if any)
- Lying deadwood: tree group (broadleaves, conifers), 2 diameters, decay status, length
- Stump data: tree group, diameter, height, decay status
- Core data: Species, dbh, length of core. Generally 1 core per plot is taken, representing the dominant, average tree.

23.1.4 Data Processing, Reporting and Use of Results

As the SWI produced detailed geographical data at sub-compartment level there is an opportunity to obtain some information from SWI data where available. Therefore the NFI plots can be classified by the manager's and owner's data, forest function, or can be compared with the SWI data on plot level.

After finishing the third period of GMS in 2008 the State Forest Service introduced the Field-Map Technology (FM) for the field work and data checking. The collected data were analysed using the FM Inventory Analyst program. The steps of data processing are as follows:

1. Calculation of height curves and heights.

Height calculation: Generally the heights of 4–6 trees per species are measured in the field. Local (i.e. plot) and global height-functions are calculated using the data collected in the field. The modelled height data are used for all trees during data processing, even for those trees that were measured. Using this method the effects of measurement error are decreased.

2. Calculation of volume for sample trees.

Based on dbh and calculated height the volume is computed using a national volume function. This function is also applied in the forest management planning system (SWI).

3. Calculation of volume for sampling area.

The sample clusters were established on the 4 × 4 km grid, with four plots per cluster. Each plot represents 400 ha. In those cases where only one year's data is to be evaluated, the plots represent 2000 ha.

4. Summary for regions or country.

From the individual tree data, expansion factors were used to generate statistics at the plot level.

In recent years the NFI method is unchanged but the scope of attributes collected has expanded to include several new forest parameters:

- Since 2011 increment cores have been collected which makes it possible to study long term growth and its connection with several meteorological variables
- One stem diameter at 0.2 m height is recorded on each plot, to facilitate an evaluation of buttressing and the slenderness of trees
- Game damage based on the chewing of small trees (smaller than 1.3 m height or with a DBH of less than 7 cm). The small trees are counted in the smallest (r = 3 m) concentric circle
- The average defoliation on the sample trees is assessed to get a general overview about forest health condition
- It is envisaged that some parameters relating to wood quality will be introduced in the near future e.g. stem damage, shape, etc.

The results of the Hungarian NFI are used to support policy formulation, forestry professionals and the wider society. Additionally NFI data are used for several reporting obligations such as the Forest Resources Assessment (FRA) and State of Europe's Forests. Other uses include international projects such as EU JRC contracts. The Hungarian NFI system is a complex monitoring system that facilitates a wide range of analyses, such as the monitoring of growing condition, health status or game damage.

23.2 Land Use and Forest Resources

23.2.1 Classification of Land and Forests

23.2.1.1 General Land Classification

While there is an opportunity to assess land use categories during the NFI classification process, more detailed and precise data can be obtained from the Hungarian Statistical Office (HSO) based on the national land register (Table 23.1).

23.2.1.2 Forest Classification

In the NFI system the plots are classified according to the FAO/COST-E43 definitions. The only difference is in OWL, where 2 sub-classes were established. In the national survey we distinguish between the OWL1 with 5–10 % canopy cover by trees and the OWL2 where the tree cover is less than 5 %, but with the shrubs and trees together cover at least 10 %. Submitting OWL data we have to sum these two sub-categories. As the first period is not yet finished, the NFI data presented in this chapter is based on the 2010–2012 surveys.

If the plot centre is located in an unplanted strip wider than 6 m within the forest, it is not classified as forest. Inaccessible plots are definitively classified as forest

Table 23.1 Land use classes and forest area (2013)

Land category	Area (1000 ha)	Area (%)	Corresponding FRA classes (FAO 2004)
Forest land[a]	1933.6	20.8	Forest, intersection with OL and OLwTC
Agricultural land	5339.9	57.4	OL, OLwTC, OWL
Water area	102.4	1.1	Inland water bodies
Built-up area	1927.5	20.7	OL, OLwTC, OWL
Total	9303.4	100	

[a]The forest land area based on the SWI data

Table 23.2 Distribution of forest land and OWL according to the preliminary evaluation of the first NFI data (2010–12)

<table>
<tr><th colspan="3">Class name</th><th colspan="2">Area (1000 ha)</th></tr>
<tr><td rowspan="6">Forest land</td><td rowspan="2">Productive forest</td><td>Stocked</td><td>1052</td><td rowspan="2">1236</td></tr>
<tr><td>Temporarily unstocked</td><td>184</td></tr>
<tr><td rowspan="2">Protective forest</td><td>Stocked</td><td>627</td><td rowspan="2">700</td></tr>
<tr><td>Temporarily unstocked</td><td>73</td></tr>
<tr><td colspan="3">Without classification</td><td>228</td></tr>
<tr><td colspan="3">Total forest land area</td><td>2164</td></tr>
<tr><td rowspan="3">OWL</td><td colspan="3">Other wooded land 1</td><td>33</td></tr>
<tr><td colspan="3">Other wooded land 2</td><td>88</td></tr>
<tr><td colspan="3">Total other wooded land</td><td>121</td></tr>
</table>

from the air photos, but cannot be accessed in the field. The difference between the forest area estimated by NFI (Table 23.2) and SWI (Table 23.1) mainly arise due to differences in the forest definition.

23.2.1.3 Forest Classification by Ownership Categories

In Hungary two types of ownership are dominant: forest owned by the state (59 %) and by private people (36 %). Other categories include co-operatives (1 %) and other owners (4 %).

23.2.1.4 Forest Management and Cutting Systems

Cleaning, selective thinning and increment thinning account for approximately 24 % of the whole drain. The final cutting accounts for 72 % of the felling volume, which consists of 70 % clear cut and 30 % regeneration cutting. Nearly 2 % is sanitary cutting and the other 2 % other cutting types including selection cutting. It should be emphasized that recently the rate of selective cutting has increased considerably.

23.2.1.5 Legal and Other Restrictions for Wood Use

After the 1996 forest law, the Hungarian Parliament approved a new forest act in 2009. It is a very comprehensive and detailed regulation. The law covers the whole forestry sector and contributes to the conservation of natural resources in Hungary with many other laws and regulations.

In Hungary the most important restrictions on forest management are related to nature conservation. There is no forest management in the strictly protected conservation areas, and only limited management in the protected areas. An increase in close-to-nature management is a possible solution to the limitations imposed on forest management in these areas. In addition there are management restrictions in the protective forest areas.

23.2.1.6 Further Classification of Forests

Further classifications of forests in national statistics are usually by administrative region, climate region, site productivity class, dominant species, age-classes and ownership categories. Table 23.3 shows the area by dominant tree species and also gives general information about the differences in results originating from NFI and SWI. The SWI estimates for area are available from the National Forestry Data Base (NFDB). The main explanations for the differences are the disparate methods and the implementation of different definitions. The NFI statistics presented is from the preliminary evaluation of data collected from 2010 to 2012.

Table 23.3 Forest area (national definition) by dominant tree species (NFDB 2013 and NFI 2010–12)

Species	NFI		SWI	
	Area (1000 ha)	Area (%)	Area (1000 ha)	Area (%)
Oak incl. *Quercus cerris* (*Quercus* spp.)	511.3	23.6	595.2	30.8
Beech (*Fagus sylvatica*)	120.0	5.5	110.3	5.7
Hornbeam (*Carpinus betulus*)	110.3	5.1	96.3	5.0
Black locust (*Robinia pseudoacacia*)	419.7	19.4	447.9	23.2
Other hardwood	208.6	9.6	109.9	5.7
Poplars (*Populus* spp.)	175.1	8.1	195.4	10.1
Other softwood	110.2	5.1	99.1	5.1
Conifers (*Pinus* spp., *Picea* spp.)	200.1	9.2	207.6	10.7
Young stand/small trees[a]	240.6	11.1		
Temporary unstocked	68.7	3.2	71.9	3.7
Total	2164.6	100.0	1933.6	100.0

[a]A plot is considered as a young stand when in the 12.62 m circle there are some sample trees, but due of the concentric circle Dbh thresholds they are not measured. The plot is considered as small trees when in the 12.62 m circle there are only trees with diameters under 7 cm or they are smaller than 1.3 m but it is assessed only inside the 3 m circle

23.2.2 Wood Resources and Their Use

23.2.2.1 Standing Stock, Increment and Drain

In Hungary, based on their area, Oak species and Black locust play an important role (Table 23.4). Due to the geographical conditions of the country there are a lot of other important tree species contributing to a rich ecosystem. Due to the traditional forest management planning process the distribution of different age classes are quite balanced.

As the NFI started 3 years ago the increment and drain cannot be calculated. The exact assessed volume of growing stock gained from NFI results will be available only after a first completed cycle. The first calculations, following the first three years data, provide preliminary estimated of growing stock (Table 23.5).

Table 23.4 Forest area (1000 ha) by age classes (NFI 2010–12)

Species	Age class (years)						
	0–19	20–39	40–59	60–79	80–99	100–	Total
Oak incl. *Quercus cerris* (*Quercus* spp.)	21.4	92.7	129.1	125.3	92.9	49.6	511.0
Beech (*Fagus sylvatica*)	1.9	14.7	14.2	25.6	28.5	34.8	119.7
Hornbeam (*Carpinus betulus*)	5.7	29.2	34.7	24.5	10.4	6.2	110.6
Black locust (*Robinia pseudoacacia*)	181.1	187.0	45.7	5.3	0.5	0.0	419.7
Other hardwood	30.4	71.2	62.4	25.4	10.1	9.1	208.6
Poplars (*Populus* spp.)	88.0	57.5	21.9	4.5	1.7	1.4	175.0
Other softwood	10.4	36.6	43.3	13.2	4.3	3.0	110.8
Conifers (*Pinus* spp., *Picea* spp.)	8.7	102.9	66.6	14.5	5.5	1.9	200.1
Young stand/small trees	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	243.3
Temporarily unstocked	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	68.7
Total	347.7	591.6	417.9	238.2	153.9	106.0	2167.3

[a]There is no information on age class within these classes

Table 23.5 Growing stock by species (NFI 2010–12)

Species	Volume (1000 m^3)	Volume (%)
Oak spp. including *Quercus cerris* (*Quercus* spp.)	149,692.2	33.0
Beech (*Fagus sylvatica*)	60,442.7	13.3
Hornbeam (*Carpinus betulus*)	24,650.1	5.4
Black locust (*Robinia pseudoacacia*)	55,376.4	12.2
Other hardwood	35,957.4	7.9
Poplars (*Populus* spp.)	43,274.0	9.6
Other softwood	28,366.5	6.3
Conifers (*Pinus* spp., *Picea* spp.)	55,891.3	12.3
Total	453,650.6	100

Table 23.6 Growing stock, current increment and gross felling by main species (NFDB 2013)

Species	Growing stock		Current increment		Gross felling	
	Volume (1000 m^3)	Volume (%)	Volume (1000 m^3)	Volume (%)	Volume (1000 m^3)	Volume (%)
Oak incl. *Quercus cerris* (*Quercus* spp.)	13,1291.1	35.8	3726.3	28.6	1934	25.0
Beech (*Fagus sylvatica*)	39,411.6	10.8	885.0	6.8	698	9.0
Hornbeam (*Carpinus betulus*)	17,337.5	4.7	334.9	2.6	306	4.0
Black locust (*Robinia pseudoacacia*)	49,571.0	13.5	3216.0	24.7	1793	23.2
other hardwood	20,593.3	5.6	866.7	6.6	253	3.3
Poplars (*Populus* spp.)	29,846.0	8.1	1718.7	13.2	1338	17.3
other softwood	23,672.3	6.5	768.1	5.9	345	4.5
Conifers (*Pinus* spp., *Picea* spp.)	54,528.9	14.9	1519.7	11.7	1065	13.8
Total	366,251.6	100	13,035.4	100	7732	100

SWI estimates for growing stock, increment and felling are available from the NFDB. In Hungary the current annual increment was about 13.1 million m^3 and the annual gross felling volume was 7.7 million m^3 in 2012 (Table 23.6). The ratio of increment to felling has remained stable over the last ten years. The distribution by main species is detailed in Table 23.6.

The total growing stock in Table 23.5 is higher than in Table 23.6, which is partly due to the higher NFI forest area resulting from methodology differences between the two surveys that have been mentioned earlier. International experience has also shown that the systematic forest inventory usually gives a higher volume than the stand-wise inventory. There are two reasons to explain this difference. The SWI generally uses national yield tables which were constructed many years ago and need to be updated. In addition, collecting data by NFI is less subjective compared to SWI.

23.3 Assessments of Wood Resources

23.3.1 Availability for Wood Supply

23.3.1.1 Assessment of Restrictions

Forest available for wood supply (FAWS) can be classified based on legal restrictions or economic conditions:

Table 23.7 FAWS classification of Hungarian forests based on SWI (NFDB 2013)

Species	FAWS (1000 ha)	non FAWS (1000 ha)	Total (1000 ha)
Oak including *Quercus cerris* (*Quercus* spp.)	542.1	53.1	595.2
Beech (*Fagus sylvatica*)	96.5	13.8	110.3
Hornbeam (*Carpinus betulus*)	87.6	8.7	96.3
Black locust (*Robinia pseudoacacia*)	437.4	10.5	447.9
Other hardwood	96.2	13.7	109.9
Poplars (*Populus* spp.)	189.9	5.5	195.4
Other softwood	91.0	8.1	99.1
Conifers (*Pinus* spp., *Picea* spp.)	200.9	6.8	207.7
Temporarily unstocked			71.9
Total	1741.6	120.1	1861.7

- Legal restriction: wood not available because the area is a forest reserve or strictly protected area;
- Economic restrictions on the availability of wood:
  - the area is a game reserve or a seed-crop stand;
  - slope is higher than 20°;
  - harvesting is not profitable.

The area of forests in Hugary by FAWS classification is presented in Table 23.7. Only 6 % of forests are considered not to be available for wood supply.

23.3.1.2 Estimations

In Hungary the whole forest is visited and classified based on the restrictions mentioned above in the SWI. There is a detailed database (descriptive and spatial) about the forest including information about legally restricted areas (e.g. nature protected, Natura 2000, etc.). Based on these detailed data sources the value and expenditure can be calculated for a region or for the whole country depending on the actual needs.

23.3.2 Stem Quality

At present there is no assessment for stem quality and assortments in the NFI. Information is collected in the SWI about the quality of the stem and the average condition of health in the compartment. The stem quality is classified into nine classes based on the proportion of stem available for roundwood and the stem form. The proportion of stem available for roundwood is calculated by dividing the total tree length by the length of stem available for roundwood. Stem quality is ranked into four classes based on health and form of the stem, with Rank 1 the highest quality class. The stem quality classes include:

0—classification not needed or stem quality is ranked 4
1—Proportion of stem <1/3 and stem quality is ranked 3
2—Proportion of stem <1/3 and stem quality is ranked 2
3—Proportion of stem <1/3 and stem quality is ranked 1
4—Proportion of stem is between 1/3–2/3 and stem quality is ranked 3
5—Proportion of stem is between 1/3–2/3 and stem quality is ranked 2
6—Proportion of stem is between 1/3–2/3 and stem quality is ranked 1
7—Proportion of stem >2/3 and stem quality is ranked 3
8—Proportion of stem >2/3 and stem quality is ranked 2
9—Proportion of stem >2/3 and stem quality is ranked 1.

23.3.3 Assessment of Change

23.3.3.1 Assessment and Measurement

The forest area is increasing year on year, mostly as a result of afforestation but in some cases natural forest expansion. Deforestation is prevented by law as it is obligatory to afforest another forest area. As current forest policy plans to increase the forest area, further afforestation is expected in the near future.

Based on the SWI methodology the whole country is surveyed continuously; therefore any increase in forest area is officially captured. As the NFI also assesses the whole country, the annual classification of the updated photos will capture any new forest areas.

23.3.3.2 Estimation of Increment

There is certain background information about increment from the former GMS. Core measurement was introduced on every plot from 2010. The evaluation of cores is an ongoing process. Increment and the volume of removed trees can be obtained from the former GMS data.

Diameter and height increment can be calculated from the NFI after repeated measurements. However as the NFI sample plots are permanent plots and the sample trees are mapped, there is an opportunity to calculate more precisely the volume increment following the second NFI cycle.

23.3.3.3 Estimation of Drain

Information about the type of felling and the assessment date is collected for all the NFI plots. As the NFI sample plots are permanent plots and the sample trees are mapped, drain will be calculated following the second NFI cycle.

23.3.4 Other Wooded Land and Trees Outside Forests

Since 2010, inventory plots have been classified according to the FAO/COST-E43 definition using aerial and satellite photos. If there is any doubt these plots are visited in the field to check if it is a forest-plot, OWL or other land category. No field measurements are taken on OWL. In the near future there is a plan to assess Other Land with Tree Cover (e.g. parks, etc.) using aerial and satellite photos.

Reference

FAO (2004) Global Forest Resources Assessment Update 2005: terms and definitions (final version). Forest Resources Assessment Programme working paper 83/E, FAO Forestry Department, Rome, 34 p

Chapter 24
Iceland

Arnór Snorrason

24.1 The Icelandic National Forest Inventory

24.1.1 History and Objectives

The Icelandic National Forest Inventory was initiated in 2001 (Snorrason and Kjartansson 2004). After four years of preparation, data sampling on field plots started in the spring of 2005. While the data sampled is used to produce valuable information for many purposes, the primary reason for starting National Forest Inventory (NFI) was the need for reliable annual data to report to the United Nation Framework Convention on Climate Change (UNFCCC). In recent years NFI data has been the backbone in data delivery to other international forest data sampling and reporting as the Forest Resource Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO) and the State of Europe's Forest (SoEF) of the FOREST EUROPE organisation (Snorrason 2010). With increasing demand for wood, wood removals and utilisation from the steadily growing new forest estate, the role of the NFI as information source of current and future growing stock is the key of quantifying the available forest resources.

24.1.2 Sampling Methods and Periodicity

The inventory design has not changed since the first NFI. Taking notice of good advice from European specialists at the collaboration platform of COST Action E43 it was decided to use a continuous inventory with a five year cycle for the cultivated

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forest (CF). Cultivated forests are defined as all forest initiated by tree plantation or direct seeding or forests originating from these forests. For the natural birch (*Betula pubescens* Ehrh.) woodland (NBW) a discrete five year inventory with a ten year interval between sampling cycle was chosen. For both classes a systematic plot sampling system was chosen but with different grid densities. In the case of cultivated forest a 0.5 × 1.0 km grid is used but for the natural birch woodland 1.5 × 3.0 km grid. Every intersection of the two grids overlapping maps of CF or NBW is visited in the field and a single circular plot is established. These maps cover all areas of forest and other wooded land. In total, 899 intersections were visited in the last five year cycle of the CF (2010–2014), of which 814 had plots that were fully or partially inside forest. In the NBW 312 intersections were visited and 210 plots established in the first inventory (2005–2009).

24.1.3 Data Collection

Stand and environmental data are collected on 200 m^2 plots both in CF and NBW. These attributes can be broadly classified into three classes:

1. Topographical data: topographical placement, topographical form, slope, aspect, Topex (to horizon and to 50 m distance)
2. Site classification: Height or species classes of forest areas, different treeless spaces inside forest (less than 0.5 ha or narrower than 20 m) or outside forest. If necessary plot is divided by mapping into subplots by site classes
3. Site description:
   (a) Management data: Forest owner, forest manager, management practices, thinning status, planting type, scarification and drainage.
   (b) Environmental data: Vegetation class, cover and indicators, soil type, soil depth and bedrock, etc.
   (c) Forest classification: Original land type (UNFCCC classes), forest class at mature state (FAO and UNFCCC classes).
   (d) Current state of forest: Age, mean height and diameter, species composition, crown coverage and storeys and thinning status.
4. Dead wood measurements: All dead wood meeting minimal size (d = 10 cm, l = 1 m) is located and measured.

Data sampling for trees and stumps are different between CF and NBW. In the case of CF they are measured and located on plots where the size is adjusted to the density of trees between 25 and 200 m^2, having at least 20 or more living trees inside the “tree measurement plot”. In NBW concentric rings are used. On the plot all trees are sampled and measured for: diameter, height, species, vitality, stem straightness, damages, etc. If the plot has not been measured within the last 5–10 years, a subsample of trees is measured for height growth and/or diameter growth by coring. If the planting year of the plantation is available from official records it is used to calculate plot age. If not, the age is either estimated by whorl counting on young trees or by coring on older ones. More information on sampling design and the sample plot measurements is to be found in Snorrason (2010).

Biomass above ground (and below ground in some cases) and stem volume is estimated for all trees measured on the plot by using country specific single-tree biomass and volume functions (Snorrason and Einarsson 2006; Bjarnadottir et al. 2007; Jónsson 2007). Biomass on each plot or subplot is summed up and scaled by the rate between the sampling unit and the plot area, 50 ha for CF and 250 ha for NBW for each whole plot.

24.2 Land Use and Forest Resources

24.2.1 Classification of Land and Forests

24.2.1.1 General Classifications

The main sources of information in this report are from the recently completed country report for the FAO FRA2015 process and the joint FOREST EUROPE/UNECE/FAO Questionnaire on pan-European quantitative indicators for Sustainable Forest Management, which has been prepared and will be used in the report of State of Europe's Forest 2015 (SoEF 2015).

The Icelandic National Forest Inventory is only responsible for mapping and measuring forest and other wooded land. Land use and land cover classification outside forest is conducted by other institutions. Spatial land cover classification for Iceland as a whole has been done recently under the Corine project of European Environmental Agency (Árnason and Matthíasson 2009). A broader land use classification is carried out annually in the National Inventory Report to the UNFCCC (NIR UNFCCC) (Hallsdóttir et al. 2013). In these two reports the forest definitions used are not comparable. When reporting to the FAO and FOREST EUROPE the FAO (2004) global forest definition is used. In the NIR UNFCCC, the forest definition is altered for one variable, tree height. Instead of using 5 m as minimum height at maturity 2 m was chosen by Icelandic authorities as minimum height at maturity (Ministry for the Environment 2006). Table 24.1 shows land use classes as reported in latest NIR UNFCCC for the year 2011.

In 2011, the total forest area according to the UNFCCC was 133,000 ha covering 1.3 % of the country. The shrubland part of the natural birch woodland covers 51,000 ha. The total forest and other wooded land were 184,000 ha in 2011.

Table 24.2 gives an overview of how different forest subclasses are reported in international reports. No official forest definition has been adopted in Iceland but the natural birch woodland has always be named "skógur" by the people, which is the Nordic name for forest although less than 10 % of these woodland can be defined as forest internationally. In a Gallup poll carried out ten years ago people

Table 24.1 Land use classification in year 2011 (NIR UNFCCC 2013)

Classes/Subclasses	Area (1000 ha)	Area (%)
Settlement	**52**	**0.5**
Forest land	**133**	**1.3**
Natural birch forest	96	0.9
Cultivated forest	38	0.4
Cropland	**129**	**1.3**
On mineral soil	71	0.7
Drained wetland	58	0.6
Wetland	**715**	**6.9**
Lakes and rivers	260	2.5
Reservoirs	58	0.6
Other wetlands	397	3.9
Grassland	**5260**	**51.1**
Natural birch shrubland	51	0.5
Other grassland	4569	44.4
Drained wetland	344	3.3
Revegetated land	252	2.5
Abadoned cropland	44	0.4
Other land	**4000**	**38.9**
Glaciers and perpetual snow	1087	10.6
Other "other land"	2913	28.3
Sum	10,288	100

Table 24.2 Forest area by forest subclasses used in international reporting (2010)

Forest sub-class	FAO and SoEF	Area (1000 ha)	Classification	Area (1000 ha)	UNFCCC
Natural birch woodland	Forest	10.7	≥5 m at maturity	10.7	Forest
	Other wooded land	84.4	2–5 m at maturity	84.4	Forest
	Other wooded land	50.6	≤2 m at maturity	50.6	Grassland/shrubland
Cultivated forest	Forest	32.0	≥5 m at maturity	32.0	Forest
	Other wooded land	4.3	2–5 m at maturity	4.3	Forest
Total forest	Forest	42.7		131.4	Forest
	Other wooded land	139.3		50.6	Grassland/shrubland

where asked about what height trees has to have to be considered a forest (IMG Gallup 2004). The mean height resulted in 2.26 m so the definition used when reporting to UNFCCC seems to suit Iceland well as a country definition. On the other hand the NFI sample data is organised in such a way that facilitates analyses using international minimal height definition of 5 m at maturity in situ. Woodland reaching 2 to 5 m height at maturity is either classified as “Other wooded land” when reporting to FAO FRA or FOREST EUROPE SoEF or as “Forest” when reporting to UNFCCC.

In this chapter the FAO definition of forest is the basis of the statistics presented. The class other wooded land is rarely used for wood utilisation as the stature, stem quality or growth does not meet criteria of economical or sustainable usage. According to the NFI results for the period 2010 to 2014, the permanently unstocked area of cultivated forest is 9 % of the gross area of the forest or around 4000 ha. Trees can be found outside forest in two land use classes:

1. Agricultural land as shelterbelt and tree groups with area under 0.5 ha
2. Urban areas as trees in parks, in home gardens and as tree rows and single trees in streets.

In the FRA2010 an estimate of “Other land with tree cover” is calculated by using results from a sample plot inventory of trees in the urban area of the capital of Iceland, Reykjavik (Viðarsson and Snorrason 2012). It showed that the mean canopy cover of trees was 9.9 % of the total urban area of the city. It will exceed 10 % cover and can then be defined as “Other land with tree cover”. Most of the trees are grown in private gardens in areas defined in the CORINE land classification system as “Discontinuous urban fabric”. Discontinuous urban fabric was estimated in the Icelandic CORINE project to be 8900 ha in the year 2000 and 9700 ha in the year 2006. The same figure was assumed for 2010 as further expansion of rural areas has halted after the economic crisis in 2008.

24.2.1.2 Classification by Ownership Category

The ownership structure of forest (42,700 ha) for the year 2010 is as follows; 34 % in public ownership (state and municipalities), 16 % by private institution’s (mostly forest associations) and 50 % by private individuals (farmers and land owners).

24.2.1.3 Forest Management and Cutting System

Cultivated forests in Iceland follow the traditional Nordic management scheme of even-aged stands. As plantations dominate the age distribution within stands is little to none. On the other hand are the natural birch forests that are managed for wood utilisation uneven-aged. The cutting system in use is selective cutting and has been practised since the establishment of the forestry authority at the beginning of the 20th century.

Table 24.3 Area estimate of main tree species in Icelandic forest covering more than 1000 ha

Species	Area (1000 ha)
Native mountain birch (*Betula pubescens*)	18.2
Siberian larch (*Larix sibirica*)	8.6
Sitka spruce (*Picea sitchensins*)	4.9
Lodgepole pine (*Pinus contorta*)	4.7
Black cottonwood (*Populus trichocarpa*)	2.9

24.2.1.4 Legal and Other Restrictions of Wood Use

According to the 1950 Icelandic forest act clear cutting is not allowed without permission from the head of the Iceland Forest Service (Forest Director), which is the forest authority of Iceland (Alþingi 1950). Permission will only be given if the land will be used for crop cultivation or if afforestation of an alternative area equivalent in size of land is to be conducted not later than two years from the time of the clear cut. Only thinnings approved by the official forest ranger are allowed. In addition about 10 % of the natural birch woodland as a whole is protected in nature reserves and national parks and as such will not be available for wood supply.

24.2.1.5 Further Classification of Forests

Table 24.3 shows the area by species canopy cover ratio of main tree species in the Icelandic forest as reported in SoEF 2015 for the year 2010. The native mountain birch (*Betula pubescens* Ehrh.) is the most common tree species present, accounting for 18,200 ha. The natural birch woodland has 10,700 ha of native mountain birch. In the cultivated forest, Siberian larch (*Larix sibirica* Ledeb.) has the highest coverage of 8600 ha and the native mountain birch is the second most common species.

24.2.2 Wood Resources and Their Use

24.2.2.1 Standing Stock, Increment and Drain

In both FRA 2015 and SoEF 2015 reports the growing stock of forest and other wooded land was estimated. Growing stock definition used was the same as defined by FAO (2015); with a minimum diameter at breast height (dbh) of 10 cm, top included, branches and stump excluded. The share of the growing stock by species in 2010 is listed in Table 24.4.

In the natural birch forest only a small portion of the state owned forest, managed by the Icelandic Forest Service, is used for wood supply. Approximately 400 ha are currently used and another 400 ha could be used in the future. Together this is only 7 % of the area of the natural birch forest. Most of the 52,000 m^3 of the

Table 24.4 Growing stock estimated in the year 2010 in thousand m^3 over bark

Species	Growing stock (1000 m^3)	Growing stock (%)
Siberian larch	59	20.1
Sitka spruce	54	18.4
Native mountain birch	52	17.7
Lodgepole pine	45	15.4
Black cottonwood	37	12.6
Norway spruce	23	7.8
Remaining species	23	7.8
Total	293	100

Table 24.5 Annual production in m^3 of roundwood by wood use (2010)

Wood use	Volume (m^3)	Volume (%)
Industrial roundwood	**3113**	**75**
Sawnwood	50	1
Roundwood	2863	69
Chips and shaving	200	5
Firewood	**1022**	**25**
Birch	246	6
Other species	776	19
Total	4135	100

growing stock of birch wood listed in Table 24.4 are therefore considered unavailable for wood supply.

Annual increment of the cultivated forest was estimated to be 33,500 m^3 in 2010. This is the growth of the living trees but trees measured five years ago that have been cut or died in the meantime are excluded so one has to consider this estimate as net annual increment.

The total drain of wood stock has not been estimated but the net drain in 2010 of commercial wood production was 4135 m^3 or 12 % of the net increment of the cultivated forest (Table 24.5). Taking into account the skewed age distribution of cultivated forests in Iceland the utilisation rate is not unreasonable for sustainable management.

24.2.2.2 Tree Species and Their Commercial Use

It has been estimated that before human settlement in the 9th century AD the natural birch woodland was one of the main terrestrial ecosystem types in Iceland with a cover of 2.8 million ha or 28 % of the land area (Sigurðsson 1977; Aradottir and Arnalds 2001). Most of this woodland cover has been lost due primarily to anthropogenic activity as land use change, grazing and over-exploitation of wood (Bjarnason 1974). As listed in Table 24.2 above the area of natural birch woodland is currently estimated at 145,700 ha. That is an increase in area from the estimate of 125,000 ha in a survey done in 1972–1975 (Sigurðsson and Bjarnason 1977) but only 5 % of the coverage at settlement. The natural birch woodland, as already mentioned, are of low stature (Jónsson 2004), so wood utilisation was restricted mainly to charcoal making and fire wood use. The charcoal making was directly linked to iron utilisation from peat and sharpening of scythes, which faded away in mid nineteenth century (Gudbergsson 1998). Extensive firewood utilisation lasted longer but at the beginning of the World War II it started to decline and ceased in the mid twentieth century. The average annual fire wood utilisation from 1888 to 1950 was around 1000 metric ton of wood. Due to the low biomass and biomass growth it has been stated that this utilisation was not sustainable and coupled with continuous grazing lead to reduction of the natural birch woodland until the middle of last century (Gudbergsson 1998). From 1950 the Iceland Forest Service continued a restricted selection cutting of 200 m^3 of wood from natural birch forest (Hallanaro and Pylvänäinen 2002). Since the 1970s wood from the natural birch forest has been used as firewood for amenity fireplaces, as a smoking wood, fence poles and in later time as firewood for culinary ovens.

Historically, the other domestic source of wood was driftwood. Although it has been confirmed to be valuable source of wood in centuries, especially for construction, no references about annual usage are available (Kristjánsson 1980).

The use of industrial roundwood from Icelandic forests is a recent occurrence and connected to the cultivation of introduced tree species that can grow faster than the native birch with straight stems into usable dimensions for sawn wood and other industrial wood. Planting of introduced tree species did not start in earnest until after the World War II, slowly increasing and peaking in 2007 when over 6 million seedlings were planted resulting in 1800 ha of plantations.

In the 1970s small fence pole production started with early thinning's of larch plantations. In the same period sporadic sawn wood production began but it was not until 2005 that industrial roundwood production exceeded 500 m^3. When a ferrosilicon plant started to buy domestic wood chips to raise the carbon content of the metal in 2010 the industrial roundwood production increased to new levels of over 4000 m^3 and are still increasing.

Firewood usage also increased upward in 2010 when a wood heating facility was installed in Hallormsstaður forest in east Iceland. The heating facility is mostly driven by larch wood from commercial thinning's in plantations located in the neighbourhood.

The annual production of commercial roundwood of different products is shown in Table 24.5 for the year 2010 (Gunnarsson 2011). The main user of industrial roundwood and chips of species other than birch is the ferrosilicon industry. Sawnwood production is only 2 % of the industrial roundwood production. Wood from birch is still mostly from selective cuttings in natural forest but the ratio of birch wood coming from cultivated forest is increasing.

The demand for domestic wood products started after the financial crisis in 2008 when the value of the domestic currency dropped and currency restrictions were enacted. Industries that were dependent on basic wood products as the ferrosilicon plant and shaving industries for animal bedding were willing to purchase domestic wood for prices that made first commercial thinning profitable.

As most of the cultivated forests are young, final cuttings are very rare. Forest stands are only removed if there is a need due to unsuccessful silviculture or to make way for another land use, which is mainly construction connected to settlements. Wood production is therefore still driven by commercial thinnings, either first or second thinning.

24.3 Assessment of Wood Resources

24.3.1 Forest Available for Wood Supply

24.3.1.1 Assessment of Restrictions

The main source of FAWS, the cultivated forest is not under any legal restriction of wood utilisation other than the sustainable principles in the forest act mentioned previously. With an increasing area of cultivated forest the FAWS ratio will increase. However, the role of the natural birch forest as a source of wood will reduce and more of the native woodlands will probably be designated for environmental protection.

24.3.1.2 Estimation

The cultivated forests are the main source of available wood. Although the majority of cultivated forests are available for wood supply some are not. To assess the availability of cultivated forest for wood supply two variables are assessed in the NFI regarding FAWS (Snorrason 2013).

The first variable classified in the NFI plots is use. In each use class a fixed ratio of FAWS was set taking into count the nature of each class. The net forest area and the proportion of available wood supply for each use class are presented in Table 24.6. Small open areas without trees inside forests (less than 20 m wide or under 0.5 ha) are estimated to 12 % of the gross forest area in the measuring period 2009–2013. Accordingly the gross forest area estimated in 2011 was 38,000 ha. Another variable classifies the NFI plot by the management authority which is used for the classification of FAWS in Table 24.7.

Different management authorities use different management objectives. For example the land reclamation afforestation has a rather low utilisation rate as the main goal of this type of afforestation is not wood production. The tree species planted are often native birch or willows and not suited to wood utilisation. The areas chosen are in addition sometimes in remote places without good connection to the road network.

Table 24.6 Classification of the stocked cultivated forest area (both forest and other wooded land by FAO (2004) definition) by use and FAWS ratio (2011)

Use class	Net area (ha)	FAWS (%)	FAWS area (ha)
Multiple forestry	14,800	80	11,840
Wood production	5520	95	5240
Land reclamation	5740	20	1150
Recreation	4930	60	2960
Summerhouse lots	1500	0	0
Research areas	280	60	170
Christmas trees	190	0	0
Shelter	290	20	60
Other usage	50	40	20
Total	33,300	64	21,440

Table 24.7 Classification of the stocked cultivated forest area by and management authority and FAWS ratio (2011)

Management authority	Net area (ha)	FAWS (%)	FAWS area (ha)
Iceland Forest Service (state)	3340	80	2670
Forest associations	5050	60	3030
Regional forest project—East	5620	90	5060
Regional forest project—East coast	360	80	290
Regional forest project—South	2020	80	1620
Regional forest project—West	2530	80	2020
Regional forest project—Northwest	1510	55	830
Regional forest project—North	4100	80	3280
Land reclamation afforestation	2390	40	960
The Soil Conservation Service (state)	560	10	60
Mt. Hekla afforestation	60	10	10
Production forests on farmland	930	90	840
Other private forest	2890	10	290
Municipalities	1940	60	1160
Total	33,300	66	22,120

The main result from this analysis was that both variables give similar results, FAWS are assessed to be about 65 % cultivated forest in Iceland. This result was used when assessing FAWS in the SoEF2015.

The FAWS ratio in the usage classification was used to calculate the growing stock available for wood supply. Out of the 0.29 million m^3 of total growing stock estimated in 2010, 0.17 million m^3 or 59 % were assessed as available for wood supply. On the cultivated forest with total growing stock of 0.26 million m^3 and FAWS stock of 0.17 million m^3 the FAWS ratio was a bit higher than the area based ratio or 66 %.

In the FAWS portion of the cultivated forest the net annual increment was estimated to be 23,700 m^3 which was 70 % of the total. Those forest areas available for wood supply have a higher productivity than the cultivated forest as a whole.

24.3.2 Wood Quality

24.3.2.1 Stem Quality and Assortments

Each tree measured on the NFI sample plot that has reached 2 m height is classified into five categories regarding stem straightness:

- A1: 5 m straight stem
- A: 3 m straight stem
- B: 2 m straight stem
- C1: Lightly bended stem
- C: Crooked and/or forked stem.

Stemwood in Classes A and B can be used as sawn timber to various degree of utilisation ratio. As shown in Table 24.5, sawnwood plays a minor role in the current wood market. Classes A1, A, B and C1 can primarily be used in ferrosilicon and the bedding industries. Class C are only usable locally in traditional fire wood production.

24.3.2.2 Assessment and Measurement

In the wood usage analysis already mentioned (Snorrason 2013) analyses of various height classes in the cultivated forest show that with increased top height better quality classes occur more frequently as shown in Table 24.8. This is as a result of the implementation of both pre-commercial and commercial thinning's which have been practiced more frequent in the ≥10 m classes than in the 5–10 m class or 44 and 13 % respectively. Only 17 % of the cultivated forest has reached top height 5 m or more (Table 24.8).

Table 24.8 Stem quality in two top height classes in the cultivated forest

Top height class	Net area (ha)	Stem quality classes (% area)				
		A1	A	B	C1	C
5–10 m	4700	12	14	14	37	23
≥10 m	1000	21	14	14	31	20

24.3.2.3 Estimation and Models

Newly made taper functions for lodgepole pine and Siberian larch (Heidarsson and Pukkala 2011) together with simulation model for temporal development of volume (Heiðarsson and Pukkala 2012) make it possible to estimate current and future merchantable wood output divided into different assortments. These functions and models have been applied locally in east Iceland (Heiðarsson and Pukkala 2012) and in north Iceland (Davíðsson 2012) but not on country level using data of the NFI.

24.3.3 Assessment of Change

24.3.3.1 Assessment and Measurement

With steady afforestation, ageing of the current cultivated forests and increasing domestic wood demand it is rather reasonable to assume that FAWS will increase, both in stock and as a ratio of total growing stock. This tendency can be noticed in the data delivered from Iceland to the ongoing FOREST EUROPE (2015) program as seen in Fig. 24.1. Growing stock has significantly increased since 1990 and the FAWS ratio of total has steadily increased from being 39 % in 1990, 49 % in 2000, 54 % in 2005, 59 % in 2010 and 65 % in 2015.

24.3.3.2 Estimation of Increment

As all NFI plots are permanent, volume or biomass increment is estimated at tree level by comparing the current size with the size five years ago. This is possible as the position of every tree on the plot is recorded. Although currently possible, increment measurements on trees that have been removed through felling or

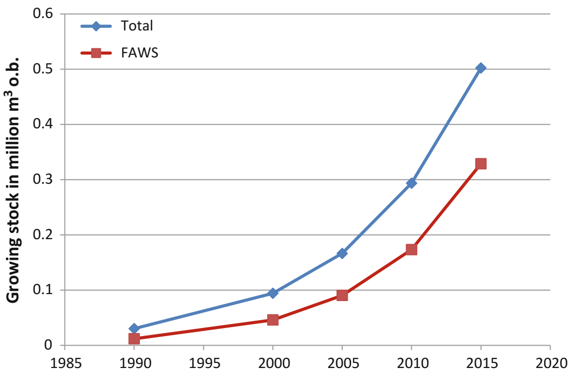

Fig. 24.1 Chronological change in growing stock in Icelandic forests

mortality have not yet been estimated on the plot as the second round of the NFI has only recently been completed. For that reason gross increment estimation has not yet been carried out but will be in the near future.

24.3.3.3 Estimation of Drain

As already mentioned has drain estimation on the plot level not yet been carried out although the data sampled allow such estimation. In the annual NIR to the UNFCCC only woody biomass removed from the forest and sold on a marked are reported as a drain and in that case as losses of carbon stock (Hallsdóttir et al. 2013).

24.3.4 Other Wooded Land and Trees Outside Forest

24.3.4.1 Assessment and Measurement

The area of other wooded land is estimated to be 139,300 ha, more than three times the area of forest (Table 24.2). On the contrary growing stock in other wooded land was estimated only 32,000 m^3 in 2010 which is 11 % of growing stock in forest in the same year. Although the growing stock can be found in other wooded land it can be stated that commercial wood utilisation is not realistic, especially in the natural birch woodland, where the growing stock is 0.2 m^3/ha. The majority, or 97 %, of other wooded land is natural birch woodland.

Trees outside forest such as trees in urban areas are another source of biomass. Just to give some glimpse of the annual amount of woody biomass collected from urban areas in the capital Reykjavík and surrounding municipalities (about 64 % of the population is living in this area), 6000 metric tonnes of woody biomass was gathered in the year of 2013 (SORPA 2014). This biomass is used to make a fertile soil-mixture called Molta.

24.3.4.2 Estimation

The Icelandic NFI includes areas that are defined as Other Wooded Land (OWL). In the category of cultivated forest OWL occurs sporadically (Table 24.2). These areas are treated the same as forest and plots are laid out in the same manner as in the forest part, including tree assessment. In the Natural Birch woodland the proportion of OWL is much larger (Table 24.2) but both forest and OWL are measured in the same way. Further information of measurement methodology is to be found in Snorrason (2010).

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Chapter 25
Ireland

John Redmond

25.1 Ireland's National Forest Inventory

25.1.1 History and Objectives

At the end of the 19th century, the area of forest cover in Ireland was estimated to be approximately 69,000 ha, or circa 1 % of the national land area. During the first 75 years of the 20th century, forestry in Ireland was almost exclusively the responsibility of the State, and by 1985 forest cover had increased to approximately 420,000 ha. The mid 1980s saw a significant increase in private forest development, with the introduction of EU-funded grant schemes aimed at encouraging private land owners, mainly farmers, to become involved in forestry (Forest Service 2007).

Despite this increase in the amount of forest cover in Ireland, the State did not have inventory information of the entire national forest estate. Coillte Teoranta (The Irish Forestry Board) owns over half of the forest estate and maintains a detailed inventory of its forests, while private estate managers also maintain inventories. However, a comprehensive and standardised inventory of the entire private forest estate has not been available. This lack of information on the composition of our forests, in relation to species, timber volumes, increment and biodiversity, has been an impediment to the sustainable management and utilisation of the national forest resource.

The undertaking of a National Forest Inventory (NFI) arose from a strategic action in the 1996 'Growing for the Future' (Forest Service 1996) policy document for the development of the forest industry in Ireland. The purpose of the NFI is to record and assess the extent and nature of Ireland's forests, both public and private,

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in a timely, accurate and reproducible manner to enable the sustainable development of our forest resource. Reliable, current and consistent information is required to inform domestic forest policy, to support forest research and fulfil national and international reporting commitments.

The 2006 NFI was the first statistical and multi-resource inventory carried out on the national forest estate. In order to assess changes in the forest estate over time repeated assessments are required. As a result, the field data collection for the second NFI commenced in 2009 and was completed in 2012. Again multi-resource information was generated including parameters such as area and species composition, growing stock (m^3), biodiversity, health and vitality, carbon content and soil type; for the entire national forest estate. Data on minor tree species and natural regeneration were also included. With this second NFI new parameters such as forest area change, volume increment and harvesting volume estimates allow, for the first time, monitoring of Sustainable Forest Management (SFM) on a temporal basis.

The predominant use of the NFI data from Ireland's first NFI cycle has been national and international reporting; including Global FRA, FOREST EUROPE, reporting related to green house gas monitoring. Research programmes are currently utilising NFI data in relation to timber supply forecasting, forest health and biodiversity.

25.1.2 Sampling Methods and Periodicity

The NFI is a detailed field survey of Ireland's forests and is based on a randomised systematic 2 × 2 km grid sample design. This grid density equates to 17,423 points nationally, each representing approximately 400 ha.

Ireland's NFI occurs on a cyclical basis. The aim is to have a 5 year period between the starting date of cycles. Field data collection takes 2 years to complete. Data analysis and reporting requires one further year.

Prior to NFI field data collection the entire 2 km grid is assessed, using the most up to date aerial photographs available, to identify those plots that are potentially forest. Following field data collection in the 1st cycle, 1742 permanent forest plots were established across the whole forest estate. These plots were reassessed in the second cycle, in addition to new forest areas which were not present in the first cycle. These new forest areas are predominantly afforested areas, but also include some natural regenerated forest areas. In total, 1827 permanent plots were established across the whole forest estate following the second NFI cycle in 2012.

Each circular NFI permanent sample plot measures 25.24 m in diameter, equating to 500 m^2. The concentric circle approach, comprising three concentric circles with different radii, is used for tree assessment. The decision about which tree is considered to be qualified is based on its position on the plot and its dbh (Table 25.1).

Table 25.1 NFI plot design

	Sub-circle 1	Sub-circle 2	Sub-circle 3
Radii (m)	3	7	12.62
Area (m^2)	28.3	153.9	500
Threshold dbh (mm)	70	120	200

25.1.3 Data Collection

Data collected in the NFI can be divided into two broad categories; plot and tree. Further information on the attributes assessed in Ireland's NFI is available in the Field Procedures and Methodology document (Forest Service 2013a).

Plot data is recorded for five main themes:

1. Administrative data: owner, restrictions for forestry, etc.
2. Stand data: Forest type, growth stage, thinning status, etc.
3. Forest storeys: plot species composition, crown cover, damages, etc.
4. Site: Aspect, slope, elevation, soil, terrain, etc.
5. Deadwood: Decay status, diameter, length, etc.

Tree data is recorded for three main themes:

1. Mapped tree data: tree position (XY), diameter, species, quality class, crown class
2. Height sample tree data: height, diameter at 6 m height, crown projection
3. Small trees: dbh, height, damage.

25.1.4 Data Processing, Reporting and Use of Results

Following field data collection, a series of checks are carried out on the raw plot data to identify logical errors. Corrections are made, where necessary. Further checks are carried out in the office to check for serious errors in the data, such as a permanent sample tree being deleted.

There are two main categories of statistics produced; area and volume. The estimation of all area statistics is dependent on the total area of Ireland, i.e. forest and non-forest. For the purpose of the NFI the official area of Ireland originates from digital datasets of administrative boundaries created by our national mapping agency, Ordnance Survey Ireland. When estimating the area of those attributes collected at plot level, such as ownership, the whole plot area is assigned to a particular class. The entire land base of Ireland is represented by 17,423 NFI plots with each one representing approximately 400 ha. For example, one plot classified as being privately owned will represent 400 ha of privately owned land nationally.

For those attributes assessed at tree level representative area is used to derive area estimates. The representative area is calculated for each measured tree on the plot that is proportional to the tree size, i.e. the larger the tree, the greater the representative area. For each forest plot, where trees are present, the sum of individual tree representative areas will equal the total plot area of 500 m^2. Where the evaluated variable, forest area, is classified in terms of tree variables (e.g. species), the representative area is used to calculate forest area. For example, in order to estimate the total area of Norway spruce the portion of each plot represented by Norway spruce is aggregated to a national level.

The estimation of growing stock, biomass, increment and drain using field data involved three steps:

- Modelling tree height
- Non-parametric k-Nearest Neighbour (kNN) modelling is used to model dbh for the trees that are missing a dbh at one occasion e.g. ingrowth tree
- Modelling tree volume and biomass.

Change estimation in Ireland's NFI is based on the direct measurement of permanent sample plots and the individual trees mapped on the plot. Modelling dbh is only used for those trees that are missing dbh at one occasion. Comparison of estimates between consecutive cycles is the basis of estimating increment and drain.

The analysis software (Field-Map Inventory Analyst) produces standardised results for reporting purposes. As errors are associated with all forms of sampling, outputs detail the calculated statistics with associated confidence intervals ($\alpha = 0.05$). The confidence interval quantifies the uncertainty in measurement by specifying the range of values within which the true value for the whole population lies. Only sampling error is included in the confidence interval; modelling errors (e.g. volume estimation) and measurement errors (e.g. dbh data) are not incorporated in the confidence intervals. Sub-totals are provided where a variable is classified by more than one attribute. The proportion of the variable in each classifier class is also included. Interpretation of the results is aided by the use of charts and graphs.

The NFI has been instrumental in estimating the carbon stock in Irish forests and their contribution to national climate change mitigation. NFI data is a crucial component of the national forest reporting system (CARBWARE), which is used to estimate annual greenhouse gas emissions and removals as submitted to the United Nation Framework Convention on Climate Change (UNFCCC) and the Kyoto protocol.

The NFI was also initiated in response to demands for multi-resource information about Ireland's forests from international and national bodies such as the Food and Agricultural Organization/Economic Commission for Europe (FAO/ECE). The NFI was central to recent reporting needs for FRA 2015 (FAO 2015) and State of Europe's Forest 2015 (FOREST EUROPE 2015).

25.2 Land-Use and Forest Resources

25.2.1 Classification of Land and Forests

25.2.1.1 General Land Classification

In the national land use classification system, land is divided into 19 categories (Table 25.2). Categorisation of land-use type is based on air-photo interpretation at each NFI cycle. Ireland's forest definition differs from FAO in terms of area (0.1 ha in Ireland) and canopy cover thresholds (20 % in Ireland).

The national definition differs from FAO in terms of the area and canopy cover thresholds. Ireland's NFI defines forest as:

> Land with a minimum area of 0.1 ha, a minimum width of 20 m, trees higher than 5 m and a canopy cover of more than 20 % within the forest boundary, or trees able to reach these thresholds in situ.

Other wooded land is defined as groups of trees that do not meet the criteria specified in the forest definition. This category covers areas of trees less than 0.1 ha, or less than 20 m in width, and/or with a canopy cover of less than 20 %.

Hedgerows are defined as linear features (<20 m wide) that have tree and/or shrub species present.

Table 25.2 Classification of total land area by land-use types (NFI 2012)

Land-use type	Area (1000 ha)	Area (%)	Correspondence to FAO (2004)
Forest	732	10.5	Partly forest
Hedgerows	272	3.9	TOF
Other woodland	48	0.7	OWL
Scrub	83	1.2	Partly OWL
Grassland	3725	53.4	
Cropland	352	5	
Bog and heath	916	13.1	
Cutaway peat (domestic)	102	1.5	
Cutaway peat (industrial)	68	1	
Bare rock	74	1.1	
Quarry	12	0.2	
Road (paved)	92	1.3	
Built land (rural)	129	1.8	
Built land (urban)	71	1	
Green space (rural)	85	1.2	
Green space (urban)	28	0.4	
Track (unpaved road)	23	0.3	
Water body	144	2.1	
Sea and coastal complex	22	0.3	
Total	6976	100	

25.2.1.2 Forest Classifications by Use

As our NFI uses the concentric plot approach, it is not permitted that a NFI plot has two land-use categories present. If a plot contains >90 % of another land-use class, then a plot shift is applied. The total forest area is subdivided into three distinctive forest area types (Table 25.3).

25.2.1.3 Classifications by Ownership Categories

The NFI uses the two main ownership categories: public and private. Over half (53.2 %) of forests are in public ownership and 342,296 ha (46.8 %) are in private ownership. The private forest estate is in effect comprised of two distinct forest types; the older non grant aided forests, referred to as Private (other), and the younger grant aided forests categorised as Private (grant aided), planted post 1980 (Table 25.4).

25.2.1.4 Forest Management and Cutting Systems

The majority of forests in Ireland are conifer and managed in an even-aged management system. Forest management normally includes:

(1) Establishment is predominantly by artificial means both in afforestation and reforestation

Table 25.3 Total forest area by forest area type (NFI 2013b)

Land-use category	Description	Area (1000 ha)
Stocked forest	Forest area with tree species present	637
Temporary unstocked forest	Forest area unstocked due to felling or fire, due to be restocked	17
Forest open area	A permanently unstocked area within the forest e.g. timber stacking area or forest roads. These areas are an integral part of the forest estate	78
Total		732

Table 25.4 Total forest area by ownership (NFI 2013b)

Ownership	Area (1000 ha)	Area (%)
Public	637	53.2
Private (grant aided)	17	34
Private (other)	78	12.8
Total	732	100

Table 25.5 Annual (2006–2012) harvest volume by harvest type (NFI 2013b)

Harvest type	Annual harvest volume (1000 m^3)	Annual harvest volume (%)
1st thinning	501	13.8
2nd thinning	183	5.1
Subsequent thinning	164	4.5
Clearcut	2768	76.6
Total	3616	100

(2) Early care of young trees including vegetation control
(3) First thinning of forest stand at 15–25 years
(4) 2–3 further thinnings during the rotation
(5) Final clearcut at 35–50 years depending on species.

Forests on certain site types are not thinned, due primarily to concerns of predisposing the forest to wind damage. Broadleaved forests are less common in Ireland and these forests typically have higher non-wood values. The older broadleaved forests tend not to be actively managed or are managed with low impact silvicultural systems. The younger grant aided broadleaved forests, tend to be more actively managed and are undergoing tending and thinning operations. The rotation period for broadleaves ranges from about 55 years in the case of *Fraxinus excelsior* to over 100 years in the case of Quercus spp.

Forest owners are required by law to apply to the forest regulator for permission to fell trees. A felling licence is issued to forest owner with associated replanting obligations. Over three-quarters of removals (77 %) are in the form of clearcuts, with 13 % from thinnings (Table 25.5). Nearly all (97 %) of the volume is from conifer tree species (Forest Service 2013b).

25.2.1.5 Legal and Other Restrictions for Wood Use

While Ireland's forest estate is impacted by a large number of restrictions, timber harvesting is not necessarily restricted to the point that it is not available. Mitigating measures exist which allow timber harvesting to proceed. The area of strictly protected forest in Ireland is very small, which does have not impact on timber supply (Table 25.6). Overall, 84 % of the stocked forest area is considered to be available. The 15 % of the stocked forest estate area classified as being unlikely to

Table 25.6 Total stocked forest area and availability for wood supply (NFI 2013b)

FAWS	Area (1000 ha)	Area (%)
Available	534	83.7
Unlikely	100	15.7
Not available	4	0.6
Total	637	100

be available is theoretically available but due to restrictions on site, such as slope, these areas are classified as being unlikely to be available.

25.2.1.6 Further Classification of Forests

In addition to the aforementioned attributes, statistics may also be generated for other classifications. Further classification depends on the reporting purpose for which the statistics are being generated. These attributes of forests in national statistics is usually by plot level variables such as European Forest Type (EFT) (Table 25.7).

The main tree species is Sitka spruce (*Picea sitchensis*) occupying 334,560 ha or 52.4 % of the stocked forest estate (Table 25.8). Other pines, composed primarily of Other pines (*Pinus* spp.), accounted for 9.7 %. The most common broadleaf species present in the estate include Other short living broadleaves, such as willow

Table 25.7 Total stocked forest area by European Forest Type (NFI 2013b)

EFT	Area (1000 ha)	Area (%)
Conifer	437	68.6
Broadleaved	111	17.5
Mixed	89	13.9
Total	637	100

Table 25.8 Total stocked forest area by species (NFI 2013b)

Species group	Area (1000 ha)	Area (%)
Sitka spruce (*Picea sitchensis* (Bong.) Carr.)	334.6	52.4
Norway spruce (*Picea abies* (L.) Karsten)	26.3	4.1
Scots pine (*Pinus sylvestris* L.)	8.0	1.3
Other pines (*Pinus* spp.)	61.9	9.7
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	10.4	1.6
Larch spp. (*Larix* spp.)	27.7	4.4
Other conifers	3.8	0.6
Oak spp. (*Quercus robur* L. and *Quercus petraea* (Mattuschka) Liebl.)	16.8	2.6
Beech (*Fagus sylvatica* L.)	9.5	1.5
Ash (*Fraxinus excelsior* L.)	20.6	3.2
Sycamore (*Acer pseudoplatanus* L.)	9.2	1.5
Birch spp. (*Betula pubescens* Ehrh. and *Betula pendula* Roth)	37.4	5.9
Alder (*Alnus glutinosa* (L.) Gaertn)	15.1	2.4
Other long living broadleaves (e.g. *Tilia cordata* Mill.)	9.4	1.5
Other short living broadleaves (e.g. *Salix* spp.)	46.2	7.3
Total	637.1	100

(*Salix* spp.) and hazel (*Corylus avellana*), representing 7.3 % of the forest estate. Birch (Betula spp.)is the next most common broadleaf species occupying 5.9 % of the forest estate.

Information on the age-class is available for all of the stocked forest estate, as the information is collected at tree level. The age of a forest is described as the number of growing seasons since initial planting or natural regeneration. Over half (56 %) of the stocked forest estate is less than 20 years of age (Table 25.9). The private forest estate has a younger age profile compared to the public estate, with 67 % aged 20 years or less in the former.

Development stage categorises the maturity classes of the forest estate. The degree of canopy closure and tree size differentiates one class from another. The stages range from young post establishment forests to overmature forests along with multistoried forests. Similar to the age class results in Table 25.9, the majority of the stocked forest area is classified into development stages that are associated with younger forests (Table 25.10). Over half of the stocked forest estate is classified as having a development stage between the classes post establishment and small pole stage.

Table 25.9 Total stocked forest area by age class (NFI 2013b)

Age class (years)	Area (1000 ha)	Area (%)
1–10	133	20.8
11–20	222	35
21–30	119	18.7
31–40	81	12.7
41–50	39	6.1
>51	43	6.7
Total	637	100

Table 25.10 Total stocked forest area by development stage (NFI 2013b)

Development stage	Area (1000 ha)	Area (%)
Post establishment	62	9.7
Pre thicket	45	7
Thicket	81	12.7
Small pole stage stand	133	21
Pole-stage stand	114	17.9
High forest stand	129	20.2
Overmature stand	10	1.6
Multistoried	63	9.9
Total	637	100

25.2.2 Wood Resources and Their Use

25.2.2.1 Standing Stock, Increment and Drain

Since 2006, the NFI has been used to estimate the growing stock of the forest estate. Following the completion of the second NFI in 2012, the NFI is also used to estimate the increment and drain components. Stem volume is measured from the stump to 70 mm top diameter over bark on trees with a minimum dbh of 70 mm. The volume of both dead and living trees is calculated.

The national definitions for growing stock, gross increment and harvest volume are detailed in Table 25.11. Estimates are based on the individual trees which are mapped in our NFI. Increment and harvest volume are calculated as mean annual estimates for the period between two consecutive NFI's. Gross increment includes an estimate of increment on those trees which were living in the first cycle and died before the second cycle. Stem wood includes all stem parts above the stump i.e. the bole with bark and stem top and conforming to the definitions of tree elements by Gschwantner et al. (2009).

The total standing growing stock of Irish forests is estimated to be over 97 million m^3 (Table 25.12), an increase of over 25 million m^3 on the 2006 s-tanding volume. Gross annual volume increment between 2006 and 2012 was 7.685 million m^3. The mean annual standing volume harvested between 2006 and 2012 is 3.6 million m^3. Nearly half (47 %) of the gross annual increment was harvested.

25.2.2.2 Tree Species and Their Commercial Use

The timber processing sector in Ireland concentrates predominately on the conifer tree species. Sitka spruce (*P. sitchensis*) is the dominant tree species in the Irish forest estate. From an economic point of view Sitka spruce is the key species for the forest industry in Ireland. Over three quarters (79 %) of the volume harvested is from *P. sitchensis*.

In 2014, 2.95 million $m^3$of roundwood were available for processing in the Republic of Ireland, a 9 % increase on 2012 production (Table 25.13). Between

Table 25.11 Definition of growing stock, increment and harvesting

Attribute	Definition
Growing stock	Volume over bark of all living trees from stump to 7 cm top diameter with dbh greater than 7 cm
Gross increment	Volume increment over bark of all living trees from stump to 7 cm top diameter with dbh greater than 7 cm between two consequetive NFI's
Drain	Volume over bark of all living trees from stump to 7 cm top diameter with dbh greater than 7 cm that were harvested or died in the subsequent NFI

Table 25.12 Tree species group by growing stock, increment and drain (NFI 2013b)

Species group	Growing stock (m^3)	Gross increment (m^3)	Drain (m^3)
Sitka spruce	57,555,180	5,393,361	2,843,123
Norway spruce	3,981,639	358,320	125,358
Scots Pine	1,056,372	35,236	8570
Other Pines	9,457,592	671,912	425,302
Douglas-fir	2,621,488	147,870	30,292
Larch spp.	3,440,816	300,292	13,200
Other conifers	1,676,250	82,580	52,928
Oak spp.	3,509,782	85,527	1624
Beech	2,775,131	83,363	11,037
Ash	2,393,014	125,968	28,710
Sycamore	1,019,760	52,886	11,320
Birch spp.	3,073,244	139,449	11,903
Alder	1,332,129	60,528	7659
Other long living broadleaves	1,379,308	55,837	2236
Other short living broadleaves	2,204,547	92,208	43,167
Total	97,476,251	7,685,336	3,616,430

Table 25.13 Roundwood available for processing in the Republic of Ireland 2006–2013 (1000 m^3)

Year	Source			Total roundwood	Roundwood product		
	Log imports less exports	Coillte output	Private output		Sawlog	Pulp	Stake
2006	214	2700	240	3154	2176	820	158
2007	57	2556	390	3003	1934	889	180
2008	106	2279	118	2503	1619	804	80
2009	−63	2354	130	2421	1602	731	88
2010	28	2217	463	2708	1603	987	118
2011	55	2299	386	2740	1580	1044	116
2012	−18	2269	343	2594	1622	841	131
2013	49	2474	328	2851	1710	1024	117
2014	68	2434	447	2949	1815	987	147

2006 and 2014 roundwood production from privately owned forests averaged just over 316,111 m^3. In 2014, 447,000 m^3 of roundwood came from privately owned forests. The annual national roundwood available for wood processing, excluding firewood and hardwood, is shown in Table 25.13 (Knaggs and O'Driscoll 2015). The sharp downturn in roundwood available for processing in 2008 and 2009 reflected the downturn in the domestic construction sector. In this time domestic sawmills were also seeking to increase their share in export markets.

In recent years the private sector has begun to make a substantial contribution to the annual harvest. This reflects the greater area of private forests reaching first thinning stage, much of which was planted in the early 1990s, and increased export market share gained by sawmills.

Forests also provide a source of renewable raw materials for fuel and wood products which help mitigate rises in greenhouse gases. Usage of wood fuels is increasing due to renewable energy polices and as young plantations enter the production stage. In 2014, 36.3 % of roundwood harvested was used for energy generation, mainly within the forest products sector (Table 25.14) (Knaggs and O'Driscoll 2015).

25.3 Assessment of Wood Resources

25.3.1 Forest Available for Wood Supply

25.3.1.1 Assessment of Restrictions

In 2012, the concept of availability for wood supply was introduced into Ireland's NFI. Plots were post-stratified using data already recorded in the NFI or through intersections with GIS datasets. Improvements to the current system will be identified prior to the next NFI. To date no consideration has been given to economic aspects.

Table 25.14 Use of forest-based biomass and as a proportion of total roundwood harvest (2010–2014)

	2010	2011	2012	2013	2014
	1000 m^3 over bark roundwood equivalents				
Wood-biomass use by the energy and forest products industry	554	572	611	660	760
Roundwood chipped for primary energy use	39	41	30	100	100
Domestic firewood use	199	214	225	230	235
Short rotation coppice	1	5	5	5	5
Wood pellets and briquettes	121	129	144	161	150
Charcoal	2	5	2	1	1
Total	916	966	1017	1157	1251
Roundwood harvest					
Roundwood available for processing	2708	2740	2594	2852	2975
Firewood harvest	199	214	225	230	235
Total	2907	2954	2819	3082	3210
Forest-based biomass as a % of total roundwood harvest	31.5	32.6	36.0	33.5	36.3

FAWS was described using the following three classes:

1. Available: Forest where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood. Includes: Areas where, although there are no such restrictions, harvesting is not taking place, for example areas included in long-term utilisation plans or intentions.
2. Unlikely: Forest where physical productivity or wood quality is too low or harvesting and transport costs are too high to warrant wood harvesting, apart from occasional cuttings for autoconsumption. Areas include:
   - Forest Type is scrub
   - Height growth status is stagnating
   - Severe water logging
   - Excessive slope (>30°).
3. Not available: Forest with legal restrictions or restrictions resulting from other political decisions, which totally exclude or severely limit wood supply, inter alia for reasons of environmental or biological diversity conservation, e.g. protection forest and other protected areas, such as those of special environmental, scientific, historical, cultural or spiritual interest. Areas classified as National Parks and Nature Reserves are included in this class.

25.3.1.2 Estimation

The majority of growing stock in Ireland is classified as being available based on our national definition for FAWS (Table 25.15).

Table 25.15 Growing stock by forest available for wood supply (NFI 2013b)

FAWS	Growing stock (1000 m^3)	Growing stock (%)
Available	86,667	88.9
Unlikely	9852	10.1
Not available	958	1
Total	97,476	100

25.3.2 Wood Quality

25.3.2.1 Stem Quality and Assortments

In Ireland's NFI, attributes relating to stem quality are assessed, but there is no stem quality or assortment classification system.

25.3.2.2 Assessment and Measurement

Stem quality assessments are carried out on each mapped tree. The following stem quality attributes are assessed:

a. Tree status i.e. dead or alive
b. Tree dbh
c. Tree height
d. Stem damage
    - Abiotic damage
    - Biotic damage
e. Stem damage
    - Forking
    - Tree break
    - Curvature
f. Rottening
    - Stem cavity
    - Presence of fruiting body
g. Branching
    - Size
    - Density
h. Base of crown
    - Living
    - Dead
i. Straightness
j. Crown projection or diameter
k. Artificial removal of branches
l. Upper diameter.

25.3.3 *Assessment of Change*

25.3.3.1 Assessment and Measurement

Ireland's NFI uses permanent sample plots and maps individual trees on the plot. As a result change assessment is completed using direct measurement at two consecutive points in time. Modelling is only used for those trees which have ingrown or have harvested/died.

The increment is assessed directly on all living trees which were mapped in the first cycle and are still present in the second cycle. This information is used to model increment on ingrowth and harvested trees. Before volume increment can be modelled, the following tree attributes have to be present for two distinct categories of trees:

1. Increment of survivor trees

    - Diameter at breast height (dbh)
      The dbh is assessed on all living trees which were mapped in the first cycle and are still present in the second cycle.

    - Height
      In the first cycle, height measurements are taken on 7 trees per species across the dbh range. From this data, a species dbh-ht model was developed for the plot to assign a height to all mapped trees on the plot. In the second cycle the same process is repeated, with a new model generated. Where less than four height sample trees are assessed, then a global species dbh-ht model is used.

2. Increment of harvested/died and ingrowth trees

    - Diameter at breast height (dbh)
      Nearest neighbour non-parametric modelling is used to estimate dbh increment. The model compares each tree that has a missing dbh with all other trees that have a dbh value from both cycles, and uses predefined attribute information to find a tree that will be most similar in terms of the attribute data supplied. The kNN modelling process uses an iterative approach which identifies those attributes most significant in predicating dbh increment.
    - Height
      After the modelled dbh has been estimated, the dbh-ht models are used to estimate tree height.

25.3.3.2 Estimation of Increment

Following the dbh and height estimation the volume of each tree is estimated for each NFI cycle, which allows calculation of volume increment. The increment

Table 25.16 Total gross annual volume increment, 2006–2012 (NFI 2013b)

Increment components	Increment (m^3)	Increment (%)
Trees surviving from previous cycle	4,171,529	54.4
Ingrowth trees on Existing plots	2,874,046	37.4
Ingrowth trees on new plots	10,483	0.1
Living to lying dead	24,173	0.3
Living to standing dead	17,854	0.2
Living to harvested tree	561,767	7.3
Deforestation[a]	25,483	0.3
Total	7,685,336	100

[a]Increment between first assessment date and removal date

estimated in Ireland's NFI includes volume increment on those trees which were living between two successive NFIs that have a dbh ≥70 mm. Gross annual volume increment between 2006 and 2012 was 7.685 million m^3 (Table 25.16). The calculation of net annual increment is possible using the components specified in Table 25.16 below, which may vary depending on reporting requirements.

25.3.3.3 Estimation of Drain

The drain estimated in Ireland's NFI includes the volume of those living trees that were removed between two successive NFIs that have a dbh ≥70 mm. Gross annual volume drain between 2006 and 2012 was 4.150 million m^3 (Table 25.17). The calculation of net annual increment is possible using the components specified in Table 25.17 below, which may vary depending on reporting requirements.

25.3.4 Other Wooded Land and Trees Outside Forests

25.3.4.1 Assessment and Measurement

During the NFI air photo interpretation exercise of other wooded land and hedgerows are assessed. Other wooded land and trees outside the forest are not assessed in the field as part of our NFI.

Table 25.17 Total gross annual volume drain, 2006–2012 (NFI 2013b)

Drain components	Drain (1000 m^3)	Drain (%)
Living to lying dead	198	4.8
Living to standing dead	224	5.4
Living to harvested tree	3616	87.1
Deforestation	112	2.7
Total	4150	100

Table 25.18 Trees outside the forest and other wooded land (NFI 2013b)

Land-use type	Area (ha)	Area (%)	Correspondence to FRA
Hedgerow	271,912	3.9	Partly TOF
Other Woodland	47,681	0.7	Partly OWL

25.3.4.2 Estimation

The area of Other Woodland and hedgerows is estimated to be 47,681 ha and 271,912 ha, respectively (Table 25.18). In the next cycle of Ireland's NFI, the classification of TOF and OWL will be incorporated at the photo-interpretation stage. There are no plans to field visit TOF or OWL plots.

25.4 Conclusion

During 2015, the third NFI cycle commenced, with six field staff having been recruited for field data collection. Field-work will last for two years and one further year is required for data analysis. The third NFI will facilitate the on-going monitoring of the national forest estate, including the assessment of change overtime.

The scope of the 3rd NFI cycle has broadened to collect more detailed information on forest damage. The only change made to the NFI design, is that the radius of the inner concentric sample plot has increased from 3 to 4 m, with a view to collecting more precise information on smaller trees.

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Chapter 26
Italy

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26.1 The Italian National Forest Inventory

26.1.1 History and Objectives

The first Italian National Forest Inventory (NFI) was carried out between 1983 and 1986, with the results referenced to the year 1985 (MAF-ISAFA 1988). That inventory adopted a single-phase sampling design and the ground survey was carried out within plots systematically distributed on a 3 × 3 km grid across the country. By the end of the 1990s the information provided by the first NFI appeared to be dated and also insufficient to meet the information requirements resulting from the international processes that commenced in the intervening years. Following a feasibility study carried out in 1999 (ISAFA 1999), a Ministerial order founded the Italian National Forest Inventory as a permanent tool for forest monitoring. At the same time, the second Italian inventory was launched in 2001. It was carried out between 2002 and 2006 (reference year 2005), with a supplementary survey on soil carbon in the years 2008 and 2009. The second Italian inventory started due to the pressing need of statistics on forest carbon pools; for this reason it was named "National Inventory of Forests and forest Carbon pools" with the acronym "INFC". Starting with the second inventory, the results of the NFI are considered to be the official statistics, but are not used for timber/wood production statistics. Previously the official forest statistics were provided by the Italian Institute for Statistics (ISTAT) and were based on information collected in the 1950s and annually

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updated through questionnaires completed by the National Forest Service (NFS) officers. Another important innovation of the second NFI has been that to provide reliable data at the regional level, since regional or sub-regional forest inventories had been carried out by only half of the Italian regions between 1985 and 2000 (Gasparini et al. 2010a; Tosi and Monteccone 2004). The planning of the third national forest inventory started in the autumn of 2012 and its first phase was carried out in 2013; its reference year is likely to be the year 2015. The aim of this inventory is to make available up-to-date statistics needed for forest policy at national and regional level and to provide the Italian authorities with the data required by international agreements. NFI data are used for national reporting for the Kyoto protocol and the UNFCCC, and for international enquiries such as the FAO Forest Resources Assessments and the Pan-European reporting. The NFI also supports public administrations carrying out regional level inventories and research institutions by providing data and/or original estimates. The three Italian inventories are also known as IFNI85, INFC2005 and INFC2015. They have been carried out by the NFS, that is responsible for the project funding, logistic and surveys. The Forest Monitoring and Management Research Unit within the Agricultural Research Council (CRA-MPF) is the scientific coordinator and is responsible for the protocols, the field staff training, data control, data processing and the publication of results.

26.1.2 Sampling Methods and Periodicity

The Italian NFI adopts a three-phase sampling design for stratification (Fattorini et al. 2006) (Fig. 26.1). The first phase is carried out by photo-interpretation of about 300,000 sampling points randomly selected (one per each square km cell of the sampling grid covering the country) using aerial ortho-photographs (black and white for INFC2005, colour and infrared for INFC2015). The photo-interpretation

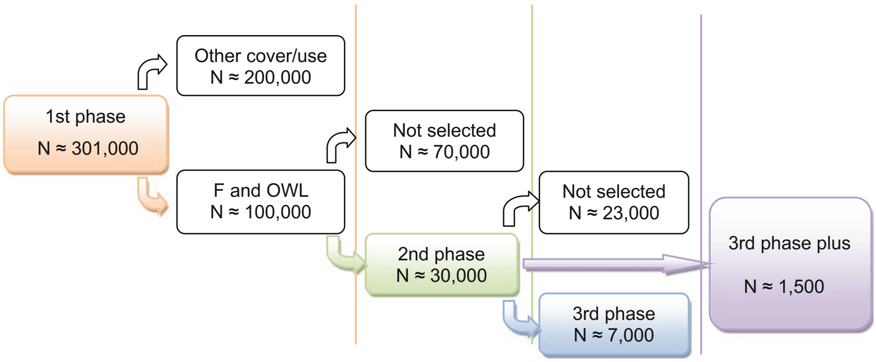

Fig. 26.1 Number of sampling points and flow diagram

is carried out by observing the land cover/land use of an area around each sampling point to derive a preliminary estimate of the extent of Forest and Other Wooded Land (OWL) at national and regional level and to define the second phase strata. The second phase is carried out in the field on a subsample of the first phase points randomly selected from forest land cover/use, stratified by Administrative Region (about 30,000 sampling points in INFC2005—one point every 349 ha of Forest and OWL). The main objective of the second phase is to refine the first phase classification, distinguishing Forest from OWL, and to identify third phase strata. Observations are carried out within circular plots of 2500 m^2, each centred on a NFI sample point. Each sample plot is classified according to a scheme consisting, among others, of 23 forest categories. The third phase is carried out on a subsample of the second phase sample plots, stratified by Region and forest category (about 7000 in INFC2005—one point every 1276 ha of Forest) (Gasparini et al. 2010a). The third phase aims primarily at estimating quantitative parameters (growing stock, annual increment, deadwood biomass, regeneration, others). Fieldwork principally concerns the assessment of trees and deadwood within two circular concentric plots (radii 13 and 4 m); regeneration and shrubs were measured in two small satellite plots (radius 2 m). In INFC2005, an additional survey (third phase plus) was carried out in 2008 and 2009 on about 1500 plots especially addressed to survey and sample litter and soil for carbon estimation (Gasparini 2011; Gasparini and Di Cosmo 2014). Third phase plus plots selection followed same criteria as for the third phase (random selection of second phase sample plots, stratified by Region and forest category). Observations and measurements on vegetation were carried out following the third phase protocol. In addition, litter and soil were sampled within three squared areas/pits (Gasparini et al. 2010b; Gasparini and Rizzo 2013) per NFI sample plot. Samples of deadwood, regeneration and shrubs were collected for laboratory analysis. Basic density values were derived for deadwood at different decay stage, while for undergrowth vegetation the dry and fresh weights were calculated (Di Cosmo et al. 2013).

The first phase of the new cycle (INFC2015) was completed during 2013–2014 and the reference year of its final results from the field surveys is planned to be 2015, with a cycle length of 10 years. The sampling design of the new cycle is unchanged, but some changes concern the distribution over time of the field surveys and the third phase sample size. A re-measurement of a large part of INFC2005 third phase plots is also planned, as their plot centre was permanently marked, even though estimates on changes will not rely on permanent plots, as no information about tree position was collected.

26.1.3 Data Collection

The data recorded for each sample point varies from phase to phase. In the first phase, each point is classified according to broad land use/cover categories consistent, at the highest level, with the Corine Land Cover system (European

Commission 1993). A subsample of the points classified as Forest or Other Wooded Land according to the FAO definition is selected for field visit during the second phase, with the aim to survey qualitative variables and definitively classify the vegetation in accordance with a system of forest categories and sub-categories. Quantitative measurements are carried out during the third phase, although some qualitative observations are also recorded. The third phase plus protocol on vegetation survey is similar to the third phase one, but further investigations and measurements are carried out on deadwood and woody understory vegetation of which samples are collected for laboratory analysis.

The most important qualitative information recorded, by broad category, is related to:

- administrative data—ownership, restriction for forestry use, planning, wood availability
- site features—land use/cover, elevation, exposure, slope, accessibility
- vegetation characteristics—inventory category, forest category and sub-category, conifer/broadleaves mixture
- stand features: crown cover, development class, age class, texture, origin, health status (defoliation, disease, damage, etc.), silvicultural system, harvest method, extraction method.

Quantitative data include:

- for all trees—species, diameter at breast height (dbh), vitality and integrity, decay class (only for dead trees)
- for sample trees—total height, height of the base of the crown, diameter increment
- for regeneration and shrubs—number of individual plants by species and dimensional class, origin, damages, individual mean weight (fresh and dry after laboratory treatment)
- for deadwood—standing dead trees, diameter at breast height, total height and decay class
- for deadwood—coarse woody debris, the two end diameters, the distance between the two (debris length) and decay class
- for stumps, diameter at cut section, height and decay class;
- for fine woody debris, weight per area unit (fresh and dry weight after laboratory treatment).

The NFI sample plot configuration is illustrated in Fig. 26.2. With reference to wood supply, concentric circular plots are used for callipering (radius 4 m: dbh $\geq$ 4.5 cm; radius 13 m: dbh $\geq$ 9.5 cm) and height/increment sample trees selection; 2 m circular plots are used for regeneration and shrub measurements. Stumps of removed trees (diameter $\geq$9.5 cm) are measured within the 13 m plot. Squared areas (S1–3) are used for litter and soil measurement and collection.

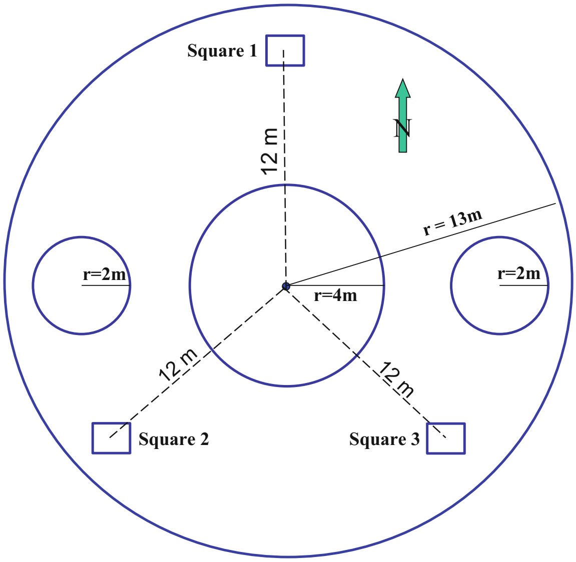

Fig. 26.2 NFI sample plot configuration

26.1.4 Data Processing, Reporting and Use of Results

Sample tree data are used to develop species-specific models for predicting total tree height from tree dbh and plot tree dominant height, in such a way to predict the height of any callipered tree (Tabacchi and Di Cosmo 2011). The stem volume (including large branches) of any tree in the plot is estimated by species-specific functions that use dbh and total tree height as independent variables and above-ground tree biomass is estimated by species-specific functions on the basis of the same two independent variables (Tabacchi et al. 2011a). The volume and biomass of all trees in the plot are summed up to get the value per hectare of the plot. Diameter increment measured for the sample trees is used to estimate the mean percent increment for the plot, which is weighed by tree size. By using the mean percent increment and tree dbh, the current annual increment of any tree in the plot is then estimated and finally current annual volume increment of the plot is obtained.

The total forest area and its distribution by forest type are calculated by a two-phase estimation process from the land use/land cover data of the first inventory phase (photo-interpretation) and the field classified forest categories and sub-categories of the second phase. The weight of each land use/land cover stratum in the Regions of Italy (*Wij*) is equal to the proportion "number of first phase sample units of the stratum divided by total number of sample units". The area of each inventory stratum *k* (forest, forest category or sub-category) is calculated by multiplying the total area of the sampling grid by the sum of the proportions of second phase sample units assigned to the inventory stratum (*Wijk*), for each land use/land cover stratum, multiplied by *Wij*. The sums of estimated areas of inventory strata at regional and national level are then calibrated with the known values of the regional/national total land area provided by ISTAT for the year 2002.

The total value for a quantitative variable (volume, biomass, increment) for each inventory stratum is derived from the sum of sample averages of the Horvitz-Thompson estimates (Horvitz and Thompson 1952) of the total of the variable multiplied by the stratum weight (combined weight, *Wij* by *Wijk*). Horvitz-Thompson (1952) estimates of the total of the variable in the sampling units of the stratum are equal to the total values of the variable measured in a plot of a prefixed area multiplied by the ratio between the area of the cell containing the sample point (1 km^2) and the plot area (Fattorini et al. 2006).

The results of the Italian NFI are made available as soon as they are obtained, by publishing on the official webpage (www.infc.it). After each cycle a book is published to make methods and results available in the most comprehensive and methodical way. The Italian NFI supports international reporting in many ways. Firstly, by providing statistics on forests and related variables that are directly usable for the reports; secondly, by computing ad hoc estimates based on NFI data; thirdly by the participation of NFI experts in workshops or technical meetings; lastly by continuous efforts to harmonise national definitions and methodologies for producing estimates eligible for international reporting requirements. The main reporting processes in which the Italian NFI is involved are: the Forest Resources Assessments of the Food and Agriculture Organization (FAO-FRA), the reporting on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, the monitoring of forest management sustainability for the Ministerial Conference on the Protection of Forest in Europe (MCPFE) and more recently for FOREST EUROPE.

26.2 Land Use and Forest Resources

26.2.1 Classification of Land and Forests

26.2.1.1 General Land Classification

The classification system adopted by the Italian NFI was defined under the requirement, stated in the NFI Ministerial order, to be consistent with the definitions agreed at the international level and the ones used by ISTAT. At the most general level (first order classification), the total country area is classified accordingly with the five CORINE Land Cover classes (European Commission 1993). The five classes are subdivided into eight second order land use/cover classes; only the most relevant for forest statistics among these are further subdivided (Table 26.1).

Table 26.1 Italian NFI classification system of land use/land cover

First order classification	Second order classification	Third order classification
Artificial surfaces	Urban parks	
	Other artificial surfaces	
Agricultural areas	Timber/wood plantations	
	Fruit plantations	
	Other agricultural areas	
Forests and semi-natural areas	Woodland	Tall trees forest
		Temporarily unstocked areas
		Other wooded land
	Grassland, pastures, uncultivated land	
	Open areas with little or no vegetation	
Wetlands		
Water bodies		

For forest, the FAO definition, as adopted in FRA2000 (UN-ECE/FAO 1997) is used; forest is made by tall trees forests, including young stands, temporarily unstocked areas and timber/wood plantations.

26.2.1.2 Forest Classification

The classification of forest (Table 26.2) is based on a system of 17 forest categories for tall trees forests, defined on the basis of the species prevalent in terms of crown cover, and three forest categories for timber/wood plantations (poplar plantations, other broadleaves plantations and conifer plantations). Forest categories are one of the stratification criteria for selecting the third phase sample (the other criterion being the Administrative Region). All the NFI statistics are produced with reference to the inventory macro-categories (Forest, OWL), the inventory categories (for the forest: tall trees forests, timber/wood plantations, temporarily unstocked areas) and the forest categories detailed in Table 26.2, either for qualitative attributes or quantitative ones, although estimates for some variables are further disaggregated (e.g. number of trees, basal area, volume, biomass and annual increment by species, by diameter class, by stand age). In Table 26.2, the area of the OWL inventory categories is given for the purpose of comparison. Forest categories are named after the prevailing tree species, in terms of crown cover. NFI statistics are available at http://www.infc.it.

Table 26.2 Area, growing stock and annual increment of the Italian Forest by forest category, and area of the inventory categories of the Other Wooded Land

Inventory category of forest	Forest categories	Area (ha)	Volume (m^3)	Annual increment (m^3)
Tall trees forests	*Larix decidua* and *Pinus cembra*	382,372	76,930,988	1,282,925
	Picea excelsa	586,082	218,166,422	4,567,710
	Abies alba	68,460	29,244,196	565,119
	Pinus sylvestris and *Pinus uncinata*	151,671	29,011,580	529,251
	Black pines group (*Pinus nigra* Arn., *Pinus laricio* Poiret)	236,467	53,280,460	1,404,011
	Mediterranean pines (*Pinis pinea* L., *Pinus pinaster* Ait., *Pinus halepensis* Mill.)	226,101	30,204,769	833,255
	Other coniferous forests	63,407	12,496,202	404,893
	Fagus sylvatica	1,035,103	240,009,507	5,597,810
	Temperate oak spp. (*Quercus pubescens* Willd., *Quercus petraea* Liebl., *Quercus robur* L.,)	1,084,247	77,405,681	2,206,439
	Mediterranean oak spp. (*Quercus cerris* L., *Quercus frainetto* Ten., *Quercus trojana* Webb., *Quercus macrolepis* Kotschy.)	1,010,986	103,797,336	3,233,075
	Castanea sativa	788,408	139,697,903	4,941,237
	Ostrya carpinifolia and *Carpinus betulus*	852,202	68,949,448	2,452,274
	Hygrophilous forests	229,054	24,382,385	960,264
	Other deciduous broadleaved forests	994,777	94,003,164	4,006,403
	Quercus ilex	620,318	45,598,302	1,453,949
	Quercus suber	168,602	8,444,671	220,298
	Other deciduous broadleaved forests	84,712	4,476,479	226,448
Timber/ wood plantations	Poplar plantations	66,269	7,518,275	621,688
	Other broadleaved plantations	40,985	1,976,387	196,488
	Coniferous plantations	14,998	2,751,832	121,672
Temporarily unstocked areas	Temporarily unstocked areas	53,981	1,070,512	47,083
	Total forest	8,759,200	1,269,416,499	35,872,293
Inventory category of other wooded land				
Short trees forest	–	124,229	–	–
Sparse forest	–	146,415	–	–
Scrubland	–	468,678	–	–
Shrubs	–	990,916	–	–
Inaccessible areas	–	398,095	–	–
	Total other wooded land	1,708,333	–	–

26.2.1.3 Classification by Ownership Categories

Overall, two third of forests are private in Italy (Table 26.3) but a larger part (87.1 %) of plantations are privately owned. Among the private ownership types, individuals hold the highest percentage (79.1 %), whereas most of the public ownership belongs to Provinces or Municipalities (65.8 %).

26.2.1.4 Legal and Other Restrictions for Wood Use

Although differences are found among the Administrative Regions and/or other public bodies (such as, for example the National Parks), permits are generally required for cutting trees. For example, 87 % of forests are on areas with restrictions for hydrogeological protection. Cuttings in these forests have to be explicitly authorised by the regional forest authority, as stated by the national law. In practical terms, this takes the form of an approval process where a harvesting plan prepared by a professional forester is submitted for approval. This plan describes what is proposed to be cut, quantities, tools used for extracting, etc.

Apart from national laws like the one described above, a number of legal restrictions may affect availability of wood supply such those listed below. However it is important to notice that if a forest area is within one of the following categories, it does not indicate, as a direct consequence, that cuttings are not allowed:

Table 26.3 Forest ownership of forests in Italy

Ownership	Type	Area (ha)	Area (%)
Private forest	Individual	4,583,893	
	Corporate	358,705	
	Other private entities	258,792	
	Unknown	596,325	
	Total private	5,797,715	66.2
Public forest	State or Region	695,153	
	Province or municipality	1,920,967	
	Other public entities	244,231	
	Unknown/not recorded	71,336	
	Total public[a]	2,931,688	33.5
Unknown		29,798	0.3
Total		8,759,200	100

[a]The sum of the public forest types differs from the overall total public by 1 ha. This is due to computational approximations (totals are estimated independently by the NFI and not as a sum of types)

National Parks, Regional Parks, Natural Reserves, Natura 2000 sites, Sites of Community Importance (SCI), Special Protection Areas (SPA) and others may include areas where cutting is definitively forbidden (strict nature reserve, that covers 93,127 ha in National Parks) but generally involves “only” stricter/different criteria for utilisation, for protection purposes. Forest areas marked by presence of special restrictions (military, or proximity to airports, roads, railways, electrical lines, etc.) is on the whole restricted (only 27,803 ha).

The characteristics that make a forest available for wood supply depend on many variables that involve legal restrictions, accessibility (e.g. slope, roading and harvesting technology) and others more explicitly related to the economical viability for forest operations. Field crews are asked to assign each plot to available/not available for wood supply. This direct classification of plots was adopted because comparable stands may be different in availability due to regional/local features, for example wood/timber market, forestry traditions, tree cutting due to family forest rights, etc.

26.2.1.5 Further Classification of Forests

Further classification of forest areas is based on forest sub-categories, broadleaves/conifers mixture, crown cover percentage, texture, vertical structure, protection status. Concerning timber/wood production, forests are classified by silvicultural system, development stage, age class and availability for wood supply.

26.2.2 Classification of Other Wooded Land and Trees Outside Forests

26.2.2.1 Other Wooded Land Classification

Other wooded land (OWL) is defined as in FRA2000 (UN-ECE/FAO 1997) and further classified accordingly into four inventory categories:

- short tree forest (formations with cover greater than 10 % of tree species with potential height in situ between 2 and 5 m)
- sparse forest (formations with cover between 5 % and 10 % of tree species with potential height in situ of at least 5 m)
- scrubland (formations with cover greater than 10 % of trees with potential height in situ less than 2 m)
- shrubs (formations with cover greater than 10 % of shrub species and tree crown cover less than 5 %).

By convention also inaccessible areas (plots neither reachable nor visible from a distance for secure vegetation classification) are assigned to OWL.

26.2.2.2 Trees Outside Forests

Trees outside forest (TOF) are not assessed in the NFI. Nevertheless, on the basis of the first phase photo-interpretation data, parallel investigations have been carried out and a number of studies completed (e.g. Paletto et al. 2006; Pignatti et al. 2011; De Natale et al. 2011; De Foresta et al. 2013). The national definition for TOF used in these studies includes "linear formations" of forest trees (at least three trees), 3–20 m width, and "small woods" of forest trees with a minimum tree crown cover of 10 %, larger than 20 m but spanning less than 0.5 ha. The mentioned studies aimed primarily to assess consistency of TOF, frequency by the two TOF components by Province as well as relations with agricultural systems and forests (e.g. distance from the nearest forest).

26.2.3 Wood Resources and Their Use

26.2.3.1 Standing Stock, Increment and Drain

Trees species composition in the Italian forests, in terms of number of trees (dbh ≥ 4.5 cm), basal area, volume, current annual increment and biomass are presented in Table 26.4. The species listed provide all together the 80 % of the timber/wood volume and the remaining 20 % is given by about thirty other species (Pignatti and De Natale 2011).

Species in Table 26.4 have been ordered by decreasing volume. All forest species in Italy have commercial value since they mainly supply fuelwood and timber to a lesser extent. For this reason, the species data in Table 26.4 is not indicative of the total potential available for wood supply. Forest area is more useful to assess availability. The proportion between the use for fuelwood and for timber is also due to inherent characteristics of the species and some of them are used exclusively or predominantly for fuelwood. Among the most important and widespread broadleaves, beech and chestnut are found either in high forests or in coppices and produce both fuelwood and timber.

The distribution of forest area by silvicultural system and development stage provides a general overview on potential wood/timber supply. Table 26.5 details the distribution of tall trees forests, whose area covers the 98 % of the total forest area in the country.

Plantations are generally available for wood/timber supply but cover only a small proportion of the total forest area (1.4 %—see Table 26.2). Quantitative NFI surveys are not carried out in OWL or TOF. For this reason, availability of wood/timber from them is not assessed and still not known for the whole country.

Increment and drain are assessed in all the third phase NFI plots, regardless of any criteria related to management, wood availability or species. Increment is calculated on the basis of the mean percent annual increment of sample plots, and statistics are produced by forest categories (Table 26.2) and by species

Table 26.4 The main thirteen tree species in the Italian forests, in terms of growing stock of volume (http://www.infc.it)

Species	Number of trees (1000)	Basal area (1000 m^2)	Volume (1000 m^3)	Annual increment (1000 m^3)	Biomass (1000 Mg)
Fagus sylvatica	1,402,336	26,996	218,746	5108	174,059
Picea excelsa	459,099	19,237	202,582	4228	101,680
Castanea sativa	954,212	19,799	130,899	4667	82,279
Quercus cerris[a]	915,137	13,786	93,965	2906	76,354
Larix decidua	142,054	9158	81,693	1438	43,835
Quercus pubescens Willd.[a]	980,276	13,202	72,228	2162	62,298
Ostrya carpinifolia Scop.[a]	1,315,310	8656	42,840	1496	39,021
Quercus ilex[a]	815,437	7117	35,174	1080	35,729
Abies alba	74,621	3312	34,344	705	17,572
Pinus nigra	116,730	4071	30,456	817	18,960
Pinus silvestris	111,837	4069	30,129	584	16,801
Pinus laricio	63,869	3407	24,693	698	10,318
Robinia pseudacacia L.[a]	295,187	3130	20,930	1004	17,206
Other species	4,303,527	42,494	250,736	8980	178,331
Total	11,949,631	178,434	1,269,416	35,872	874,443

[a]Species used exclusively or predominantly for fuelwood

Table 26.5 Tall trees forest by silvicultural system and development stage (http://www.infc.it)

Silvicultural system	Development stage	Area (ha)
Coppices	Young stands	361,615
	Adult stands	2,045,382
	Mature stands	1,216,183
	In regeneration stands	18,124
	Uneven-aged sprout coppice (coppice selection)	21,471
	Development stage not classified	369
	Total	3,663,143
Even-aged high forest and singled coppice	Seedling	12,478
	Sapling	27,615
	Pole	95,934
	Mature and over-mature	530,039
	Regenerating forest (clear cut)	839,177
	Development stage not classified	3412
	Even-aged high forest and singled coppice	369
	Total	1,509,023
Uneven-aged and irregular high forest	Not relevant	1,648,943
Special or not canonical silvicultural system	Not relevant	1,761,860
Tall trees forest	Total	8,582,968

(Table 26.4). Drain is estimated as the volume of trees removed in the twelve months before the survey, from the stump diameter (Table 26.6).

Stand origin is natural or semi-natural in the 85 % of forest area. Once the plantations are excluded, forests are almost exclusively established with natural regeneration by means of coppice shoots (about 43 % of the tall trees forest area is covered by coppice forests) and seeds from seed bearing trees.

Generally stands are simply cut when they are mature (70 % of forest area under silviculture) and the 23 % of them is treated also with tending, thinning during the rotation and other practices. The remaining 7 % is managed more intensively (with practices typical of plantations or stands cultivated for non-wood forest products).

Table 26.6 Drain (volume of stem and large branches of trees cut in one year) from the Italian forests

	Tall tree forests	Plantations	Temporarily unstocked areas	Forest
Total (m^3)	13,362,266	409,213	25,384	13,796,864
per hectare (m^3)	1.6	3.4	0.5	1.6

26.3 Assessment of Wood Resources

26.3.1 Forest Available for Wood Supply

26.3.1.1 Assessment of Restrictions

A strict national definition for forest available for wood supply (FAWS) does not exist, and the UNECE-FAO reference definition is used to classify the plot as forest available/not available for wood supply. Field staff are asked to make a synthesis of all useful information/evaluations (restrictions due to laws, orography, physiography, roads, stand characteristics, local uses, others) that suggest whether or not cuttings are feasible/realistic. The evaluation is also based on the economic value of wood and timber.

Whether or not the NFI plot is contained in a protected area (whichever the type) is generally known before going to the field, from accessible national GIS database. Maps are also available on other types of restriction/protection status, such as the hydrogeological protection areas. As the survey is conducted by NFS foresters working in their own region, they are generally aware of local additional restrictions and are also encouraged to ask for the cooperation of the forest office based in the specific area where the NFI plot is located.

Variables on legacy status and related to availability for wood supply are:

- general restrictions for nature conservation
  - inclusion or not in National Parks (by degree of protection in case of plots in National Parks)
  - state natural reserves, regional parks, regional natural reserves, other protected areas (classified according to the national law)
  - NATURA 2000 sites (Special Areas of Conservation—SACs—and Special Protection areas—SPAs)
  - Ramsar List of Wetlands of International Importance
- special restrictions
  - military
  - proximity to airports, roads, railways
  - electrical lines.

Other kinds of variables related to FAWS are recorded in each plot, including: terrain gradient; roads (distance and difference in level between plot and nearest road); elevation; ground roughness; accessibility.

Based on NFI field staff assessment of FAWS, a large majority (88.4 %) of the forest area (7,741,176 ha) is available for wood supply. The direct judgment of availability assessed in the field represents the most reliable synthesis of the influence of the various factors (site related, legal, and economic) affecting wood availability in the specific context of the Administrative Regions.

26.3.2 *Wood Quality*

26.3.2.1 Stem Quality and Assortments

The Italian NFI does not provide estimates on stem quality and assortments. Official statistics on timber/wood production in Italy are not provided by the NFI, and are not based on NFI data on drain.

Italy is traditionally a timber/wood importing country. According to FAO (2013 data), half of the production of timber and wood in the decade 2002–2012 consisted of woodfuel and only about 30 % of the production was made of assortments related to stem quality (Fig. 26.3). Statistics refer to round wood, wood chips and particles, wood residues, sawn wood. Distribution of forest species usable for timber production varies consistently along the country, as well as forestry traditions linked to their use, markets and presence of local industries. In spite of expertise and time required for the assessment of stem quality during the NFI survey, the gain of such an evaluation is thought worthless, because of the many factors affecting timber production.

26.3.3 *Assessment of Change*

26.3.3.1 Assessments and Measurements

The stem and large branch volume increment (upper stem diameter limit for branches and top—5 cm) of living trees is assessed in the third phase plots. Variables related to the increment assessment are:

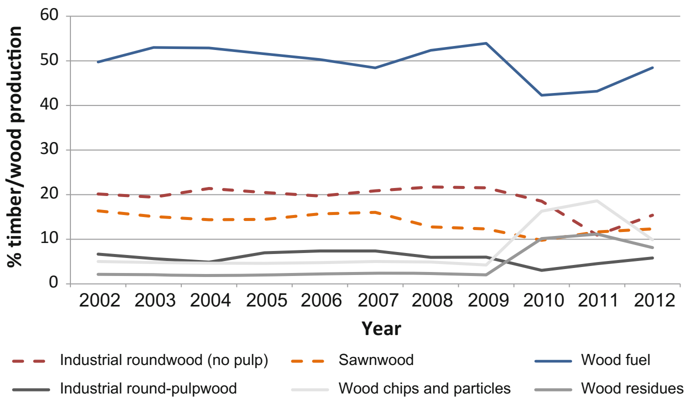

Fig. 26.3 Percentage of timber/wood production by item in the decade 2002–2012 in Italy (data from FAO 2013)

1. diameter increment—one specimen core is taken with a borer from the sample trees in the plot and annual increment is measured from bark to pith.
2. height increment—the height of the cored trees at the inventory year and that at the former time (nominally one year before) is estimated by tree height prediction models based on dbh and plot dominant height.

26.3.3.2 Estimation of Increment

To estimate the annual increment, cores are taken from sample trees. The sample trees are selected among those callipered in the NFI plot and free from visible faults, using a protocol based on both random and representative criteria. The five trees nearest to the plot centre, the three largest ones and two of the rarest by species or size in the plot are selected as sample trees. As the trees in the last two categories may be also among the nearest to the plot centre, the total number of sample trees per plot ranges between five and ten.

At sample tree level, the data recorded for volume increment estimation are: species, diameter over bark and total height. In order to estimate the current diameter increment, one core per sample tree is taken with a Pressler increment borer at 1.30 m above ground level. The core is taken along with the plot centre direction, in order to avoid systematic annual rings eccentricity due to site features, such as slope, prevailing winds and others. The thickness of the outermost 5 rings (excluding the current year ring) of each core is averaged to get the mean annual increment (of the radius, at this stage). The former dbh of the tree (nominally one year before the callipering) is computed as the current dbh minus the mean annual dbh increment, assuming that bark thickness does not change during the five years period.

Sample trees heights, i.e. the total tree height of the current year and tree height one year before the inventory year, needed for increment estimation are calculated using the following model, developed using 45,332 sample tree diameter-height data collected during the NFI survey:

$$\hat{h}_{ij} = (a_1 + a_2 H_{dom})[1 - \exp((a_3 + a_4 H_{dom}) d_{ij})]^{(a_5 + a_6 H_{dom})} \qquad (26.1)$$

where h_{ij} is the height of the generic tree i in the generic sample plot j
d_{ij} is the *dbh* of tree i in plot j
H_{dom} is the dominant height of the plot j
a_x are species dependent coefficients (55 height-predicting equations).

The volume of a tree is estimated by species specific prediction equations (Tabacchi et al. 2011a, b) of the following type:

$$\hat{y}_1 = b_1 + b_2 d_i^2 h_i + b_3 d_i \tag{26.2}$$

where y_i is the volume of the generic tree i
d_i is the *dbh* of tree i
h_i is the total height of tree i
b_x are species specific regression coefficients (26 volume-prediction equations).

The percent volume increment of a generic sample tree z in the plot j (pv_{zj}) is obtained by the following formula:

$$pv_{zj} = 100\left[\left(2\Delta d_{zj}/d'_{zj}\right) + \left(\Delta h_{zj}/h'_{zj}\right)\right] \tag{26.3}$$

where Δd_{zj} is the annual *dbh* increment of the sample tree z in the plot j, known from the ring width measurements.

d'_{zj} is the *dbh* of the tree z in the plot j one year before the inventory year, known from callipering and tree ring width)
Δh_{zj} is the annual height increment of the generic sample tree z in the plot j, known from model (26.1)
h'_{zj} is the height of the tree z in the plot j one year before the inventory year, known from model (26.1).

The percent volume increment (pv) of all the z trees sampled in a plot j are used to calculate the mean weighed percent increment of the plot j (pv_j), by the following formula:

$$pv_j = \sum_{z=1}^{m}\left(Vol_{zj} \times pv_{zj}\right) \Bigg/ \sum_{z=1}^{m} Vol_{zj} \tag{26.4}$$

where

m is the number of the sample trees in the plot j
pv_{zj} is the percent volume increment of the generic sample tree z in the plot j
Vol_{zj} is the volume of the generic sample tree z in the plot j, known from model (26.2).

The current annual increment of the generic tree i callipered in the NFI sample plot j (Δv_{ij}) is then obtained by the following:

$$\Delta V_{ij} = Vol_{ij} \times pv_j \tag{26.5}$$

where

Vol_{ij} is the volume of tree i in plot j, known from model (26.2)
pv_j is the mean weighed percent volume increment for the trees in the plot j, known from (26.4).

Finally, the annual volume increment of the growing stock in plot j as a whole (ΔV_j) is obtained by the sum of the annual volume increment of each tree in the plot:

$$\Delta V_j = \sum_{i=1}^{n} \Delta v_{ij} \times f_{ij} \tag{26.6}$$

where

n is the number of trees callipered in the plot j (dbh ≥ 4.5 cm)
f_{ij} is the expansion factor of the tree (two factors, depending on tree dbh or plot radius to obtain the annual increment per area unit).

The increment of trees that were cut or of those trees that have died is not estimated. The increment estimated by the Italian NFI is that of living trees at a certain point in time. Such a procedure assumes that the current stand conditions are reasonably like those of the very recent past (from which the rings width information are taken, on average) as well as of the near future, for which estimation is considered valid.

26.3.3.3 Estimation of Cuttings, Removals and Mortality

Cuttings are estimated by predicting the volume (volume of stem and large branches) and biomass (total aboveground biomass except stump) of trees felled in the 12 months preceding the survey and whose stump diameter is equal to or greater than 9.5 cm. Stumps are surveyed in the 13 m radius plots, recording the species, the diameter at the cut section (two cross diameters) and the height (two heights, the minimum and the maximum height). Weather the felling was carried out in the last year before the field inventory survey or earlier is assessed visually (observing the condition of wood at the cut section, the decay status of stumps, etc.), but may also be reported from the local forest service station that oversaw the felling operation. The procedures for estimating the volume and the biomass of each felled tree are similar with those adopted for intact living trees, once the dbh of removed trees has been predicted. This is predicted using the two following equations, one for conifers (26.7) and one for broad-leaved species (26.8) (MAF-ISAFA 1988):

$$dbh = -2.42525 + 0.87427\, d_{stump} \tag{26.7}$$

and

$$dbh = -1.43966 + 0.77839\, d_{stump} \tag{26.8}$$

Based on the two equations, the minimum dbh considered for removed trees is 5.9 cm for the conifers and 6.0 cm for the broadleaved species. The height of each removed tree is estimated by the model (26.1).

Both the stem and large branch volume (upper diameter for branches and top—of 5 cm) and the total above ground tree biomass (stump, stem, tree top, large branches and small branches) are estimated by the species specific prediction model (26.2). The overall volume of extracted trees for the entire sample unit is obtained by summing up the volumes of all the trees removed.

The aim of the measurements and estimation procedures described is to assess the wood/timber removed in one year. No distinction is made between cuttings from living trees and the removal of trees which died naturally. For instance, in case of trees downed from a storm (broken section <1.30 m) and afterwards extracted for wood/timber use, their volume is estimated as part of the removals without any further specification between downed from storm or from routine felling.

Despite the accurate information recorded in the field, statistics on removals are published only as total values for the inventory categories (tall trees forest, plantations, temporarily un-stocked areas) and Administrative Regions. In fact, as stumps from recent cuttings are observed in quite a limited number of plots, estimates by any further detail (forest category, tree species, etc.) are affected by considerably high standard errors.

26.3.3.4 Estimation of Forest Area Change

Changes in forest area are derived from repeated NFI assessments. More precisely, the first two phases of any NFI cycle provide an updated forest area estimate comparable with the former one. Such an approach became possible starting with INFC2005, when the Italian NFI was founded as a permanent tool for forest consistency monitoring. The first phase photo-interpretation of the third Italian NFI (INFC2015) and the forthcoming second phase will allow to assess the changes in the decade 2005–2015. Forest area changes from the time of the first Italian NFI (1985) to 2005 have been estimated by reclassifying the IFNI85 categories into the INFC ones in order to allow consistent comparisons. This approach was used for the FAO-FRA reporting (Mariano et al. 2010) and also for the UNFCCC and Kyoto Protocol reporting.

26.3.4 Other Wooded Land and Trees Outside Forests

26.3.4.1 Assessment and Measurement of OWL

The area of other wooded land is assessed during the first two inventory phases and is estimated to be 1,708,333 ha or 5.7 % of the country area. A number of qualitative second phase variables are surveyed, and the related estimates are published in the web site. Among those variables, many are related to wood availability: coniferous, broadleaved and mixed area; variables on restrictions and protection status; accessibility; others. Availability for wood supply itself is also explicitly assessed, as discussed for forests. However, quantitative measurements on trees are not carried out, since plots in OWLs are not surveyed in the third phase, so that OWL tree volume and biomass are unknown.

26.3.4.2 Assessment and Measurement of TOF

Trees outside of the forest area was first estimated after the photo-interpretation carried out in 2005, using a parallel study (TOF Inventory) that was also the basis of subsequent investigations. Data interpreted from NFI personnel on the 4785 points classified as TOF were checked for validation and additional information recorded (quantitative and qualitative attributes such as land/cover use, width, length, distance from forest, etc.). Each TOF-point was also assigned to the surrounding land use. The total area covered by TOF (woodlots and hedgerows) was estimated as a proportion of TOF sampling units on total NFI points. TOF area covers about 452,000 a (S.E. = 1.5 %) that is 1.5 % of the country area. Two thirds of TOF area is made by hedgerows and the remaining by woodlots. TOF are mainly present in agricultural areas (cropland 82 %, pastures 6 %); the remaining 12 % is found in urban and periurban areas (10 %) and in not cultivated/not managed lands (2 %) (De Natale et al. 2011).

Countrywide studies on the quantitative attributes related to TOF growing stock have not been carried out until present and national statistics on volume and/or biomass are not yet available. However, from a Regional field survey investigation (Regione Veneto, De Natale et al. 2011) it emerged that 66.8 % of TOF area is still managed and the wood is utilised (coppicing, pollarding, pruning), showing that TOF are potentially interesting for wood supply.

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Chapter 27
Japan

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27.1 The Japanese National Forest Inventory

27.1.1 History and Objectives

In Japan approximately two-thirds of the country is covered in forests. Forests are primarily distributed over steep mountainous terrain, and given this association the terms forest and "the mountain" are often used interchangeably. Japan experiences high levels of precipitation, which can occur in heavy rainfall events such as during the short rainy season or typhoons. While Japanese forests are hit by these natural disasters, they play an important role in the prevention of natural disasters and mitigate against flood events. In addition, forests are also valued for their contribution towards the mitigation of global warming, maintenance of the water quality and biological diversity.

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Due to the multiple functions that forests fulfill, it is important to manage forests in a manner that maintains their healthy status. However, there have been occasions in the past when the forests were degraded. At the beginning of Meiji era in 1860s and 1870s, Japan adopted the values of European civilisation which rapidly progressed the modernisation of forest management. At the time, wood was used for various tasks associated with the development of modern industries such as building materials, footing and pilling for construction, mining, telegraph pole, railroad sleeper, shipbuilding and paper manufacturing. As forest harvesting was carried out for many domestic uses there was a lot of pressure on forests which resulted in the serious degradation of the forests and disasters occurred frequently due to the removal of forests. The Japanese Government enacted a Forest Act in 1897, which included provisions to regulate forest harvesting.

In the 1930s and 1940s during the World War II, a large quantity of wood was required for military purposes. A large quantity of wood was needed to rebuild many cities which were damaged during the war. Therefore, the Forest Act was revised in 1951, which established the Forest Planning System. Under the Forest Planning System, cutting regulations were strengthened by introducing appropriate minimum cutting age for licensing the felling of private forests.

Due to the risk that unplanned cuttings pose to the sustainable management of forest resources, the Forest Planning System is intended to promote planned and appropriate forest management from a long-term viewpoint. Data are collected and recorded in the form of forest registers and forest planning maps are prepared for all forests as specified in the Forest Act. The results are used for formulating National, Regional and Municipal Forest Plans, which are prepared by the Minister of Agriculture, Forestry and Fisheries for all forests, by prefectural and municipal governments for private forests and by the Regional Forest Offices of the Forestry Agency for national forests.

When Japan participated in the Montreal Process Working Group on Criteria and Indicators for Conservation and Sustainable Management of Temperate and Boreal Forests, there were many criteria and indicators which did not correspond to the attributes assessed in the Forest Planning System forest register. Therefore, the Forest Agency launched the Forest Resource Monitoring Survey in 1999 to address the reporting requirements of the Montreal Process. This survey monitors changes in the quality and quantity of forests at a national scale, incorporating some of the indicators identified in the Montreal Process. The objectives of this survey are to collect a broad range of data and information on forests, to monitor and assess the progress towards sustainable forest management, and to incorporate the results into forest-related policies.

The first round of the sample-based Forest Resource Monitoring Survey was conducted during the years 1999–2003. Following the first Monitoring Survey, the second round (2004–2008) and the third round (2009–2013) Monitoring Survey were conducted in a same manner of the first round. The fourth round Monitoring Survey began in 2014. Throughout the four Monitoring Surveys the attributes assessed have remained the same, while the purpose was changed from the assessment of forest resources to include also the wider monitoring of forest ecosystem diversity in 2010.

27.1.2 Methods and Periodicity

To create the Regional Forest Plans under the Forest Planning System, prefectural governments and the Regional Forest Offices of the Forestry Agency prepare forest registers and forest plan maps for every sub-compartment, and update them every five years when the Regional Forest Plans are revised. Recent information on forest harvesting can be used to update the forest registers. All logging activities in private forests must be reported to the mayors of municipalities or to prefectural governors and those in national forests are based on the Forest Plan created by the heads of the Regional Forest Offices of the Forestry Agency. Information on other forests is updated using the results of field surveys or by applying standard yield table from the region.

The sampling design of the Forest Resources Monitoring Survey incorporates 0.1 ha plots that are located on a national 4 × 4 km grid. The total number of sample plots is around 23,600. Forest cover at the sample points is firstly assessed from aerial photos, which identified 16,000 sample plots as the target of the forest field survey. The survey is designed so that approximately 3200 plots or one-fifth of the total number of plots are visited for data collection annually. Each plot is circular with an area of 0.1 ha and is divided into three concentric, circular sub-plots with radius of 5.64 m for the small circular sub-lot, 11.28 m for the medium circular sub-plot, and 17.84 m for the large circular sub-plot.

27.1.3 Data Collection

For the conventional forest inventory under the Forest Planning System, forest registers are produced for sub-compartments in all private and national forests. Attribute information is recorded to describe the status of forests stands. They include following variables:

- Species
- Stand age
- Average diameter at breast height (dbh)
- Average height
- Annual stand increment
- Growing stock (estimated from empirical yield tables)
- Location
- Name of the owner
- Area

- Site index
- Legal designations.

In Forest Resources Monitoring Survey plot-level assessments of the, site conditions are described, including the following variables:

- Altitude
- Direction and degree of slope
- Surface geology
- Soil type
- Local topography
- Distance from roadway
- Degree of soil erosion
- Damages by disease, insects, wildlife or climate
- Stand type
- Dominant species
- Operation records during the last 5 years.

Land-use type, legal designations and stand age are checked on the forest registers prior to fieldwork.

For sample trees in the plot, tree variables are measured, and the minimum dbh of sample trees varies according to sub-plot size. Tree variables include:

- Species
- Dbh
- Viability
- State of bark
- The presence of cavity.

In addition, a sub-sample 20 trees are randomly selected across the plot for height measurement. Dead trees and signs of animal damage are recorded if observed. Stumps, fallen trees, and understory vegetation are also measured and recorded.

27.1.4 Data Processing, Reporting and Use of the Results

The Forestry Agency processes the inventory data to produce statistics, which is used for forest policy formulation. Japan's national forest inventory serves as the primary source of information for the assessment of sustainable forest management and is used to report forest information for the Montréal Process criteria and indicators. The information is also used to report on the quantity of carbon absorbed and discharged from the forest for Kyoto Protocol in United Nations Convention on Climate Change (UNFCCC). The inventories also provide baseline data for the Forest Resources Assessment (FRA) program of the Food and Agriculture Organization of United Nations (FAO).

27.2 Land Use and Forest Resources from the Forest Planning System

27.2.1 Classification of Land and Forests

27.2.1.1 General Land Classification Under the Inventory

In the Forest Planning System, the target area of the inventory is forest land prescribed by the Forest Act. Other land uses are not classified during the Forest Planning System. The forest area was 25.08 million ha as of March, 2012.

In the Forest Resources Monitoring survey, land use at all sampling plots is interpreted from the latest aerial photograph or high resolution satellite images at the beginning of each round of the survey, and are classified into four categories, i.e. forest land, agricultural land, water bodies and other land. During the interpretation process the first purpose is to distinguish between "forest" or "non-forest". Those forest plots become the target of field survey. Categories of "non-forest" are not defined in the Forest Resources Monitoring Survey manual. Estimates of forest land from the first (2003) and second (2008) rounds of the survey were 25.39 million ha and 25.73 million ha, respectively.

27.2.1.2 Forest Classification by Function

The Forestry Agency submitted the country report for FRA2015, and the forest class is defined in it as Table 27.1 (FAO 2014).

In the Basic Plan for Forest and Forestry in 2011, forest is divided into seven categories according to its function. These functions are headwater conservation, mountainous disaster prevention, amenity formation, public health and recreation, cultural conservation, biodiversity conservation, and wood production. The Forestry Agency classifies all forests into three categories of forests for fulfillment of multifunctional roles of forests: managed single storied forest, managed multi-storied forest and natural/regenerated forest. The Forest Agency established threshold areas that each forest management category should reach by (Table 27.2). Two-thirds of Japan's land area is covered with forests, with a total forested area of 24.958 million ha.

Forests are defined as land on which trees and/or bamboo grow collectively, together with those trees and bamboo, or any other land that are provided for collective growth of trees and/or bamboo. Lands that are utilised mainly for agriculture, residential use, or other similar purposes, are not included. Forests are classified into the following two categories: (1) National forest: Forest where land is owned by the national government, or where land is owned by other party but the national government implements silviculture under a contract which defines the share of profit between the national government and landowner(s). (2) Private forest: Forest other than national forest, including forests that are owned publicly

Table 27.1 Total land area of Japan by forest classification and national definitions (FAO 2014)

National class		Definition	Corresponding FRA classes (FAO 2004)	Area (1000 ha) (2012 yr)
Forest	Forest with standing trees	Forest that has canopy cover of 30 % or higher. Young stands with the degree of stocking of 0.3 or higher are included	Forest, OL[a]	23,618
	Bamboo forest	Forest that does not fall under "forest with standing tree" and is dominated by bamboo (excluding bamboo grass)	Forest, OL[a]	159
Forest without standing trees	Cut-over land	Forest without standing trees that has gone through final harvest and are temporarily under-stocked and are expected to regenerate	Forest, OL[a]	100
	Under-stocked land	Forest without standing trees that does not fall under "Cut-over land"	Forest, OL[a]	1081
Non-forest			OL	12,837
Total		Total land area of Japan		37,795

[a]Japan's definition of 'Forest' is land spanning more than 0.3 ha

Table 27.2 Forest area in 2010 and area projected to be present in 2030 by forest management category (Forestry Agency 2011)

Category	Area in 2010 (1000 ha)	Aim area in 2030 (1000 ha)
Managed single storied forest	10,300	10,000
Managed multi-storied forest	1000	2000
Natural/regenerated forest	13,800	13,100
Total	25,100	25,100

such as by local/prefectural governments but not by the national government. Lands with trees and/or bamboo are not included in forests if: (a) Owned and managed by national government agencies other than the Forestry Agency (since the land is not provided mainly for growing trees and/or bamboo) (b) Spanning not more than 0.3 ha and isolated from adjacent forests.

In 2010, there were only 24,128 ha that could be classified as Reforestation as defined by the FAO (2004).

27.2.1.3 Classification by Ownership Categories

Within Japan's policy framework, "non-national government owned forest" is defined as any forest other than those owned by the national government. Therefore, in addition to privately owned forests, it includes forests publicly owned by prefectural or municipal governments and by communal bodies. While most of the nationally-owned forests are managed by the Forest Agency (described as "national forests" in this paper), some are managed by other government agencies such as the Ministry of Defence (e.g. training fields) and the Ministry of Finance (e.g. national land property). Non-national government owned forest occupies 69.4 % of total forest land area. Forest ownership as of March, 2012 is shown in Table 27.3 (Forestry Agency 2014b).

27.2.1.4 Forest Management and Cutting Systems

Planted forests in Japan are managed in even-aged and uneven-aged management systems. While the area of even-aged forest was 10.3 million ha, multiple storied forests only accounted 1 million ha (Forestry Agency 2011). In Japan, there has been a policy shift in forest management towards (1) diversification and lengthening of rotations, (2) promotion of multiple storied forest management and natural

Table 27.3 Forest area and rate against total forest land by ownership as of March, 2012 (Forestry Agency 2014b)

Type of ownership			Area (1000 ha)	Area (%)
National government owned	Forestry agency		7610	30.3
	Others		64	0.3
	Subtotal		7674	30.6
Non-national government owned	Public forest	Prefecture	1210	4.8
		Municipality	1709	6.8
		Subtotal	2919	11.6
	Private forest		14,437	57.6
	Others		51	0.2
	Subtotal		17,407	69.4
Total			25,081	100.0

forest management, and (3) promotion of comprehensive forest use (Forestry Agency 2013).

The harvested wood volume cannot be distinguished by the type of harvesting. However, statistics on forestry work projects contracted by forest management entities show that the total area of commercial thinning by forest management entities in 2010 was around 89,000 ha and clear-cutting was 62,000 ha (Forestry Agency 2014b).

27.2.1.5 Legal and Other Restrictions for Wood Use

The Minister of Agriculture, Forestry and Fisheries or Governors assign protection forests to maintain some functions such as headwater conservation, mountainous disaster prevention and amenity formation. The Basic Plan promotes the planned designation of protection forest. In protection forests, logging of standing trees and conversion of land are restricted. This system was established in 1897 when the Forest Act was enacted. As of March 2013, the area of protection forest was 12,090,759 ha. This is equivalent to approximately 31 % of land area and approximately 47 % of forest land area. There are 17 kinds of protection forests according to the public purposes. The main protection forests functions are head-water conservation and soil run-off prevention. The area of each kind of protection forest is given in Table 27.4 (Ministry of Agriculture, Forestry and Fisheries 2013). Restrictions on cutting in protection forests varies from forest to forest. Restrictions are permanent in these areas including a limit on the cutting area even in forests

Table 27.4 The area of protection forest by purpose as of March 2013 (Ministry of Agriculture, Forestry and Fisheries 2013)

Purpose	Area (1000 ha)
Headwater conservation	9128
Soil run-off prevention	2564
Landslide prevention	59
Shifting sand prevention	16
Windbreak	57
Flood damage prevention	0.6
Tidal wave and salty wind prevention	14
Drought prevention	125
Snow drift prevention	0.03
Fog inflow prevention	62
Snow avalanche prevention	19
Rock fall prevention	2
Fire protection	0.4
Fish breeding	60
Navigation landmark	1
Public health	699
Scenic site conservation	28

where cutting is possible. When cutting is conducted in the forest where cutting is possible, the permission must be sought from the Minister of Agriculture, Forestry and Fisheries or Governors. A report on the location, owner, cutting area, and its volume is required.

27.2.1.6 Classification by Stand Age Class for Planted Forest

The stand age class is defined in 5 year intervals in Japan, and the highest class includes all tree ages above 90 years. Two-thirds of Japan's land area is covered with forests, with a total forest area of 25 million ha. Approximately 40 % of these forests are artificially planted forests and are now mature enough for intensive harvesting. The area of planted forests by stand age class as of March 2012 is given in Table 27.5 (Forestry Agency 2014b). The area of planted forest with a stand age greater than 40 years occupies 66.2 % of planted forest. This distorted age class structure is caused by increase of planting from a surge in wood demand for postwar revival in 1960s and 1970s and the slump of the wood price due to price competition with imported timber.

Table 27.5 Area of planted forest by stand age class as of March 2012 (Forestry Agency 2014b)

Stand age class (years)	Conifer forest (1000 ha)	Broad-leaved forest (1000 ha)	Total (1000 ha)
1 (1–5)	63.4	9.4	72.8
2 (6–10)	100.1	14.1	114.3
3 (11–15)	144.5	14.6	159.2
4 (16–20)	214.7	16.3	231.1
5 (21–25)	325.6	21.7	347.3
6 (26–30)	556.1	28.0	584.1
7 (31–35)	829.9	21.7	851.6
8 (36–40)	1089.5	21.9	1111.4
9 (41–45)	1535.5	29.3	1564.8
10 (46–50)	1597.8	33.6	1631.5
11 (51–55)	1442.5	30.7	1473.2
12 (56–60)	898.4	22.2	920.6
13 (61–65)	336.0	9.4	345.4
14 (66–70)	189.6	4.3	193.9
15 (71–75)	158.9	5.4	164.2
16 (76–80)	133.2	4.7	137.9
17 (81–85)	101.6	3.4	105.0
18 (86–90)	83.9	3.4	87.3
19 (>90)	166.7	7.5	174.2
Total	9968.0	301.7	10,269.7

27.2.1.7 Classification by Species for Planted Forest

In planted forests, conifer trees are the primary species (97.1 %), including Japanese cedar (*Cryptomeria japonica*), Japanese cypress (*Chamaecyparis obtusa*), and Japanese larch (*Larix kaempferi*). They occupy 78.6 % of the total area of planted forest and they are mainly used for sawing. The planted species and their area as of March 2012 are given in Table 27.6 (Forestry Agency 2014b).

27.2.2 Wood Resources and Their Use

27.2.2.1 Growing Stock and Increment

Sixty percent of Japan's forests are natural forests including forests that were once used as coppices, while 40 % are planted forests. This current makeup of forests is the result of human activities and the rehabilitation of forest resources. In particular, the planted forest standing stock has grown by roughly 5.4 times over the course of the past half century (Forestry Agency 2014a).

The growing stock is defined as the stem volume, over bark, of all standing trees more than 3 cm in diameter at breast height, above ground up to the end of the stem, but does not to include branches (FAO 2014). The volume of bamboo stands is not included in growing stock. The growing stock of the planted forests by stand age class as of March 2012 is given in Table 27.7 (Forestry Agency 2014b). Comparable estimates of growing stock planted forest and natural forest from the Forest Resources Monitoring Survey was 2.72 billion m^3 in the first round (1999–2003) and 3.27 billion m^3 in the second round (2004–2008). Increment of growing stock is obtained dividing the difference of growing stocks at two different times with their interval. Increment of growing stock between 2007 and 2012 was 78

Table 27.6 The planted species and their area as of March 2012 (Forestry Agency 2014b)

Species		Area (1000 ha)
Conifer	Japanese cedar (*C. japonica*)	4475.2
	Japanese cypress (*C. obtusa*)	2598.8
	Pine spp. (*Pinus thunbergii*, *P. densiflora*, etc.)	848.8
	Japanese larch (*L. kaempferi*)	1001.6
	White fir (*Abies sachalinensis*)	779.8
	Yezo spruce (*Picea jezoensis*)	86.6
	Others	177.2
Broad-leaved	Sawtooth oak (*Quercus acutissima*)	65.8
	Other oak sp.	14.4
	Others	221.4

Table 27.7 Growing stock of Planted forest by stand age class as of March 2012 (Forestry Agency 2014b)

Stand age class (years)	Conifer forest (1000 m^3)	Broad-leaved forest (1000 m^3)	Total (1000 m^3)
1 (1–5)	49	7	56
2 (6–10)	442	175	618
3 (11–15)	7809	547	8357
4 (16–20)	20,384	1077	21,461
5 (21–25)	44,163	2106	46,269
6 (26–30)	98,740	3688	102,428
7 (31–35)	184,695	4288	188,983
8 (36–40)	286,422	5680	292,102
9 (41–45)	456,287	8112	464,399
10 (46–50)	521,998	8880	530,879
11 (51–55)	511,814	7316	519,130
12 (56–60)	346,510	5024	351,535
13 (61–65)	138,732	1960	140,691
14 (66–70)	83,209	848	84,057
15 (71–75)	69,551	1138	70,688
16 (76–80)	57,170	1189	58,359
17 (81–85)	44,226	896	45,122
18 (86–90)	36,922	833	37,755
19 (>90)	72,595	2019	74,614
Total	2,981,719	55,784	3,037,503

million m^3 per year in the planted forests (Ministry of Agriculture, Forestry and Fisheries 2013).

Recently, Japan's planted forests have begun to reach maturity and are ready for harvest. However, the productivity of domestic forestry is still very low because of the small size of forest parcels in private ownership and because new forest owners are reluctant to invest in active forest management after inheriting forest property from their parents. As a result, domestic forest resources are not fully utilised, and some forests are at risk of losing their ability to provide multiple environmental functions because of the lack of proper forest management (Forestry Agency 2013). As a result, the growing stock of planted forest greater than 40 years occupies 78.3 % of total growing stock in planted forest.

Growing stock by tree species is given in Table 27.8 (Forestry Agency 2014b). The growing stock of Japanese cedar (*C. japonica*) occupies 57.6 % of the total growing stock in the planted area. This is caused by the fact Japanese cedar (*C. japonica*) was widely planted throughout Japan and is now concentrated in the high age classes.

Table 27.8 Growing stock by tree species in the planted area as of March 2012 (Forestry Agency 2014b)

Species		Growing stock (1000 m^3)
Conifer	Japanese cedar (*C. japonica*)	1,748,777
	Japanese cypress (*C. obtusa*)	668,114
	Pine spp. (*P. thunbergii, P. densiflora*, etc.)	195,549
	Japanese larch (*L. kaempferi*)	220,746
	White fir (*A. sachalinensis*)	115,703
	Yezo spruce (*P. jezoensis*)	5628
	Others	27,203
Broad-leaved	Sawtooth oak (*Q. acutissima*)	7247
	Other oak sp.	691
	Others	47,845

27.2.2.2 Tree Species and Their Commercial Use

In 2011, the size of the domestic log production increased by 6.4 %, reaching 18.29 million m^3. Production of domestic logs by major tree species is given in Table 27.9. Log production of the three main planted species (Japanese cedar (*C. japonica*), Japanese cypress (*C. obtusa*), and Japanese larch (*L. kaempferi*)) occupies 77.8 % of total domestic log production.

The main commercial use of domestic logs is for sawn wood. Production of domestic logs by division of demand is given in Table 27.10 (Ministry of Agriculture, Forestry and Fisheries 2013).

In 2011, Japan's wood demand increased by 4 % from the previous year, reaching 72.73 million m^3 (roundwood equivalent), due to the recent increase in new housing starts. As a result the self-sufficiency rate for wood in 2011 was

Table 27.9 Production of domestic logs by major tree species as of March, 2011 (Ministry of Agriculture, Forestry and Fisheries 2013)

Species		Production (1000 m^3)
Conifer	Japanese cedar (*C. japonica*)	9649
	Japanese cypress (*C. obtusa*)	2169
	Japanese black pine and Japanese red pine (*P. thunbergii* and *P. densiflora*)	580
	Japanese larch (*L. kaempferi*)	2420
	Yezo spruce and white fir (*P. jezoensis* and *A. sachalinensis*)	953
	Others	215
	Subtotal	15,986
Broad-leaved tree		2304
Total		18,290

Table 27.10 Production of domestic logs by division of demand as of March 2011 (Ministry of Agriculture, Forestry and Fisheries 2013)

Division of demand	Production (1000 m^3)
For sawn wood	11,492
For veneer sheet and plywood	2524
For wood chips	4274
Total	18,290

26.6 %, up 0.6 % from 2010. The demand for lumber volume dropped to one third of the peak year in 1973, due to the long-term decline in the number of domestic housing starts. The volume of domestic wood used for plywood production has increased sharply since 2000, although wood demand for plywood production as a whole is on the decline. Wood demand for chip and pulp production is also on the decline due to a decrease in paper production (Forestry Agency 2013).

27.3 Assessment of Wood Resources

27.3.1 Forest Available for Wood Supply

Japanese forests are managed on a sub-compartment basis using the forest registers and forest planning maps compiled under the Forest Planning System. The forest area available for wood supply can be considered as those forests which have reached cutting age and do not have any receive legal restrictions. In Japan, GIS data for almost all forests has been prepared by the Forest Agency for national forest and prefectural governments for private forests. Therefore, variables in forest registers can be referred to spatially. This sub-compartment based GIS data can be used for the assessment of the forest which is available for wood supply.

In Japan, another restriction for harvesting operations are the steep mountain slopes. There are no legal restrictions for skidding machines according to slope, but the most suitable machine can be selected depending on the transport distance and slope. While almost all planted forests are accessible, the availability of forest for wood supply depends on harvesting cost at that time. Several relevant variables with regard to topographic restriction are assessed in the Forest Resources Monitoring Survey. They include variables such as slope aspect, angle of inclination, local topography, and sloping distance from nearest forest road.

The potential of Japanese forests for wood supply is estimated from forest registers from the area of the forest with the age higher than cutting age. In the planted forest area, those forests potentially available for wood supply are the forests whose age class is ten (45–50 years) or higher amounting to 5.23 million ha in 2012 (Forestry Agency 2014a).

27.3.2 Wood Quality

In the Japanese NFI, wood quality is not investigated. Only damage and characteristics of form of sample trees are recorded in the Forest Resources Monitoring Survey.

27.3.3 Other Wooded Land and Trees Outside Forests

The Forest Planning System does not assess other wooded land as defined by FAO (2014). In the Forest Resources Monitoring Survey, aerial photos are interpreted to identify whether land use at 4 × 4 km grid intervals is forest or not. During the interpretation process, the only non-forest land-use identified are agricultural land and water bodies. Therefore, there is no data available for estimating the area of other wooded land. The Forestry Agency does not define trees outside forest or is it reported for FRA 2015.

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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[a] of all stands (m^3/ha)	228	196	−14.9	229	207	−9.6	244	222	−9.0
GSV[a] of mature stands (m^3/ha)	304	251	−17.4	300	260	−13.3	315	276	−12.4
GAI[b] (m^3/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

[a]Mean growing stock volume

[b]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	%	1000 ha	%	
Scots Pine *Pinus sylvestris* L.	374.4	37.0	262.9	30.2	51.9	24.5	689.2	32.9	2.2
Norway Spruce *Picea abies* L.	221.9	22.0	123.9	14.3	23.1	10.9	368.9	17.6	3.1
Birch *Betula* spp.	186.4	18.4	186.3	21.4	56.4	26.6	429.0	20.5	2.9
Aspen *Populus tremula* L.	60.0	5.9	66.0	7.6	13.5	6.4	139.5	6.7	5.1
Black alder *Alnus glutinosa* L.	96.1	9.5	87.4	10.1	26.4	12.4	209.8	10.0	4.2
Grey alder *Alnus incana* L.	21.4	2.1	85.3	9.8	30.7	14.5	137.5	6.6	5.2
Oak *Quercus robur* L.	23.3	2.3	22.0	2.5	3.2	1.5	48.5	2.3	8.8
Ash *Fraxinus excelsior* L.	11.7	1.2	13.3	1.5	2.3	1.1	27.3	1.3	11.7
Others	15.7	1.6	22.1	2.5	4.5	2.1	42.4	2.0	9.4
Total	1011	100	869	100	212	100	2092	100	1.1
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^3 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)												Gross mean annual increment (GAI)			Total cuttings of living and dead trees		
	Total		Error of estimation (%)	Species composition[a] (%)									Total		Error of estimation (%)	Total		Error of estimation (%)
	Mill m^3	%		P	S	B	Ap	BA	GA	O	Ah	Oh	Mill m^3	% from GSV		Mill m^3	% from GSV	
Pine (P)[a]	212.9	42	2.5	83	10	5	0	0	0	1	0	1	6.29	3.0	2.5	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	3.7	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	3.4	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	5.9	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	4.9	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	6.0	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	9.8	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	13.2	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	11.4	0.12	39	35.0
Total	510.2	100	1.4	37	21	17	6	8	4	3	1	3	17.8	3.5	1.4	8.97	50	4.7

[a]Dominant tree species: P—*Pinus sylvestris,* S—*Picea abies,* B—*Betula pendula, B. 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[b]	Total cuttings		Final cuttings				Intermediate cuttings[a]					
			Total		From them clear-cut		Total		From them thinning			
									Pre-commercial		Commercial	
	Area, 1000 ha	Stem volume (mill m^3)	Area, 1000 ha	Stem volume (mill m^3)	Area, 1000 ha	Stem volume (mill m^3)	Area, 1000 ha	Stem volume, (mill m^3)	Area, 1000 ha	Stem volume (mill m^3)	Area, 1000 ha	Stem volume, (mill m^3)
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

[a]The main area of intermediate cuttings contains area of salvage cuttings

[b]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^3/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^3/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 (mill. m^3)	Wood structure								Branches	Dead trees
		Size of industrial wood (cm)				Fuel wood over bark	Total merchant-table	Felling residues[a]	Volume of stem		
		>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

[a]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^3 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^3 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)

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

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

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

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

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

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

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

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

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

For temporary plots gross periodical increment

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

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 m^3 are in forests of I–II group (strict reserves and special purpose forests) and 4.43 million 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 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 m^3/ha) and III–IV group (1.8 m^3/ha). Only 0.4 m^3/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 m^3/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 m^3/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^3) (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^3/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[c]	Volume[a] of dead trees (m^3/ha) 1998–2002	Newly dead trees[a] (m^3/ha)			Felled dead trees[a] (m^3/ha)			Dead trees what wood became unusable (m^3/ha)						Volume[a] of dead trees (m^3/ha) 2008–2012	Structure[b] of wood volume (%)	
		1998–2007	2003–2012	1998–2012	1998–2007	2003–2012	1998–2012	1998–2007	2003–2012	1998–2012					Unusable trees	Completely decayed
										Total	From them decayed					
											Completely	Partially				
												Volume	Share of decayed wood (%)			
Pine	6.7	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	16
Spruce	6.4	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	7
Birch	5.3	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	12
Aspen	8.8	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	12
Black alder	6.2	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	5
Grey alder	6.5	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	31
Oak	6.7	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	1
Ash	8.6	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	12
Other	5.7	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	4
Total	6.4	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	100

[a]Trees, of which wood is suitable, as minimum, for fuel wood
[b]Data presented by tree species independently on stand in which tree is growing
[c]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^3/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^3/ha/10 years. Mortality in ash stands was high as a result of heavy disease damage, totalling 45.7 m^3/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^3/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 loosing 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^3)			
	Total		Coniferous	Broadleaves	Total	
	A (mill. ha)	P_A^a (%)			V	P_V^a (%)
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

[a]P_A, P_V—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.

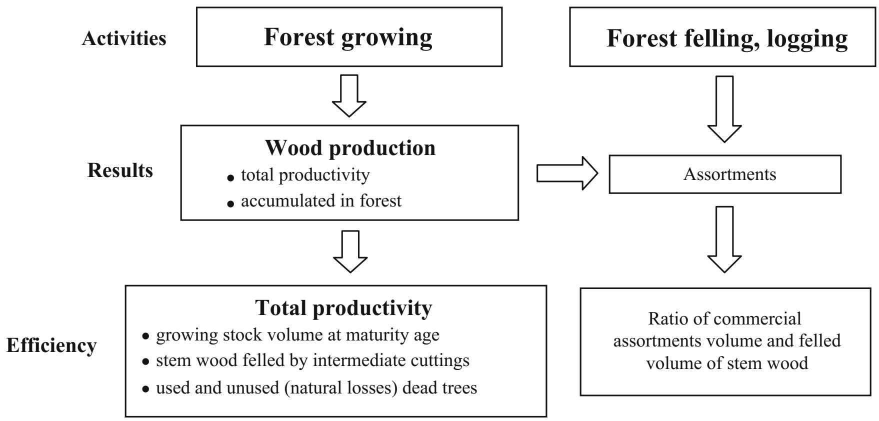

Fig. 28.1 Scheme of wood flow and its monitoring

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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Chapter 29
Grand Duchy of Luxembourg

Georges Kugener

29.1 The National Forest Inventory of the Grand Duchy of Luxembourg

29.1.1 History and Objectives

In the context of the resolutions of the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and to meet the sustainable forest management commitments, the Grand Duchy of Luxembourg decided to implement a permanent National Forest Inventory (NFI) in 1990.

At that time the country used a full census (for public forests only), primarily at the scale of forest compartments, to provide general information on the type of stands, structure and volume per hectare. Satellite imagery and digital maps were also used to provide area estimate for small forest areas and various thematic maps.

The general aim of the NFI is to report on the state and the evolution of forests as concerning: the wooded and non-wooded area, stand composition, growing stock, regeneration, forest health and biodiversity. The inventory is becoming an important source of information for reporting to international organisations and a very pertinent tool that is relevant to the national forest policy decision-making. It facilitates monitoring the extent to which the sustainable forest management has been applied in managed forests.

Field data collection for the first inventory cycle began in 1998. Detailed results, including methodological aspects, of this first inventory cycle were published in 2003 in a well-documented textbook entitled "La forêt luxembourgeoise en chiffres" (The Luxembourgish forest in figures).

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A second inventory cycle was launched in 2009 and the results were published in 2014. It was an update of the forest situation based on features and indicators relating to the whole territory in order to keep records of the sustainable management of national forest heritage.

Comparison between the data from the two cycles allowed, for the first time in Luxembourg, to identify major trends of forest evolution. It became possible to assess changes in areas and volume, both in public and private forests. Also to some extent the forest productivity could be evaluated. It was also possible to assess the impact and the sensitivity of measures applied for more than 150 years and aimed at promoting sustainable management of the forests of the Grand Duchy. In Table 29.1 the main features of the national forest inventory of the Grand Duchy of Luxembourg are described.

29.1.2 Sampling Methods and Periodicity

The inventory is based upon a single-phase, non-stratified sampling based on plots that are distributed, on a systematic basis, at the intersections of a rectangular

Table 29.1 Description of the national forest inventory of the Grand Duchy of Luxembourg

Features of the inventory	General description
Type	Permanent (10 years cycle), inventory
Scale	National
Objectives	Characterisation of forest zones which have been defined by the United Nations Economic Commission for Europe (UNECE) and the Food and Agriculture Organization of the United Nations (FAO). Identification of the non-forest areas (globally). Both private and public properties are concerned
Sampling technique	Simple systematic sampling (single phase non-stratified). Every sampling point is located at the intersections of 1000 (east-west) × 500 m (north-south) grid. One point is the "image" of 50 ha. The whole country is covered by about 5200 sample points
Sampling unit	The sampling unit consists of five concentric circular plots where the measurements are realised (radii of 2, 4.5, 9, 18 and 30 m)
Sampling rate	The sampling rate is 0.2 %. It is calculated on the basis of the size of the inventoried circular plot with 18 m radius (0.1 ha)
Measuring cycles: duration and intervals	Duration of a measuring cycle: 2–3 years Interval between two successive cycles: 10 years The first cycle started between 1998 and 2000 and the second cycle between 2009 and 2011
Aerial photographs and cartography	The photo-interpretation and national cartographic maps were applied to pre-classify the sampling points (e.g. forests, roads, open areas, etc.) and to support the organisation of the field operations (plot location, remote identification of forest types)

1000 × 500 m grid across the whole country. Nearly 1800 permanent plots were established during 1999–2001 and were remeasured during 2009–2011. One can consider that the estimates provided by the national forest inventory correspond to reference years 2000 and 2010. The sampling intensity is 0.2 %.

In the inventory each sample unit comprises different plots (Fig. 29.1) which sizes are adapted to the nature of the collected data. The main sampling unit consists of several concentric circular plots with radii varying from 2 to 30 m. All living and dead standing trees with diameters (d) of at least 7 cm are measured on the three main plots as follows:

– plot with radius of 18 m: trees with d ≥ 40 cm
– plot with radius of 9 m: trees with 20 cm ≤ d < 40 cm
– plot with radius of 4.5 m: trees with 7 cm ≤ d < 20 cm.

Another plot of radius of 30 m is used to collect information dealing with stand structure, health conditions, main forest functions (water protection, recreation and biodiversity), sustainable management, storm and game damage. Furthermore special attention is paid to the presence of biotopes referring to the directive "Habitat" 92/43/CEE and also to wetlands, rocks, open areas.

In addition to this sample unit configuration, 4 small plots of radius of 1 m are also used; one plot has a radius of 2 m and the center of this plot is the plot center. One of them is established at the plot center and the others are located at distances of 5 m from plot center in the cardinal directions. They are used for measuring variables linked to regeneration including cover percentage and species

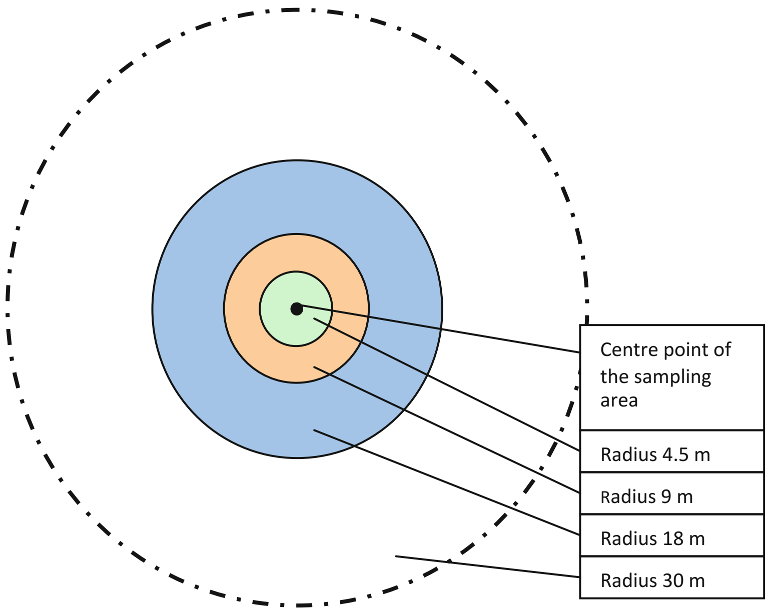

Fig. 29.1 Design of sampling area

composition for different stages of development. Saplings are defined as those trees with height >0.3 m and diameter at 1.3 m < 7 cm. The 9 m radius circle is used to measure lying dead trees (or pieces of wood) of at least 7 cm diameter and 1 m long. Edges and transition zones are observed along transects at the interception of the 18 m radius circle and the type of stands or type of land uses before shifting the plot into the dominant type (circle tangent to the intercept line).

29.1.3 Data Collection and Data Processing

The majority of data are collected in the field and, but for some parameters the data can be assessed from administrative and cartographic sources. The information assessed is divided in four categories:

- general data: administrative information, ownership type, plot location
- site variables: land use class, topography, soil characteristics
- stand variables: structure, age, stage of development, sylviculture, health status
- tree variables: location, species, diameter at 1.3 m, total height.

An electronic recorder is used in the field so that a first quality control can be made. The encoded data are then transferred into the database to be checked again and processed through an automated verification procedure. Numerous parameters are computed using data which refer to sample units, tree species and individual trees.

For each tree basal area and volume to upper diameter to limit of 7 cm are estimated. Sample tree volume (stem and branches over bark) are calculated from volume equations based on regression models most commonly used in Belgium. Volume of standing and lying deadwoods are also estimated. Areas regarding to productive and non-productive forests are estimated through the dot grid method (1 sampling point falling in such areas corresponding to 50 ha).

Furthermore since 2012 growing stock increment and evolution of wooded areas are assessed from the comparison of the two successive inventories.

29.2 Land Use and Forest Resources

29.2.1 National Forest Area

The main information provided by the inventory concern the forest land area of the Grand Duchy. Conventionally forest land includes forests devoted to production, protection, conservation and multiple-use objectives. Forest land is defined as having a minimum area of 0.5 ha with tree crown cover of more than 10 %, comprising trees able to reach a minimum height of 5 m at maturity. In this respect it should be noted that the forest area is remaining stable between 2000 and 2010 amounts to 91,400 ha which corresponds to a forest cover of more than 35 % (Table 29.2). This rate has not changed during the last ten years and is lower than the European average level but higher than in neighbouring countries: France (32 %), Germany (32 %) and Belgium (23 %).

29.2.1.1 Classification of Forest Stands

Luxembourgish forest is composed of about two-thirds deciduous forest and one-third coniferous forest (Table 29.3). Despite the high proportion of beech, oak and spruce forests which represent nearly 60 % of the stands, there is a significant presence of mixed stands (mixed beech-oak-hornbeam forests, other mixed deciduous forests, mixed forests with a dominance of conifers). This proportion shows a quite remakable diversity of species at the national level in spite of the dominance of stands with a more homogenous composition.

29.2.1.2 Classification by Ownership Categories

Two types of forest owners can be distinguished: private owners and public owners. The latter include the state, municipalities, and public institutions (church councils, social insurances, companies where the state is a shareholder, etc.). The private forests are managed by private bodies and/or by private persons whereas the public

Table 29.2 Forest land classification

Forest land		Area in 2000 (ha)	Area in 2010 (ha)
"Forest"	Stands	85,750	85,300
	Clearcuts	650	850
	Forest roads	450	350
	Clearings (surface between 10 and 50 ares)	400	300
	Wetlands (surface between 10 and 50 ares)	250	200
	Feeding areas (surface between 10 and 50 ares)	(0)	(50)
	Bushes, shrubs (surface between 10 and 50 ares)	250	550
	Linear elements (roads, overhead power lines)	500	800
	Hydrologic elements	250	300
	Sub-total "forest"	88,500	88,700
"Other forest land"		1800	1700
"Groves of trees"		1150	1000
Total forest land area (ha)		91,450	91,400

Table 29.3 Species distribution in Luxemburg's forests and rate of change from 2000 to 2010

Type of stand	Area (ha)	Area (%)	Change in % (2000–2010)
Beech	18,350	21.3	−0.7
Oak	15,850	18.4	−1.1
Broad-leaved trees	1650	1.9	−1.0
Beech-oak-hornbeam mixed forests	12,700	14.7	+2.9
Other mixed deciduous forests	4800	5.6	−0.4
Mixed forests with a dominance of deciduous trees	2000	2.3	+0.8
Other deciduous trees	2700	3.1	+0.9
Total deciduous stands	58,050	67.3	+1.4
Spruce	16,200	18.8	−1.2
Pine	650	0.8	−0.4
Douglas fir	2650	3.1	+0.2
Larch	350	0.4	−0.1
Mixed coniferous	2000	2.3	−0.3
Mixed forests with a dominance of conifers	5050	5.9	+0.0
Other conifers	350	0.4	+0.1
Total coniferous stands	27,250	31.7	−1.7

forests that come under the Forestry Regime are managed by the Nature and Forest Administration (Administration de la Nature et des Forêts).

In spite of an increase of the proportion of the total area of public forests, the proportions of private and public owners of the Luxembourgish forest remain nearly the same, 54 % private and 46 % public (Table 29.4). The difference of these two types of ownership has been reduced at 7350 ha (8 % of the forest area) compared to 9350 ha in 2000 (10 % of the forest area).

The public forests are mainly composed of deciduous forest (80 %) whereas the private forests are divided in almost equal parts in deciduous forest (56 %) and coniferous forest (42 %) which mainly consists of spruce forest (68 %) (Table 29.5). This situation remains stable for the private owners in contrast to the

Table 29.4 Forest area by type of ownership

Type of ownership	Forest area (ha)	Area (%)	Area change (%)
Municipalities	30,900	33.8	+1.0
State	9950	10.9	+0.2
Public institutions	1150	1.3	0.0
Sub-total public forest	42,000	46.0	+1.2
Private	49,400	54.0	−1.2
Sub-total private forest	49,400	54.0	−1.2
Total	91,400	100.0	0.0

Table 29.5 Area by type of stand and type of ownership

Type of stand	Public forest			Private forest		
	Area (ha)	Area (%)	Area change (%)	Area (ha)	Area (%)	Area change (%)
Beech (*Fagus sylvatica*)	12,000	29.3	−0.2	6350	14.0	−1.5
Oak (*Quercus* spp.)	6600	16.2	−0.4	9250	20.4	−1.5
Broad-leaved trees	800	2.0	−0.8	850	1.9	−1.0
Beech-oak-hornbeam mixed forests	8900	21.8	+3.9	3800	8.4	+1.7
Other mixed deciduous forests	2350	5.8	−0.6	2450	5.4	−0.3
Mixed forests with a dominance of deciduous trees	850	2.1	+0.9	1150	2.5	+0.6
Other deciduous trees	1000	2.5	+0.6	1700	3.7	+1.2
Total deciduous stands	32,500	79.7	+3.4	25,550	56.3	−0.8
Spruce (*Picea* spp.)	3150	7.7	−0.7	13,050	28.8	−0.9
Pine (*Pinus* spp.)	400	1.0	−0.5	250	0.6	−0.3
Douglas fir (*Pseudotsuga menziesii)*	900	2.2	−0.1	1750	3.9	+0.4
Larch (*Larix* spp.)	200	0.5	−0.4	150	0.3	+0.1
Mixed coniferous forests	750	1.8	0.0	1250	2.8	−0.5
Mixed forests with a dominance of conifers	2700	6.6	−2.2	2350	5.2	+1.6
Other conifers	(50)	(0.1)	+0.1	300	0.6	+0.1
Total coniferous stands	8150	19.9	−3.8	19,100	42.2	+0.5

public forest where the gap between deciduous and coniferous is growing, especially due an increase of beech-oak-hornbeam mixed stands.

29.2.2 Wood Resources and Their Use

Wood production remains an important facet of Luxembourg's forest policy. In this context it is essential to characterise and quantify the timber resource in terms of species, structures and growing stock or even size categories. On one hand this allows the forest manager to better plan his silvicultural interventions and on the other hand the timber industry can evaluate the potential wood supply over the short and medium term. The evaluation of carbon stocks and the description of potential forest habitats for fauna and flora are other important outcomes of the use of such data.

The standing stock volume of stem wood over bark is about more than 31 million m^3 (Table 29.6). The coniferous stands and especially the mixed

Table 29.6 Volume of heavy timber by structure and type of stand

Structure	Type of stand	Volume of heavy timber logs			Total volume of heavy timber		
		Average volume per hectare (m^3/ha)	Change in the average volume per hectare (m^3/ha)	Total volume (m^3)	Average volume per hectare (m^3/ha)	Change in the average volume per hectare (m^3/ha)	Total volume (m^3)
High forest	Beech	362	+35	6,629,000	443	+42	8,104,000
	Oak	300	+45	2,206,000	349	+51	2,566,000
	Broad-leaved trees	176	+69	291,000	191	+74	315,000
	Beech-oak-hornbeam mixed forests	355	+15	4,132,000	431	+20	5,020,000
	Other mixed deciduous forests	151	+28	612,000	169	+30	685,000
	Mixed forests with a dominance of deciduous trees + other deciduous trees	186	+52	696,000	199	+50	747,000
	Total deciduous high forests	312	+30	14,566,000	373	+34	17,437,000
	Spruce	442	+93	6,986,000	442	+93	6,990,000
	Douglas fir	379	+91	986,000	379	+91	986,000
	Pine and larch	352	+43	352,000	354	+43	354,000
	Mixed coniferous forests	513	+167	975,000	513	+167	975,000
	Mixed forests with a dominance of conifers + other conifers	318	+42	1,687,000	341	+44	1,809,000
	Total coniferous high forests	413	+85	10,987,000	418	+86	11,114,000
Coppice		254	+46	2,607,000	264	+53	2,711,000
Total of stands		337	+49	28,159,000	374	+54	31,262,000

coniferous forests are characterised by average volumes per hectare higher than those observed in the deciduous stands. Among the latter, other mixed deciduous forests represent the lowest volumes.

In terms of evolution over time the average volume per hectare of standing total heavy timber has increased during the period 2000–2010 as well as for the deciduous forests (+34 m^3/ha, +11 %), the coniferous forests (+86 m^3/ha, +26 %) and coppice (+53 m^3/ha, +22 %). Heavy timber includes those stem and branches that have top diameter >7 cm in diameter.

The volume of firewood in high forests is significantly represented in the public forest: more than 80 m^3/ha, thus 20 % of the volume of standing heavy timber. Only the half of this volume is found in private forest ownership, the majority of which are, covered by conifers. At stand level firewood reserves are highest in the deciduous forests, the mixed forests with a dominance of conifers and other coniferous forests. Beech forests and the beech-oak-hornbeam mixed forests supply firewood volumes which are quite higher than those generally found in other stands.

The annual volume increment of high forests amounts to 10 m^3/ha/year or 758,000 m^3/year (Table 29.7). The removals represent about 59 % of this increment. However, this national average is subject to local variations according to present species, age, forest site productivity, etc.

Table 29.7 Increment and removals of heavy timber by type of stand

Type of stand	Increment (m^3/ha/year)		Removals (m^3/ha/year)	
	Heavy timber logs	Total heavy timber	Heavy timber logs	Total heavy timber
Beech	5.8	7.7	3.9	4.8
Oak	5.1	6.2	2.9	3.4
Broad-leaved trees	6.2	6.8	1.2	1.3
Beech-oak-hornbeam mixed forests	5.7	7.4	4.2	5.2
Other mixed deciduous forests	5.0	5.8	2.3	2.6
Mixed forests with a dominance of deciduous trees + other deciduous trees	6.2	6.8	1.6	1.8
Total deciduous high forests	5.6	7.2	3.5	4.2
Spruce	16.2	16.3	10.4	10.4
Douglas fir	16.6	16.6	9.8	9.8
Pine and larch	9.6	9.8	4.2	4.2
Mixed coniferous forests	15.3	15.4	7.5	7.5
Mixed forests with a dominance of conifers + other conifers	9.0	9.8	4.3	4.6
Total coniferous high forests	14.5	14.7	8.6	8.7
Total of high forests	9.0	10.0	5.4	5.9

Chapter 30
New Zealand

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30.1 The New Zealand National Forest Inventory

30.1.1 History and Objectives

The nature of New Zealand's woody vegetation and history of National Forest Inventory in New Zealand is described in more detail by Beets et al. (2010). There has not been a National Forest Inventory (NFI) in the past that completely covered the total New Zealand forest area. The current effort is motivated by requirements to report Land Use, Land-Use Change, and Forestry (LULUCF) activities under Article 3.3 of the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC), as well as the ongoing annual reporting of plantation forests established with the primary objective of wood production where the resource description is useful for policy advice and resource planning. The

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objectives of the inventory continue to evolve from issues of wood supply or carbon sequestration to include biodiversity, ecological and environmental considerations.

The current national inventory activity is a cross-government programme managed and funded by the Ministry for the Environment (MfE) in partnership with the Ministry for Primary Industries (MPI) and the Department of Conservation, with support from several other government departments and two Crown Research Institutes; New Zealand Forest Research Institute Limited (Scion) and Landcare Research New Zealand Limited.

The Department of Conservation integrates the NFI into their National Biodiversity Monitoring and Reporting Programme, to provide comprehensive information on biodiversity across public conservation lands. The NFI also provides data on the state of New Zealand's forest for MfE's environmental reporting programme. These data also provide volume estimates for the United Nations Forest Resource Assessment and carbon stock for New Zealand's Montreal Process Criteria and Indicators report.

New Zealand's woody vegetation (excluding horticulture) can be divided into three distinct types:

1. Indigenous Forest Land (7.8 million ha)
2. Exotic Production Forest Land (2.1 million ha)
3. Grassland with Woody Biomass (Other Wooded Land) (1.4 million ha).

The characteristics of each type differ from the other so substantially that assessment techniques, sampling design and inventory management are also very different. Forest land area reported here includes forest roads, skid sites and unstocked areas within the mapped forest area, as reported in New Zealand's Greenhouse Gas Inventory 1990–2013 (Ministry for the Environment 2015).

Three-quarters of New Zealand's indigenous high forests are publicly owned and protected within the conservation estate. The upland forests are extensive and often remote, in difficult, steep, heavily-dissected country where weather can quickly deteriorate to impede ground access, and with some of the most difficult flying conditions in the world. The exotic production forest consists of moderately fast-growing, intensively managed planted forests, of which 90 % is radiata pine (*Pinus radiata* D. Don). Two-thirds of the forests are corporate-owned; the remainder is mainly under a variety of private ownerships, with many farm forests and woodlots.

Grassland with woody biomass is defined as wooded grassland that is unplanted and does not exceed 5 m height. Vegetation communities include indigenous alpine shrubs above the tree-line, regenerating shrubs and trees on lightly-grazed pasture and fast colonising "scrub" of exotic "weed" species such as gorse (*Ulex europaeus*). Lightly stocked riparian plantings are also included in this category.

The first NFI conducted using aerial photography and systematic sampling (pseudo-random sampling) was the National Forest Survey 1946–55, (Thomson 1946; Masters et al. 1957; McKelvey and Wardrop 1963) which was confined to indigenous forest. A National Exotic Forest Survey was carried out in planted forest with data collected between 1959 and 1963. In both cases there was no commitment to remeasure these forests in any form of continuous large-scale inventory.

A regularly updated plantation forest resource information system was set up to produce the National Exotic Forest Description (NEFD) in a cooperative approach between government and forest owners (Butler et al. 1985). Administered now by MPI (see http://www.mpi.govt.nz/news-and-resources/statistics-and-forecasting/forestry/), this is a compilation of an annual postal survey of forest owners, managers and consultants who manage planted production forests, (Ministry for Primary Industries 2014). For many years from its beginning the NEFD acted as an effective NFI, updated annually with a level of age class detail that would have been too expensive for a conventional plot-based NFI.

The Land Use and Carbon Analysis System (LUCAS) has been developed over the last decade (see www.mfe.govt.nz), motivated by the need to meet New Zealand's reporting requirements under the UNFCCC and the Kyoto Protocol. A grid-based sample design with ground plots has been established across New Zealand as the basis for NFI in indigenous forest and shrubland, pre-1990 planted forests and post-1989 planted forests.

30.1.2 LUCAS NFI Sampling Methods and Periodicity

The pre-1990 indigenous forest has been sampled on an 8 × 8 km grid with 1256 nested Permanent Sample Plots (PSP's) of 0.12 and 0.04 ha established between 2002 and 2007 as the first inventory period (Payton et al. 2004). The initial remeasurement of this plot network took place between 2009 and 2014. This inventory covers natural forest, which includes self-sown introduced woody species. As mapping of pre-1990 natural forest improves over time, revision of the inventory plot numbers takes place to maintain the representativeness of the inventory. The full set of plots in pre-1990 natural forest will be remeasured again (third inventory period) across a 10 year period starting in 2014 (Ministry for the Environment 2015).

Pre-1990 planted forest was sampled using the same grid in 2010, resulting in 192 measured ground plots of 0.06 ha size. Airborne scanning LiDAR data was collected from 893 plots, including those that were ground measured. The LiDAR-only plots are located on a 1 km (north–south) by 8 km (east–west) grid within the mapped area of pre-1990 planted forest (Beets et al. 2012a). These LiDAR plots are part of a double-sampling approach and have been successfully used to improve the precision of the carbon stock estimates in pre-1990 planted forests (Beets et al. 2012a). The pre-1990 planted forest ground plots were re-measured for the first time during the New Zealand winter of 2015.

Post-1989 planted forest was sampled with 0.06 ha circular PSP's on a systematic 4 × 4 km grid coincident with that used for the pre-1990 forest inventories

(Moore and Goulding 2005). The initial post-1989 planted forest inventory was carried out during the New Zealand winters of 2007 and 2008 at 246 sites consisting of up to four sample plots in a cluster arrangement. A second inventory was carried out during the winters of 2011 and 2012 where only the centre plots (0.06 ha) of the earlier established cluster plots were re-measured and additional plots were established based on mapping improvements. In total, 342 plots were ground-measured from the mapped area of post-1989 planted forest in the second inventory period (Ministry for the Environment 2015). Twenty plots were also established in post-1989 natural forest and measured for the first time in 2012.

LiDAR data were captured for 25 post-1989 plots in 2007–2008 in addition to those that were ground measured (Beets et al. 2011a). This was originally to allow a double-sampling approach to overcome bias introduced by any failure to gain access to private land. In practice, access was generally unrestricted, so LiDAR was used to improve the precision of the carbon stock estimates using a ratio estimator procedure. LiDAR data were acquired at a minimum of three returns per square metre, with aerial photography captured at the same time to aid in data analysis for both post-1989 and pre-1990 planted forests (Ministry for the Environment 2015).

All ground plot centres in planted forests were located during ground inventories using a 12-channel differential GPS for sub-meter LiDAR co-location and for relocation in future inventories (Beets et al. 2011a). The pre-1990 and post-1989 planted forests sample plots were intended to be remeasured on a five-year cycle. The location of the LUCAS NFI forest plots is shown in Fig. 30.1.

30.1.3 LUCAS NFI Data Collection

Plots in indigenous forest are sampled using a method designed for the purpose of calculating carbon stocks and biodiversity (Payton et al. 2004). Carbon-specific data are collected to calculate the volume of trees, shrubs and dead organic matter present. For trees, species, diameter and height are collected. Stage of decay is estimated for dead wood, which is otherwise measured for volume as for trees. Shrub dimensions are measured while litter samples are taken on about one-third of plots. Wood densities collated from representative studies are used to estimate biomass and carbon from the estimated volume (Beets et al. 2012b).

The ground measurements in the planted forest inventories include: stem diameters of all live and dead trees at breast height; a sample of tree total heights for each tree species; pruned heights, measurement of dead wood and soil fertility samples for predicting wood density (Beets et al. 2011a). Silvicultural information, including tree age, stocking rate (stems per hectare) and timing of pruning and thinning activities, is gathered from forest owners and also estimated by field teams on site (Herries et al. 2013).

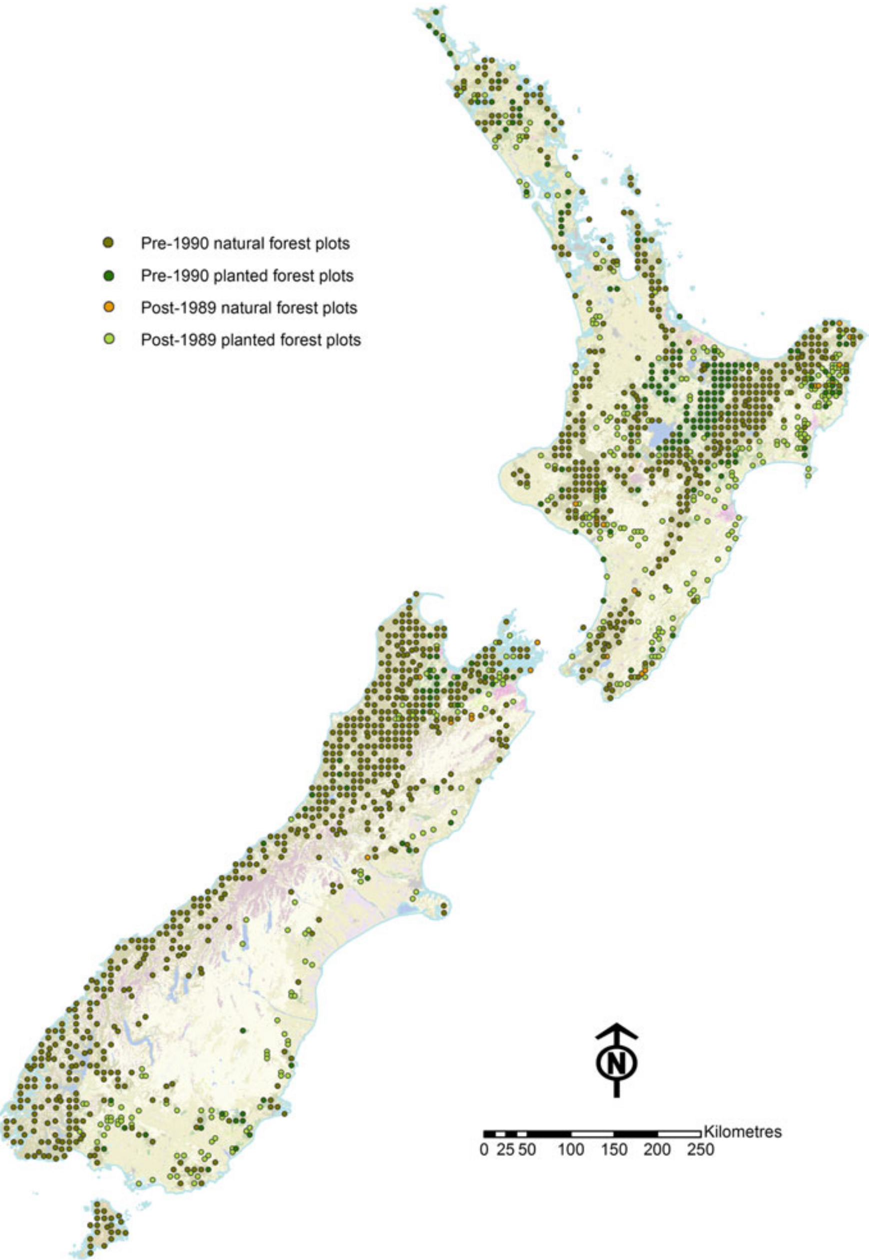

Fig. 30.1 Location of New Zealand's LUCAS NFI forest plots

30.1.4 LUCAS NFI Data Processing, Reporting and Use of Results

For indigenous forest plots, above-ground live tree biomass is estimated for trees (>2.5 cm dbh) from dbh and height by applying species-specific allometric equations and wood density (Beets et al. 2012b) to plot measurements. Below-ground biomass is estimated as 20 % of total living biomass. Dead wood (woody debris with a diameter over 10 cm) is estimated from plot measurements and allometric equations, while the litter pool is estimated from laboratory analysis of samples collected at one-third of the plots. Shrub volume is converted to carbon based on species and/or site-specific conversion factors determined by destructive harvesting of reference samples. Methods are currently slightly different for post-1989 (Beets et al. 2014) and pre-1990 natural forest subcategories (Holdaway et al. 2014).

Indigenous forest biomass in above ground, below ground, deadwood and litter pools is summed to allow calculation of carbon stocks and carbon stock changes for greenhouse gas inventory reporting (Ministry for the Environment 2015). These data are not used for reporting on, or planning the harvest of, merchantable timber stocks in indigenous forests. The Department of Conservation has integrated the NFI as an important component of their National Biodiversity Monitoring and Reporting Programme. This aims to provide comprehensive information on the status of New Zealand's indigenous forests and shrubland (e.g. biodiversity, health) on public conservation lands.

Crop tree data collected in the planted forest inventories is modelled using the Forest Carbon Predictor (Beets et al. 2011b), which incorporates growth models for the two main species, a wood density model, a stand tending model and the C-Change carbon allocation model (Beets et al. 1999). Carbon and volume yield tables are derived for each plot and combined into an average national age-based yield table for each of the two planted forest sub-categories (pre-1990 and post-1989).

A simulation approach combines the area by age class distribution from the NEFD (see Sect. 30.1.5 of this report) with the average national yield tables based on LUCAS and simulates afforestation, deforestation, harvesting and replanting over time. The simulation produces annual estimates of carbon stocks and stock changes since 1990 for greenhouse gas reporting (Ministry for the Environment 2015). This approach makes use of the higher resolution age class distribution available from the NEFD and the statistically defensible carbon stock information derived from the LUCAS NFI plot network. The planted forest simulation is carried out on a net stocked area basis. LUCAS mapping provides gross planted forest areas and uses plot data to estimate a ratio of gross to net stocked area. The yield tables represent carbon per net stocked hectare, with carbon in unstocked forest components estimated separately.

Carbon estimates are a critical part of UNFCCC and Kyoto reporting and are also reported in New Zealand's Montreal Process Criteria and Indicators report (Ministry of Agriculture and Forestry 2009). Stem volume, biomass and carbon estimates are provided for the Food and Agriculture Organization of the United Nations Forest Resource Assessment (FAO 2010). The inventory data from the LUCAS planted forest NFI may in future also contribute towards the forecasting of national and regional wood availability in planted forests. This is less of a requirement for natural forests which are not generally available for production.

The NFI also provides data on the state of New Zealand's indigenous and planted forests for MfE's environmental reporting programme and the natural forest inventory is the foundation for the Department of Conservation's national reporting on the status of New Zealand's indigenous forest and shrubland.

30.1.5 NEFD Data Collection, Processing, Reporting and Use of Results

In parallel to the plot-based NFI, New Zealand maintains a postal survey-based forest resource information system covering all major planted forests; the National Exotic Forest Description (NEFD). The NEFD is the primary source of national net stocked area data by species, age class and tending regime for planted forests. It is published annually by MPI to assist with resource policy planning and development. Each year the NEFD area dataset is compiled from a survey of forest owners and consultants who own or manage planted production forests (Ministry for Primary Industries 2014). These forests are managed intensively and most of the area is well described in the owners' databases with detailed information derived from their own inventory programmes. Methods are being developed to improve data capture from smaller forests.

NEFD area data are collected for 66 territorial authorities within nine wood supply regions. Six species or species-groupings are recognised: radiata pine, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), cypress species (*Cupressus* spp.), other softwoods, *Eucalyptus* species and other hardwoods. Four stand tending regimes are used for radiata pine (based on the intention to prune and/or production thin) and two for Douglas-fir (based on production thinning intentions).

The NEFD Regional yield tables for the main species groupings and management regimes are produced periodically to coincide with the preparation of regional and national wood availability forecasts. The yield tables are primarily based on yield information provided by large forest owners and consultants. The data collected for the NEFD are used to develop wood availability forecasts that present potential harvest volumes by broad log grades under various scenarios of yield regulation. These are developed within a forest estate modelling system and incorporate the harvest intentions of the major forest owners (Ministry of Agriculture and Forestry 2010). The NEFD yield tables are not used as a basis for national carbon reporting because the LUCAS yield tables provide defensible unbiased estimates for which uncertainty limits can be calculated.

The NEFD annual survey and wood availability forecasts provide data; to inform government policy, for a range of international reporting obligations, to assist with infrastructure planning decisions, and to identify wood processing opportunities.

30.2 Land Use and Forest Resources

30.2.1 Classification of Land and Forests

30.2.1.1 General Land Classification

New Zealand uses a hierarchical land classification system for reporting in the national greenhouse gas inventory (Ministry for the Environment 2015) (Table 30.1). The key thresholds for defining forest land are:

– minimum area of 1 ha
– minimum tree species crown cover of 30 %
– minimum height of 5 m at maturity in situ.

A width criterion of 30 m is used to distinguish between shelterbelts and forests —narrower shelterbelts are included within the surrounding land use classification such as cropland or grassland. Wider shelterbelts of at least 1 ha are classified as forests. Similarly linear unstocked features such as roads that are associated with forests and are less than 30 m wide will be classed as forests and contribute to the gross area of forests.

The Forest Resource Assessment (FRA) forest class has the same 5 m threshold for height, but lower thresholds for area (0.5 ha) and cover (10 %). It also has a lower width criterion (20 m) for determining if roads and powerlines through forest land still qualify as forest.

The land use classes in Table 30.1 may be further stratified based on plot data from the NFI. For example, post-1989 forest can be divided into a regenerating natural forest component and a planted forest component. Stocked plantation forest can be identified separately from riparian forest and other non-productive areas. Natural forest can be stratified into regenerating forest and tall forest (Table 30.2).

More detailed stratification into natural forest types is available from the earlier forest survey maps (Nicholls 1977) and EcoSat (Shepherd et al. 2005) but the classes are not well aligned with NFI plot data and are not used for annual greenhouse gas inventory or forest production planning.

30.2.1.2 Classification by Ownership Categories

Forest ownership categories are not used in LUCAS NFI analysis and reporting. Most tall indigenous forest is owned by the State and managed for conservation

Table 30.1 Land use classes according to the national definition with area estimates (Ministry for the Environment 2015) and correspondence with FRA classes

Class name		Description	Gross area (1000 ha)	Corresponding FRA classes (FAO 2004)
Forest land	Pre-1990 natural forest	Areas that, on 1 January 1990, were and presently include • tall indigenous forest • dense self-sown exotic trees, such as wilding pines and grey willows • broadleaved hardwood shrubland • temporarily unstocked areas associated with this forest land use	7835	Forest, other land with tree cover, other wooded land, other land
	Pre-1990 planted forest	Areas that, on 1 January 1990, were and presently include • radiata pine (*Pinus radiata*), Douglas fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.) or other planted species • harvested areas within pre-1990 planted forest • temporarily unstocked areas associated with this forest land use	1438	Forest, other land with tree cover, other wooded land, other land
	Post-1989 forest	Forest that was established after 31 December 1989 including • radiata pine (*Pinus radiata*), Douglas fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.) or other planted species • forests arising from natural regeneration of indigenous tree species • self-sown exotic trees, such as wilding conifers or grey willows • temporarily unstocked areas associated with this forest land use	660	Forest, other land with tree cover, other wooded land, other land
Crop-land	Annual cropland	Annual crops, cultivated ground and associated linear shelterbelts	372	Other land, other land with tree cover
	Perennial cropland	Orchards and vineyards and associated linear shelterbelts	105	Other land, other land with tree cover, other wooded land
Grass-land	High producing	High quality pasture and associated shelterbelts of <1 ha or <30 m in width	5808	Other land with tree cover, other land
	Low producing	Low fertility pasture and tussock, montane and coastal herbfields, and associated linear shelterbelts of <1 ha or <30 m in width	7545	Other land with tree cover, other land
	Grassland with woody biomass	Grassland with woody species that are not expected to reach forest criteria over a 30–40 year period, including alpine shrubland and pasture with trees <30 % cover (e.g. rural golf courses)	1364	Other land with tree cover, other wooded land

(continued)

Table 30.1 (continued)

Class name	Description	Gross area (1000 ha)	Corresponding FRA classes (FAO 2004)
Wetlands	Includes open-water and vegetated sub-categories, which may include non-forest woody vegetation	681	Other land, other wooded land, other land with tree cover, forest
Settlements	Parks, gardens, golf courses associated with built-up areas	225	Other wooded land, other land with tree cover, other land
Other land	Montane rock, scree, river beds, sand dunes, permanent ice etc.	895	Other land
Total		26,925	

Table 30.2 Classes within forest land and their areas in 2013 according to the New Zealand NFI (Ministry for the Environment 2015)

Class name		Description	Area (1000 ha)	
Forest land	Pre-1990 natural forest	Tall forest	6628	7835
		Regenerating natural forest	1207	
	Pre-1990 planted forest	Productive area (net stocked area)	1223	1438
		Unstocked area	151	
		Riparian and soil control	63	
	Post-1989 forest	Productive area (planted forest net stocked area)	539	660
		Unstocked area (planted forest)	79	
		Regenerating natural forest	41	

purposes. The NEFD captures planted forest data by ownership category for planted forests (Table 30.3). It also reports regional planted forest area by six ownership size classes, ranging from owners with less than 40 ha to owners with more than 10,000 ha.

30.2.1.3 Forest Management and Cutting Systems

Most natural forest is not managed for timber production so little silviculture is carried out there. Where management of natural forest for timber does take place it may be under continuous cover, coupe harvesting or clearfell systems. Only 50,000 ha of natural forest is currently managed under Sustainable Forest Management plans.

Forest management and cutting system information is not reported by the LUCAS NFI, but stand management records, assumptions and field assessments are

Table 30.3 Forest area according to the national forest definition by ownership categories

Forest category	Ownership category	Area (1000 ha)
Planted forest[a]	State-owned enterprise	11
	Local government	47
	Central government	37
	Registered public company	1
	Privately-owned	1665
	Sub total	1765
Tall indigenous forest[b]	State-owned	5180
	Privately-owned	1448
	Sub total	6628
Total forest		8839

[a]*Planted forest*—NEFD net stocked area as at 1 April 2014 excluding harvested areas awaiting restocking and adjusted to the New Zealand NFI area (Ministry for the Environment 2015)
[b]*Tall indigenous forest*—total 2013 area from the New Zealand NFI (Ministry for the Environment 2015); state-owned from draft 2015 Montreal process report; privately owned from the difference

used when deriving yield tables from plot data. The NEFD planted forest survey asks respondents to classify their forest area into management regime for the main species based on the intended implementation of green crown pruning and/or production thinning. Planted forests are generally managed on a clearfelling system, and currently only 13 % of planted forest area is intended to produce logs from production thinning (Ministry for Primary Industries 2014).

The radiata pine tending regime categories are:

- pruned with production thinning
- pruned without production thinning
- unpruned with production thinning
- unpruned without production thinning.

The Douglas-fir tending regime categories are:

- with production thinning;
- without production thinning.

"Pruned" refers to pruning carried out before age 12 so that more than 50 % of the stems in the planned final crop stocking will contain a pruned butt log of not less than four metres in length. "Production thinning" refers to the extraction of thinnings for commercial use.

About 58 % (899,000 ha) of the radiata pine area in the NEFD is, or is expected to be, pruned to a height of at least four metres. The area of radiata pine classified under a production thinning regime is about 16 % of the total. Less than 0.5 % of total planted forest production in 2012 came from production thinning (Ministry for Primary Industries 2014).

30.2.1.4 Legal and Other Restrictions for Wood Use

Government policy is that indigenous forest on public conservation land will not be harvested. The two exceptions to this policy are: (1) 12,000 ha of indigenous forest in western Southland that was made available for timber production in exchange for the protection of virgin old growth forest adjoining Fiordland National Park; (2) The West Coast Wind-blown Timber (Conservation Lands) Bill passed in 2014 allows trees wind-blown during Cyclone Ita in April 2014 to be salvaged within a five-year period. Up to 8640 ha of forest on the West Coast was estimated to be eligible for salvage harvesting under this Act (Platt et al. 2014). Privately-owned indigenous forests are also available for harvesting under the provisions of the Forests Act. This requires harvesting of indigenous forests to have an approved Sustainable Forest Management Plan or Permit.

Forest clearance is governed under the Resource Management Act which is administered by Regional and District Councils. Subject to the provisions in Council plans, small areas of indigenous forest may be able to be cleared. The Resource Management Act also covers earthworks and harvesting in planted forests. The provisions of the Forests Act apply if forest is to be harvested for timber production.

Regulations under the Climate Change Response Act provide the rules for participation of forestry in the Emissions Trading Scheme including forest definition thresholds and liabilities associated with harvesting and deforestation, but do not place additional restrictions on forest management. Some private forests have legal protection under various covenant arrangements but these generally apply to indigenous forests—covenanted planted forest areas are outside the sample frame of the NEFD survey of production forests and therefore would not be included in wood supply forecasts.

30.2.1.5 Further Classification of Forests

Planted forest area by broad species grouping is provided by the NEFD (Table 30.4). Species proportions are provided by the NEFD (Ministry for Primary Industries 2014) and are adjusted to the NFI area (Ministry for the Environment 2015). The NEFD publishes planted forest area in five-year age classes for each of

Table 30.4 Productive planted forest area by species (2013)

Tree species	Area (1000 ha)
Radiata pine (*Pinus radiata*)	1583
Douglas fir (*Pseudotsuga menziesii*)	109
Cypresses	10
Other softwoods	24
Eucalyptus spp.	22
Other hardwoods	13
Total	1762

the 66 territorial authority boundaries, by species grouping (and tending regime in the case of radiata pine). It also reports total net stocked area, standing volume inside bark and area-weighted average age for each territorial authority. Standing volume estimates are based on the broad NEFD regional yield tables. The total national planted forest net stocked area is also published by single-year age classes.

30.2.2 Wood Resources and Their Use

30.2.2.1 Standing Stock, Increment and Drain

Data on standing stock volume and increment were obtained from the New Zealand NFI used for the national greenhouse gas inventory (Ministry for the Environment 2015) (Table 30.5). The inventory reports carbon stocks and fluxes annually from 1990. The standing stock volume is a precursor to the carbon stock and flux analysis.

Planted forests standing stock is generally reported as "under bark" in New Zealand. A multiplying factor of 1.17 was used to produce the "over bark" estimates provided here. Definitions used are given in Table 30.5. Approximately 85 % of the total growing stock at harvest age is commercial (i.e. recoverable merchantable volume). However, total growing stock reported here includes the volume of all trees at all ages with dbh over 2.5 cm and there is little or no merchantable component in young stands with small trees. The commercial growing stock has not been estimated.

Planted forest growing stock and increment are sourced from the New Zealand NFI area as reported in the Forest Resource Assessment (Ministry for Primary Industries 2015). Standing stock of planted forests was projected to 2015 using the average annual increment for the last 5 years for which data are available. Increment is reported net of drain from forest harvesting, while drain is sourced from MPI's roundwood removal data (Table 30.6).

New Zealand's standing stock estimates for tall indigenous forest, regenerating forest and shrubland are reported as "over bark" and in terms of dry matter of above-ground live biomass. Estimates provided here (Table 30.7) are taken or

Table 30.5 Definitions for volume of planted forest standing stock, increment and drain

Quantity	Definition
Growing stock	Volume over bark of all living trees with a minimum diameter of 2.5 cm at breast height (or above buttress if these are higher). Includes the stem from ground level up to a top diameter of 0 cm, excluding branches
Net increment	Average annual volume of gross increment over the given reference period less that of natural losses and harvesting (drain), measured to minimum diameters as defined for "growing stock"
Drain	Estimated annual volume under bark in roundwood harvest, derived from mill out-turn

Table 30.6 The volume of standing stock, increment, and drain on planted forest land

Tree species	Growing stock (million m^3) over bark	Net increment (million m^3/year) (net of drain)	Drain (million m^3/year)
All planted forest species	746 (2015)	15 (2015)	29.58 (2014)
…of which coniferous	735		
…of which broadleaved	11		

Table 30.7 The above-ground biomass standing stock, increment, and drain on pre-1990 natural forest land

Woody vegetation class	Above-ground standing biomass (million tonnes dry matter)	Biomass increment (million tonnes dry matter/year)	Biomass drain (million tonnes dry matter/year)
Tall forest	2337.8		
Regenerating forest and shrubland	145.4		
Sum: tall indigenous forest and regenerating forest and shrubland	2483.3	29.8	21.2
…of which coniferous	305.1		
…of which broadleaved	2175.5		
Grassland with woody biomass	47.7		

derived from Holdaway et al. (2014). The proportion of broadleaved (87.7 %) and coniferous (12.3 %) species is taken from Beets et al. (2009), which provides an estimate of the proportion of coniferous and broadleaved species in New Zealand's indigenous forest based on the LUCAS field inventory. Grassland with woody biomass is adapted from Wakelin and Beets (2013).

30.2.2.2 Tree Species and Their Commercial Use

By far the most economically important plantation species in New Zealand is radiata pine, a versatile timber species native to North America. This makes up 90 % of the planted forest resource and 95 % of roundwood production in 2013. Radiata pine sawn timber is used in many applications including construction, mouldings, furniture, and packaging. It is peeled and sliced for veneer which is used to make plywood and increasingly laminated veneer lumber. It is also used to make other panel products, including medium density fibreboard and particleboard. Both mechanical and chemical pulps are produced from radiata pine as well as a range of paper and paperboard products. Treated roundwood is used for posts and poles and there is extensive use for energy. Douglas-fir, the second most common plantation species is mainly used for above-ground timber framing.

Wood processing waste is used extensively for energy generation, enabling the wood processing industry to be 70 % self-sufficient in energy. In 2014, 55 % of total roundwood production was exported as roundwood, mainly to East Asia. The relatively small volume of timber produced from natural forest is mainly used for speciality purposes including furniture and cultural uses.

30.3 Assessment of Wood Resources

30.3.1 Forest Available for Wood Supply

30.3.1.1 Assessment of Restrictions

The LUCAS NFI is not used for wood supply analysis so does not consider the availability of forests for harvest. No forecasting of future wood supply from indigenous forests is conducted.

By definition, all areas included in the annual NEFD survey is production forest planted for the purposes of timber harvesting and can be assumed to be technically and legally available. Separate assessments have been made of the economic availability of forests under difference scenarios, as some small, remote forests on steep sites may not be economic to harvest in all but the most favourable conditions. Some area may therefore be excluded from wood supply forecasts as a result of these analyses and on the advice of local experts.

The wood availability forecasts rely extensively on the knowledge of forest industry representatives within each region to verify the information contained within the NEFD database, provide growth and yield estimates and provide harvest intentions over the immediate 15 year period. In some regions the NEFD areas of small forest owners are reduced and further reductions are made to over-mature areas (e.g. Ministry of Agriculture and Forestry 2006).

The main focus of the wood availability forecasts is to present alternative scenarios for the harvest of the small grower resource, which is concentrated in a relative narrow band of ages due to a period of high but unsustained afforestation in the mid-1990s. In practice, harvesting of forests is managed to maximise the benefits to the enterprise that owns them. Each enterprise has its own harvesting strategy based on the forest owners' objectives, market conditions and the forest estate it owns or manages.

30.3.2 Wood Quality

30.3.2.1 Stem Quality and Assortments

Grade specifications for logs produced in New Zealand are determined by negotiation between the buyer and seller—there is no officially prescribed standard. Typically a planted forest log grade is defined in terms of factors including log size (minimum, maximum or average small end diameter; maximum large end diameter; length) and quality (species; straightness; branch/knot characteristics; internode length; clear-wood recovery; defect allowances; ovality; pith location; fibre stiffness; treatment e.g. debarked, sapstain treated, condition). Additional factors such as environmental certification may also be included as a grade requirement (Katz 2005).

For broad planning purposes, the NEFD maintains regional yield tables with three log grades: pruned veneer and sawlogs, unpruned sawlogs and pulp logs (Ministry for Primary Industries 2014).

30.3.2.2 Assessment and Measurement

The LUCAS NFI captures both physical stem attributes and silvicultural treatments from the plot network. Pruned height, timing and number of pruned lifts of all sample crop trees are captured. Thinning intensity and timing is captured for each sample plot. Green crown height of sample crop trees is captured. Descriptive codes describing stem form are also captured and include; broken stem, dead or defective top, toppled stem, crooked stem, forked primary stem, multi-leader, scar, sweep, leaning, hollow trunk and abrupt diameter reduction. Soil samples are taken for site fertility and wood density. Increment cores are taken for stem aging. Field assessment methodology is described in the LUCAS Planted Forest Data Collection Manual (Herries et al. 2013).

Planted forest owners carry out their own pre-harvest inventory programmes to characterise their stands in terms of potential log grade assortments. This involves detailed stem descriptions and measurements (including branch location, size and angle, wood density cores, stem acoustic speed for stiffness estimation, etc.) in stands of harvestable age, followed by analysis using software to simulate harvesting and optimise cross-cutting. Detailed stem descriptions of this nature are not carried out in the LUCAS NFI programme which deals with all age classes and does not attempt to characterise the resource by log grades.

30.3.2.3 Estimation and Models

Merchantable stem volume by log grade assortments is not estimated or reported by the LUCAS NFI, although the data collected could be used to broadly classify planted forest volume.

The crop tree plot data collected in the planted forest NFI is modelled using the Forest Carbon Predictor (FCP) developed for the two most common plantation tree species in New Zealand, radiata pine and Douglas-fir (Beets et al. 2011b). To enable predictions of carbon, and its precursor stem volume, in New Zealand's planted forests, the FCP integrates:

- the 300 Index growth model (Kimberley et al. 2005) for *Pinus radiata*
- the 500 Index growth model for Douglas-fir (Knowles 2005)
- a wood density model (Beets et al. 2007)
- a stand tending model (Beets et al. 2011b)
- the C_Change carbon allocation model (Beets et al. 1999).

The 300 Index and 500 Index growth models are widely used within the New Zealand forestry industry and produce a productivity index for forest plots derived from stand parameters. These stand parameters include: stand age, mean top height, basal area, stocking and stand silvicultural history. Plot latitude and altitude are also included in the models. The growth models use these parameters to predict stem volume under bark over a full rotation. The growth models account for past and future silvicultural treatments using plot data, stand records and assumptions of future management events (Beets et al. 2011b). The pruned component of stands is identified separately by the growth model, potentially allowing pruned log volume to be extracted.

The wood density model (Beets et al. 2007) uses site mean annual temperature, soil fertility, age and stocking to determine the mean density of stem wood growth sheaths produced annually in *Pinus radiata*. Wood density is an important variable in the estimation of carbon, and has been used as a surrogate for wood strength and stiffness.

The stand tending model (Beets et al. 2011b) is required because New Zealand's plantation forests are intensively managed and, therefore, pruning and thinning provide the majority of the inputs to the dead wood and litter pools. The FCP requires silvicultural history inputs to predict changes between live and dead biomass pools over time. A stand tending model has been incorporated into the FCP that makes use of existing data to identify and rectify potential gaps in the stand history.

The C_Change carbon allocation model (Beets et al. 1999) is integrated into the FCP and is designed to apportion carbon to needles, branches, stems, roots and reproductive parts via growth partitioning functions. Dead wood and litter pools are estimated by accounting for losses to the live pools from natural mortality, disease effects on needle retention, branch and crown mortality and silvicultural management activities.

The individual plot yield curves generated by the FCP are combined into estimates of above-ground live biomass, below-ground live biomass, dead wood and litter in an area-weighted and age-based carbon yield table for the productive area of each planted forest subcategory. Plots that are located outside the productive area within the mapped forest boundary are used to provide emission factors for unstocked areas in the post-1989 and pre-1990 planted forest categories (Paul et al. 2014).

The FCP does not incorporate a model for predicting log yields. A modelling framework (Forecaster; West et al. 2013) is available that does include this functionality as well as the models for stand growth, tending, wood density and carbon allocation described above. It would be possible to analyse the plot data in Forecaster to produce volumes by log grade if there was a need for this information at the level of resolution available from the NFI.

30.3.3 Assessment of Change

30.3.3.1 Assessment and Measurement

Annual gains and losses in the LUCAS planted forest NFI are estimated using the FCP derived age-based carbon yield table in conjunction with subcategory specific area by age class distributions, harvesting statistics, afforestation and deforestation data. This simulation approach is used because New Zealand has good current and historical information on its planted forest estate from the NEFD. A simulation approach allows for estimates back to 1990 and projections forward in order to meet UNFCCC reporting requirements. However, direct permanent sample plot based stocks and stock changes can be estimated from the data at NFI measurement dates.

The pre-1990 and post-1989 planted forests sample plots are intended to be re-measured on a five-year cycle. This provides direct validation of the modelled growth and the assumptions used to create the age-based yield tables. The estimation of gains and losses of the LUCAS natural forest NFI is based on the field measurements on permanent plots at two consecutive points in time. Growing stock in planted forests is also estimated annually from the NEFD yield tables and the age class distribution.

30.3.3.2 Estimation of Increment

Annual gains in planted forests are estimated using the NFI derived age-based yield table in conjunction with the mapped planted forest area and NEFD derived areas by age class. The simulation approach groups same aged cohorts and gains are estimated as these cohorts transition from one year to the next in the yield tables. The yield tables are validated by the increment growth of crop trees recorded between NFI measurements.

30.3.3.3 Estimation of Drain

Annual carbon losses in the LUCAS planted forest NFI includes permanent sample plot based and national statistics derived estimates. Permanent sample plot-based losses include; natural mortality, thinning, pruning and the subsequent decay of deadwood and litter. The NEFD provides annual harvested area and deforestation is mapped by LUCAS. Losses due to harvesting and deforestation are estimated by applying an emission factor from the appropriate yield table to the reported area. Harvest residues are decayed using a temperature-dependent decay profile as described in Garrett et al. (2010). Annual estimates of volume under bark in roundwood harvested are derived from wood processing sector returns.

30.3.4 Other Wooded Land and Trees Outside Forests

30.3.4.1 Assessment and Measurement

Grassland with woody biomass (other wooded land) consists of grassland where the cover of woody vegetation does not meet, nor has the potential to meet, the New Zealand forest definition. This can be due to the current management regime (e.g. periodically cleared for grazing), or to characteristics of the vegetation or environmental constraints (e.g. alpine shrubland). Grassland with woody biomass is therefore a diverse category. To account for these differences, grassland with woody biomass is split into permanent and transitional subcategories. Emission factors for each type of grassland with woody biomass are derived from the Land Use and Carbon Analysis System (LUCAS) plot network.

Unlike the forest subcategories in the NFI, the grassland with woody biomass sample is incomplete with partial coverage of sample points. The vegetation is assessed using satellite imagery where sample points in grassland with woody biomass have not been measured in the field.

Other land use classes reported in the greenhouse gas inventory can also include woody vegetation, such as perennial cropland, wetlands and settlements (including trees in parks). None of these non-forest lands are a significant source of industrial roundwood, although they may be used as a source of firewood for domestic heating.

30.3.4.2 Estimation

New Zealand's NFI currently only provides carbon stock in grassland with woody biomass (Table 30.7). Carbon stock change within grassland with woody biomass is currently not estimated. Emission factors are used for the other land uses.

30.4 Conclusion

The development of New Zealand's plot-based NFI was initially motivated by requirements to report LULUCF activities under the UNFCCC and the Kyoto Protocol. The NFI was established to estimate carbon stock and stock change in

New Zealand's forests. Estimation of potential timber production from natural forests has not been a priority as less than one percent of the total area of these forests is currently managed for timber production. Inventory objectives continue to evolve to include biodiversity, ecological and environmental considerations in both natural and planted forests.

The existing postal survey of planted forest owners provided a good basis for monitoring these forests and projecting wood supply while the resource ownership was concentrated within relatively few, large organisations. As planted forest ownership has fragmented it has become more difficult to obtain information from the many small forest owners through this approach. The plot-based NFI provides complementary data and has potential to contribute more towards the forecasting of wood availability in these forests in future.

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Chapter 31
The Netherlands

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31.1 The Netherlands National Forest Inventory

31.1.1 History and Objectives

National Forest Inventory assessment began in the Netherlands in 1938 and from 2012 to 2013 NFI6 was completed. NFI5 was designed as a continuous forest inventory and NFI6 builds on this. In between NFI4 (1980–1985) and NFI5 (2001–2005) a project was carried out to estimate volume, increment and harvest levels in the Dutch forests (Houtoogststatistiek en Prognose oogstbaar hout (HOSP)) (1988–1999) (Schoonderwoerd and Daamen 2000). During this project increment—and volume models were developed that are currently still in use. Yield tables were used to predict the volume and increment before the HOSP results became available.

Since 1968 the NFI was restricted to the forest area, all non-forested areas were excluded from the NFI. In NFI6 most of the permanent plots from NFI5 were revisited making it possible to determine the increment, fellings and removals in Dutch forests.

NFI5 was designed as a policy oriented, multiple use, GIS based forest monitoring network. It was designed to provide the Dutch government, on a cyclic 10 year basis, with actual information about Dutch forests. The main variables that were assessed during NFI5 were standing stock, ownership, stand age, management

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status, biodiversity (flora), carbon stock and recreation. In NFI6 most variables were reassessed, except biodiversity and recreation. Biodiversity and recreation in the forest are now covered by other types of assessments. The NFI covers all of the forest area in the Netherlands.

31.1.2 Sampling Methods and Periodicity

Within NFI6 the forest area is derived from the Dutch LULUCF 2009 land use database (Kramer et al. 2009; Van den Wyngaert et al. 2012). The LULUCF 2009 forest map is also used to determine whether the forest areas fulfil the minimum area criterion of more than 0.5 ha. Generation of this LULUCF 2009-forest map, a 25 × 25 m raster map, is not part of the NFI activities, but the responsibility of the Dutch LULUCF team. The NFI5 plot locations were arranged on a 1 × 1 km grid. Within each grid cell a random point location was selected as the potential location for the field plot. NFI6 used the same grid and plot locations as were used in NFI5 as a starting point. The grid was placed over the LULUCF 2009-forest map and all points that were situated inside LULUCF-forest were checked with recent aerial photographs. The aerial photo analyses revealed that 198 plot locations of the 3745 plot locations, selected during the map analysis, appeared not to be situated inside forest. These 198 plots were excluded from NFI6. The majority of the 3547 remaining plot locations were clearly situated inside forest. For a very small number of the 3547 plot locations the aerial photo analyses could not clarify whether they were inside forest or not. These plots were selected for field assessment as well. The field assessment resulted in 3393 plot locations that were actually situated inside forest. These 3393 field plots assessed during NFI6 represent a forest area of 373,480 ha. As a result each NFI plot represents 110 ha of forest. The FAO forest definition is used to determine the forest area. The time span between the measurements of the NFI5 and NFI6 is 7 years.

31.1.3 Data Collection

The NFI data consist of two main categories: stand and tree data. Stand variables describe the characteristics of the forest (stand) where the field plot is located. If a plot is situated in a naturally regenerated area within a forest stand, the characteristics of the regeneration area are described and not the characteristics of the surrounding stand. For tree measurements, trees are measured on a circular plot around the plot centre with a radius including a minimum of 20 trees. The radius is rounded upwards to whole metres with a minimum of 5 m and a maximum of 20 m.

The stand data can be described in the following categories:

- Administrative data: ownership category, restrictions for forestry, etc.
- Site description: forest management type, European Forest Type, crown cover of the shrub and tree layer, thickness of litter and humus layer, etc.
- Growing stock: main tree species, year of establishment (age), dominant height, development class and their size, type of establishment, mean height, regeneration, etc.
- Accomplished silvicultural measures: type of harvesting.

The tree data consists of:

- Trees dbh ≥ 5 cm including dead tree data: species, diameter, tree class, crown class and stem quality
- Sample trees (first tree (dbh > 5 cm) of every species on the plot): species, diameter, height, tree class and crown class
- Trees dbh < 5 cm and height ≥ 2 m data: species and number per species.

31.1.4 Data Processing, Reporting and Use of Results

The calculation of area estimates is straightforward, where the number of plots in the class (e.g. ownership, main tree species, forest type) is divided by the total number of plots multiplied by total forest area.

Growing stock estimates and associated parameters are estimated by calculating per ha values for the plots, multiplying these by the forest area they represent and adding up to the total value.

Conversion from dbh to stem volume is done by species specific functions derived from the data on sample trees. Based on the diameter and height information from the sample trees of each tree species the volume of each sample tree is estimated by using the equation of Dik (1984). The derived tree volume and dbh are used in a regression analysis to establish volume functions for the most common tree species. Based on the derived volumes functions the volume for each tree is calculated, including standing and lying dead trees.

Information on forest growth is derived from the permanent sample plots. In NFI5 50 % of plots were established as permanent, i.e. location of individual trees is known. Models for basal area growth of individual trees were developed. These models were subsequently used to calculate growth on temporary plots. Information on removals (timber harvest) is derived from permanent plots.

The area represented by a sample point is estimated by dividing the forest area by the number of sample points. If a sample plot is divided into several stands, the stand where the plot centre is positioned is taken to represent the whole plot.

The Dutch NFI mainly provides estimates at the national level, but some of the estimates are also provided for each of the 12 Dutch provinces. The estimates include among others forest area, growing stock, increment, fellings, regeneration, and dead wood (Schelhaas et al. 2014). The results of the Dutch NFI are used as basis for decision-making in policy, forest management, forest products industries, and for evaluating the consequences of the decisions taken. Reporting obligations of many international processes and organisations are fulfilled using the data and results of NFI. Reporting processes include: the Collaborative Forest Resources Questionnaire (CFRQ), the Forest Resources Assessment (FRA), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 of the Kyoto Protocol, the indicators and criteria for sustainable forest management for FOREST EUROPE (FOREST EUROPE, UNECE and FAO 2011), and other international enquiries.

31.2 Land Use and Forest Resources

31.2.1 Classification of Land and Forests

31.2.1.1 General Land Classification

The national land use classification system, as defined by the National Statistical Office (CBS), divides land into nine main classes with 38 subclasses. The main classes are infrastructure, build-up area, semi build-up area, recreation area, agricultural land, forest and nature area, inland water bodies and outside water bodies and foreign land. Forest is included in the main category forest and nature area. A forest area should be at least 1 ha to be included in the forest sub category. As a result of this 1 ha criterion the forest area based on the CBS classification does not correspond with the FAO forest definition and is for this reason not used in the NFI.

As well as the land use classification system of the National Statistical Office another land use database of the Netherlands (Landelijk grondgebruiksbestand Nederland (LGN) (Hazeu et al. 2014) is also in use. The LGN database is raster database with 25 × 25 m resolution covering the entire Dutch territory and presenting the land use in 39 classes. From 1986 the database is frequently updated with a 3–5 years interval. It is based on a combination of geodata and satellite images. The main classes are agriculture land, forest, water, build-up area, infrastructure and nature. The forest class is divided into the subclasses broadleaved and coniferous.

The LGN map is closely linked to the Basiskaart Natuur that is used to construct the Dutch LULUCF 2009 forest-non forest map for the Netherlands (Kramer et al. 2007, 2009; Van den Wyngaert et al. 2012) (Table 31.1). As described above this map is used to determine the Dutch forest area and to assign the location of the field plots in NFI6. In the NFI, the FAO forest definition is used to determine the forest area in the Netherlands. The area for other wooded land and trees outside the forest

Table 31.1 Land use in the Netherlands based on the LULUCF 2009 land use database (Kramer et al. 2009; Van den Wyngaert et al. 2012)

LULUCF code	Land use	Area (ha)	Area (%)	Corresponding FRA classes (FAO 2004)
10	Other grassland	1,201,729	28.9	OL, OlwTc
11	Nature grassland	140,632	3.4	OL, OlwTc
14	Patches of trees (<0.5 ha)	22,092	0.5	OlwTc
20	Cropland or bare grounds	924,863	22.3	OL, OlwTc
30	Heather	49,128	1.2	OL, OlwTc
40	Forest	373,480	9.0	Forest
70	Inland and outland water	785,994	18.9	
80	Reed swamps	25,947	0.6	OL, OlwTc
90	Shifting sands	3,766	0.1	OL, OlwTc
91	Dunes, beaches and sandbanks	34,747	0.8	OL, OlwTc
101	Build area	349,282	8.4	OL, OlwTc
102	Railways	6,561	0.2	OL, OlwTc
103	Roads	233,279	5.6	OL, OlwTc
	Total	4,151,498	100	

is not determined in the Netherlands. For NFI5 a forest/non-forest map was constructed, based on top 10 vectors, the CBS land use classification system and the FAO forest definition. This was not repeated for NFI6 as a forest non forest map was already available from the LULUCF team.

31.2.1.2 Forest Classification by Use

In the Netherlands the area of forest and the non-forest are identified. In the classification process no distinction is made between productive and non-productive forests or between protected and not protected forest areas. The forest area is classified after the field measurement. The type of use assigned to a forest is mainly derived from the forest management system that is allocated to each field plot during the field assessment. Table 31.2 shows the distribution of the Dutch forest area over the different types of forest management systems that are identified in the NFI6. Approximately three quarters of the Dutch forest area is classified as high forest. Nearly 14 % of the forest area consist of various plantings of trees and shrubs that full fill the minimum criteria of the forest definition. Such as landscape plantings or linear plantings. A further 3.5 % of the forest area consists of specific forest types such as coppice. Other wooded land and trees outside of the forest are not reported in FRA because the area is unknown.

Table 31.2 Forest management systems in the Dutch forest according to NFI6 (Schelhaas et al. 2014)

Forest management system	Forest area (1000 ha)	Area (%)
High forest	287	76.8
Even-aged high forest	219	
Uneven-aged high forest	57	
Regeneration area	6	
Clearcuts	5	
Specific forest types	13	3.5
Coppice	4	
Osiery	2	
Estate forest	5	
Others	2	
Other types of plantings	51	13.7
Landscape planting	11	
Linear plantings	11	
Natural regeneration non forest land	22	
Others	7	
Unknown	22	6.0
Total	373	100

31.2.1.3 Classification by Ownership Categories

Prior to 2014 all Dutch forest owners that owned a forest area of more than 5 ha had to register at the Bosschap (a former commodity board that unites owners, managers, contractors, employees and authorities involved in the management of forest and nature). More than 70 % of the Dutch forest area was registered and as such the type of ownership for this forest area was known. The following categories of ownership were distinguished by the Bosschap: individuals, municipalities, provinces, State forest service, Other state owned, water boards, Nature organisations, foundations and associations, recreation boards and water companies. Based on these classes a distinction can be made between private and public forest. Since 2014 the Bosschap does no longer exist as all commodity boards have been removed by the Dutch government. As a consequence this important data source for the type of ownership is no longer available.

The Bosschap registration was completed on an annual basis enabling the annual change between ownership categories to be determined. In NFI6 the type of ownership is assigned to the field plots by making use of the land register (cadastre). As the land register might sometimes be outdated, the type of ownership was checked during the field work when possible. Based on NFI6, 48 % of the Dutch forest was publicly owned, 51 % was in private ownership and for the 1 % of the forest area remaining the ownership was unknown (Table 31.3).

Table 31.3 Forest area by ownership categories according to NFI6 (Schelhaas et al. 2014)

Ownership category	Forest area (1000 ha)	Area (%)
Public ownership	180.5	48.2
State Forest Service	98.6	26.4
Other state owned	21.8	5.8
Provinces	2.3	0.6
Municipalities	53.2	14.2
Other public ownership	4.6	1.2
Private ownership	190.5	51.1
Nature conservation organisations	72.1	19.4
Companies	21.1	5.7
Estates	19.7	5.3
Organised others private	11.0	2.9
Individual private owners	66.5	17.8
Unknown	2.5	0.7
Total	373.5	100

31.2.1.4 Forest Management and Cutting Systems

Although the majority of forests in the Netherlands are even-aged (Table 31.2), forests are more and more managed in an uneven-aged management system. A good practice model for forest management is as follows:

1. Establishment with natural regeneration, sowing or planting, mainly according to the owner's decision
2. First thinning at an age of 25–30 years, pre commercial/sanitation fellings are rarely performed
3. A number of thinnings (e.g. app. every 5–7 years) during the rotation
4. To the end of the thinning cycle larger regeneration cuttings of 1–4 times the tree height are performed to enhance regeneration (natural and to a lesser extent planting)
5. Final cutting is undertaken, but clearcuts at the end of the rotation are not common practice although they are performed. The final cutting age differs largely between forest owners and tree species.

Under bullet 4 the traditional forestry term rotation is mentioned to indicate the period between the establishment of the stand and the moment that the last tree of this stand is felled. Due to the fact that small scale forest management is the main type of management in the Netherlands it is very difficult to indicate the average length of the rotation.

The share of removals from thinnings and final fellings (clearcuts) is not exactly known, but it is estimated to be 70 % from thinnings and 30 % from final fellings in volume terms. The re-measurement of the permanent plots during NFI6 show that in the period between the NFI5 (2001–2005) and the NFI6 (2012–2013) clear felling had been undertaken on 4 % of these plots, thinnings were undertaken on

52 % and no fellings were undertaken on the remaining 42 % of the permanent plots. Clearcutting has made way for small-scale interventions and therefore clearcuts made up only 1.3 % of the forest area in 2013.

Forest owners decide on whether or not to harvest their forest, harvesting is not compulsory. Within 3 years after a final felling through a clearcut, the new forest must be re-established by natural regeneration, planting or sowing. Thinnings are not restricted, but the authorities have to be notified. Forest owners decide also whether to perform a thinning or not.

31.2.1.5 Legal and Other Restrictions for Wood Use

The following factors mainly affect the availability for wood supply in the Netherlands (Table 31.4).

A. Protected areas

Forestry operations are not performed in forest reserves (IUCN code I). The 60 forest reserves in the Netherlands range from 4 to 200 ha and cover a total forest area of 3000 ha. No forest management is permitted in forest reserves, they are designated as research locations.

More than 31,000 ha of forest are located inside National parks (IUCN code II). Being situated within the borders of a national park does however not automatically preclude forest management and timber harvesting. The intensity of forest management and the associated timber removals may, in some cases, differ from the situation of the forest area outside national parks.

The area of forest in IUCN codes III to VI is estimated to be approximately 56,000 ha.

In total 20–30 % (70–100,000 ha) of the Dutch forest is designated for nature conservation. Inside these forests timber production is not the primary management goal. Timber is removed, but only to enhance natural processes or to for instance reduce the share of introduced tree species. The majority of this

Table 31.4 Restriction classes

Category	Relevance in the Netherlands	Comment
Protected for biodiversity	Highly relevant	Forest operations restricted or not allowed
Recreation areas and living areas	Relevant	Forestry operations restricted
Cultural heritage	Relevant	Forestry operations not allowed or restricted (area is small)
Military areas	Relevant	Forestry operations restricted
Ownership	Highly relevant	Forestry operations restricted or not allowed
Site characteristics and logging costs	Relevant	Forestry operations non-profitable with current prices and technology

forest area belongs to nature conservation organisations or the State forest service.

B. Recreation areas and living areas
Within recreation areas and residential areas in forests the aim of forest management is on maintaining the non-wood values. Timber is however harvested, but at low levels.

C. Cultural heritage
Some cultural heritage sites are managed in a way that there is no threat to the site, resulting in no removals or very low harvest levels. These cultural heritage sites do however cover a very small forest area. The size of this forest area is unknown.

D. Military areas
The forests in a large part of the military areas are managed in the Netherlands and timber is produced. However, in some of the area timber production is not possible for safety reasons.

E. Ownership
The availability of wood supply is very much affected by the attitude of the forest owner to timber production within their forest. Especially small forest owners (<5 ha) tend to be reluctant to producing timber in their forest or do not consider harvesting timber from their forest at all. These forest owners account for approximately 57,000 ha (16 % of the total forest area) owned by 28,000 individual holdings.

F. Site characteristics and logging costs
Elevation and slope is not an issue for timber production in Dutch conditions. Other site conditions such as the soil bearing capacity is an issue under very wet conditions and on peat soils. This results in high logging costs or no harvesting possibilities at all. High harvest cost is also encountered in specific (unique) forest types, such as coppice, forests in landscape parks, floodplains, etc.

31.2.1.6 Further Classification of Forests

The further classification of forests in the NFI is by dominant tree species, age class, type of forest (e.g. high forest, coppice, etc.), forest composition (mixed, monoculture, etc.). With a share of 30 % in area and 25 % in the growing stock volume Scots pine is the most common tree species in the Netherlands (Table 31.5). Due to the fact that broadleaved tree species are promoted above coniferous tree species in forest management the share of European oak is increasing. European oak currently accounts for 17.2 % of the area and 19.8 % of the growing stock volume. In particular, this type of forest classification is used to determine whether a forest is available for wood supply or not. The majority (80 %) of the Dutch forest consists of high forest. More than 80 % of this high forest is classified as even-aged forest, despite the efforts to change this to mixed uneven-aged forest.

Table 31.5 Forest area (National- and FAO definition) and growing stock volume by dominant species in 2013 (Schelhaas et al. 2014)

Species	Area (1000 ha)	Growing stock volume (Million m^3)	Volume (%)
Scots pine (*Pinus sylvestris*)	111.8	20.2	25.0
European oak (*Quercus petraea* and *Q. robur*)	64.3	16.0	19.8
Birch spp. (*Betula spp.*)	24.8	4.5	5.6
Douglas fir (*Pseudotsuga menziesii*)	18.9	6.7	8.3
Japanese Larch (*Larix kaempferi*)	18.2	3.9	4.8
Poplar and willow (*Populus and Salix spp.*)	18.6	3.7	4.6
Beech (*Fagus sylvatica*)	15.4	5.3	6.6
Ash (*Fraxinus excelsior*)	13.1	2.7	3.3
Spruce (*Picea abies*)	12.7	3.5	4.3
Other deciduous	29.1	8.4	10.4
Other coniferous	17.4	5.3	6.6
Shrubs	1.6	0.7	0.9
Clearcut	5.3		
Unknown	22.3		
Total	373.5	80.9	

Table 31.6 Forest area (National- and FAO definition) by age classes in 2013 (Schelhaas et al. 2014)

Age class (years)	Area (1000 ha)	Area (%)
1–14	23.3	6.3
15–34	52.2	14.0
35–54	80.4	21.5
55–74	85.4	22.9
75–94	62.2	16.7
95–114	32.6	8.7
115–134	8.9	2.4
135–154	3.2	0.9
155–174	2.2	0.6
>175	0.8	0.2
Unknown	22.3	6.0
Total	373.5	

The average age of the Dutch forest is 62 years (deciduous: 58 years and coniferous: 67 years) according to the results from NFI6. The age-classes are derived from the planting years that are recoded in 20 year intervals. Due to the fact that large scale cuttings have been substituted by small scale interventions in Dutch forest management during the last decades the forest area that is under regeneration is quite small. Although the results of NFI6 (Table 31.6) show that the reduction in the share of the youngest age class has been stopped compared to the results of the NFI5.

31.2.2 *Wood Resources and Their Use*

31.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock, increment and drain (natural losses and fellings) are based on the re-measurement of permanent plots. They are calculated as volume of stemwood overbark. Stemwood according to the Dutch NFI includes all stem parts above ground and to a top diameter of 0 cm. Trees and shrubs with a dbh of 5 cm or more are included. Trees below this threshold are not included in regular NFI estimates. The volume of standing stock can be divided into the volume of growing stock and volume of standing dead wood. Increment and drain are calculated as mean annual estimates for the period between two consecutive NFIs. The estimation is based on the permanent sample plots. The volume of drain is further stratified into natural losses and nine harvest types. The national definitions for standing stock, increment and drain are compiled in Table 31.7.

During NFI6, 1235 permanent field plots that were established during NFI5 were re-measured. This facilitated the estimation of the increment and fellings (drain) in Dutch forests for the first time since the finalisation of the HOSP project in 1999. Table 31.8 gives the estimates of standing volume, increment and fellings by tree species.

The Dutch forest area has a growing stock volume of 80.9 million m^3 of stemwood overbark and an additional standing volume of dead wood of 2.4 million m^3 stemwood overbark. The volume increment is estimated to be 2.7 million m^3 per year and almost 1.3 million m^3 are felled each year. The harvest level is consequently 48 % of the increment.

31.2.2.2 Tree Species and Their Commercial Use

All tree species in the Dutch forests have a commercial value, but in terms of growing stock the main tree species is Scots pine (*Pinus sylvestris*, 25.0 %),

Table 31.7 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with dbh ≥ 5.0 cm over bark, including the above ground bole (wood and bark) and to a top diameter of 0 cm
Increment	Volume increment of surviving trees with dbh ≥ 5.0 cm over bark plus the volume of ingrown trees into the circular plot between two consecutive NFIs
Drain	Volume of trees with dbh ≥ 5.0 cm over bark at the first measurement that were found to be harvested in the subsequent NFI

Table 31.8 Tree species—volume, increment, cuttings (Schelhaas et al. 2014)

Species	Growing stock volume (Mm^3)	Increment (1000 m^3/year)	Fellings (1000 m^3/year)
Scots pine (*Pinus sylvestris*)	20.2	535	352
European oak (*Quercus petraea* and *Q. robur*)	16.0	394	131
Birch spp. (*Betula spp.*)	4.5	142	31
Douglas fir (*Pseudotsuga menziesii*)	6.7	335	157
Japanese Larch (*Larix kaempferi*)	3.9	154	115
Poplar and willow (*Populus and Salix spp.*)	3.7	151	130
Beech (*Fagus sylvatica*)	5.3	142	42
Ash (*Fraxinus excelsior*)	2.7	126	33
Spruce (*Picea abies*)	3.5	158	102
Other deciduous	8.4	354	36
Other coniferous	5.3	185	90
Shrubs	0.7	48	1
Total	80.9	2724	1267

followed by the European oaks (*Quercus petraea* and *Q. robur*, 19.8 %) and the sum of Douglas fir and larch (*Pseudotsuga menziesii*, *Larix spp*., 13.1 %).

The main use of industrial roundwood of pine is sawn timber (46 %), fibre production (44 %) and production of poles (10 %). Industrial roundwood of the European oaks is mainly used for sawn timber (50 %), fibre production (45 %) and poles (5 %). Douglas fir and larch are important species for private forest owners as the majority of the high quality industrial roundwood is used for sawn timber (66 %), with the remainder used for fibre production (23 %) and poles (11 %).

The use of wood for bioenergy is increasing, resulting in an increasing removal of roundwood and harvest residue from the forest on top of the harvest of industrial roundwood. Roundwood that is extracted for bioenergy purposes is mainly used as fuelwood by private households and to a lesser extent by biomass energy plants. The roundwood harvested for energy purposes mainly consists of broadleaved species and may contain industrial roundwood suitable for panel production or as sawn wood. Due to the fact that the volumes are too small to separate them from the rest of the harvested volume, the woodchips from tops and branches are mainly used by biomass energy plants of different size in the Netherlands or abroad, but harvest levels are still very low.

31.3 Assessment of Wood Resources

31.3.1 Forest Available for Wood Supply

31.3.1.1 Assessment of Restrictions

A number of different sources are used to determine the forest area that is available for wood supply in the Netherlands. In particular, the forest type classification is used to determine whether a forest is potentially available for wood supply or not. Forest type classification is allocated to each NFI plot using the stand characteristics, soil type and appearance of the forest.

The forest area that is potentially available for wood supply is reduced to the forest area actually available for wood supply by applying the restriction classes from Table 31.3. These restriction classes are ideally allocated to the NFI plots using GIS based analyses. Maps containing information on the nature conservation areas, recreation and living areas, cultural heritage sites and military areas would be used in these analyses. Until now the estimation of the forest available for wood supply is mainly based on a straight forward estimation of the area that is not available for wood supply.

The restriction that is imposed by the ownership of the forest is not taken into account to determine the area that is actually available for wood supply. The main reason for this is due to the fact that the main forest management goals of private forest owners are not known and can for that reason not be taken into account. As such the analyses to determine the forest area available for wood supply is mainly a theoretical approach and does not include actual information on the main forest management goals.

The extraction of woody biomass, in the form of harvesting residues, from the forest is not taken into account in the availability for wood supply analysis although the issue is getting more and more important. Other restrictions, such as nutrient availability and increased soil compaction, do apply for this type of harvesting and this issue asks for more attention in forest management and forest research.

31.3.1.2 Estimation

The most recent estimation of the forest available for wood supply (FAWS) has been performed for the FOREST EUROPE 2015 enquiry. According to NFI6 almost 82 % of the forest in the Netherlands has a production component. It consists of even and uneven-aged high forest. Part of this area is in a transitional face in which it is transformed from a productive plantation into “natural” forest consisting of native mainly broadleaved tree species. After this face the forest will be managed as nature in which wood production is not important. The forest area with a production component is selected as the area of FAWS in the FOREST EUROPE 2015 enquiry.

31.3.2 Stem Quality

31.3.2.1 Stem Quality and Assortments

Individual trees are assessed for stem quality in the NFI. Assortments are not assessed during field data collection nor are they derived during subsequent data analysis.

31.3.2.2 Assessment and Measurement

Wood quality is assessed on trees with dbh > 18 cm and a straight main bole. If the number of trees with a dbh > 18 cm on the field plot is large, a sample of 15 % of the total number of trees is taken. For these trees the stems are assessed according to sawlog criteria. These criteria are not based on a national standard and include:

1. No damage on the stem
2. Number of branches at the first 6 m of the stem (classes: <3, 3–5 or >5 branches with a diameter of >2 cm)
3. Bends of less than 1 cm per metre in the first 6 m (yes = <1 cm, no = >1 cm).

No further wood quality assessments are taken on the other trees on the plot. The assessment of the timber quality is not a major issue in the Dutch NFI. This is mainly caused by the fact that the Netherlands doesn't have a very large roundwood processing industry and forest management is not focusing on timber production. However, as a result of the current economic situation, there is an increasing awareness that forests need a strong economic component to be managed sustainably.

31.3.3 Assessment of Change

31.3.3.1 Assessment and Measurement

The growing stock is estimated for all NFI plots in the Netherlands. All change variables are directly estimated from measurements at permanent NFI-plots at two consecutive points in time, 1235 plots in NFI6. Important change variables, in the context of forestry, are growth and yield (timber harvest). Other change variables (windthrow, mortality, wood decay) are estimated as well, however, they are not as vital to the forestry sector as growth and yield.

On permanent NFI-plots the following characteristics of all trees within the plot are recorded:

- Location (coordinates) of the tree
- Species
- Dbh

- Social status (alive/from dominant cohort, alive/younger/older than dominant cohort, dead/standing, dead/lying)
- Crown position (under/in/above canopy)
- Yield status (cut/harvested, cut/not harvested, windthrow/harvested, windthrow/not harvested).

The permanent plots established during NFI5 were re-measured for the first time during NFI6. As the location of the trees on the plot was recorded during the first measurement cycle, the trees can be reassessed and new trees (ingrowth) recorded.

On the individual tree level a distinction is made between the change in tree status (alive/dead, standing/lying, present/absent) and the change in tree dimension. The vast majority of trees show some change in dimensions over time and these changes are recorded on the permanent NFI plots. The change in dimension is calculated in terms of dbh, basal area, stem volume, woody biomass (dry weight) and CO_2-equivalents. For each tree in the sample this change in dimensions is attributed to natural and man-made processes which shape forest development (Table 31.9).

Table 31.9 Change in tree status and quantifiable natural and man-made processes

Tree status in previous NFI	Tree status in current NFI	Dimension change attributed to
Alive, standing	Alive, standing	Growth
Alive, standing	Alive, lying	Unaccounted for
Alive, standing	Dead, standing	Growth, mortality and decay[a]
Alive, standing	Dead, lying	Growth, windthrow and decay[a]
Alive, standing	Dead, lying	Growth, cut (no harvest) and decay[a]
Alive, standing	Absent	Growth, cut and harvest[b]
Alive, standing	Dead, dbh < 5 cm	Mortality and decay[a]
Dead, standing	Alive, standing	A miracle[c]
Dead, standing	Dead, standing	Deterioration
Dead, standing	Dead, lying	Windthrow followed by decay
Dead, standing	Dead, lying	Cut (no harvest) followed by decay
Dead, standing	Absent	Harvest
Dead, standing	Dead, dbh < 5 cm	Decay
Dead, lying	Dead, lying	Decay
Dead, lying	Absent	Harvest
Dead, lying	Dead, dbh < 5 cm	Decay
Absent	Alive, standing	Ingrowth[d]

[a]Observed change is outcome of growth and deterioration
[b]Growth prior to harvest is not observed
[c]Generally, it is assumed that the tree was erroneously declared dead
[d]Growth is not observed

For each permanent plot, change is characterised by computing the change variables on a per ha basis. Mean annual change is calculated by dividing change variables by the number of growing seasons in between the subsequent measurements. This number does not need to be an integer; as adjustments are made for survey dates during summer. Finally, mean annual change is calculated by taking the mean of all plots and total change for the Dutch forest is then straightforwardly calculated by scaling up to the total forested area. Change variables are not restricted to the forest available for wood supply.

31.3.3.2 Estimation of Increment

Stem volume is calculated by applying a species specific volume function for the tree. The volume function is polynomial, with dbh as the input variable and the output is the stem volume over bark:

$$V_{stem} = b_0 + b_1 * dbh + b_2 * dbh^2 \tag{31.1}$$

The b-coefficients are estimated from observations on sample trees. Sample trees are measured for their dbh and height. Stem volume is calculated for these sample trees from published volume tables (Dik 1984, 1990, 1992; Schoonderwoerd 1993):

$$V_{stem} = c_0 * dbh^{c1} * height^{c2} \tag{31.2}$$

A weighted least squares procedure is used (Cunia 1964) on the (dbh, V_{stem}) pairs to estimate the b-coefficients of Eq. (31.1). Two weighting factors are applied:

1. The dbh of the tree, to decrease the influence of very big trees on the outcome of the estimation process
2. The share in basal area of the tree's species on the plot, to account for possible variations in h/dbh dimensions caused by certain mixtures of species.

For some species groups the b-coefficients have been determined for nutrient poor and nutrient rich separately as the difference appeared to be significant.

Basal area growth of individual trees is modelled, resulting in individual tree growth models for forest trees of the main species. These models have been based on the recorded growth between NFI5 and NFI6 of the trees on the permanent plots and do for this reason represent the growth conditions in the period between the two NFIs.

The increment model is as follows:

$$I_G = a_0 + a_1 * g^{p1}/G^{p2} + a_2 * (g/t)^{p3} \tag{31.3}$$

I_G	annual basal area growth on individual tree level (cm^2/year)
g	individual tree basal area (cm^2)

G	basal area (per ha) of the forest surrounding the individual tree (m^2/ha), divided by 100
t	age of the tree (year)
a_0, a_1, a_2, p_1, p_2, p_3	parameters estimated by non-linear regression.

31.3.3.3 Estimation of Drain

NFI data from permanent plots are used for estimating the fellings, removals and mortality. Basically fractions of probabilities are estimated for each tree class (species, size class, age class, social position), either for the probability of being felled or die. These probabilities (or models) are used in combination with the temporary plot data to estimate total harvest volume and total mortality.

To determine the probabilities all trees on the permanent plots with two measurements have been grouped based on a combination of NFI6 diameter class, tree species and forest owner. For each of these established groups the fraction of felled or died trees is determined (on an annual basis). If the fraction of trees that were felled or have died trees could not be determined for one of the groups, the fraction for this group is manually estimated by using available data for the same species in other groups. The width of the diameter classes is 5 cm. Forest owner is used as a determining factor as forest management is strongly influenced by forest ownership, which ultimately effects the probability of a felling taking place.

Minor problems with the approach used to estimate change in the Dutch NFI are:

1. If a small tree (dbh $\geq$ 5 cm) is in the current NFI plot, but wasn't present in the plot during the previous NFI, then it is assumed to be ingrowth. Ingrowth trees are assumed to have had a dbh of zero at the time of the previous NFI.
2. If a tree was present during the previous NFI, but wasn't during the re-measurement, the tree is assumed to be harvested. A distinction is made between the harvest of dead trees (during the previous NFI) and living trees. The increment of felled trees is estimated by using individual tree growth models. As the exact date of harvest is not known the time the trees were felled is set at the halfway point of time in between two NFI-measurements.
3. A tree that was alive at the time of the previous NFI, but is standing dead has obviously died since the previous NFI. Increment of trees that have died in between two measurements is neglected. Most of these trees have died of severe competition, or of old age. In both cases these trees' growth is considered as negligible.
4. Lying dead trees in permanent plots, that were upright living trees in the previous NFI, are in general wind thrown. If wind thrown trees are harvested they are recorded as harvested, and not as windblown. The resulting change in size of wind thrown trees can be positive (due to growth during the years before the 'storm') or negative (due to the decay of the wood after the tree has fallen). These two components cannot be estimated separately and it has been decided to

estimate the combined effect. Generally, the trees are smaller in size in the current plots. It is most probable that healthy trees are more firmly secured and do not easily get blown over, while trees that have suffered severe competition are most susceptible to wind throw.

5. Wind thrown trees that stay alive after they have fallen, have sufficient roots and root activity to keep them alive. Sometimes they form new vertical growing shoots that eventually can reach treelike dimensions. This phenomenon, although fairly rare, needs more attention during the next NFI. Since these situations could not be properly addressed and field workers couldn't rely on an unambiguous instruction on how to deal with them. In most cases during NFI6, the windthrown bole is probably recorded as 'gone' and the new shoots are recorded as ingrowth if their dbh exceeds 5 cm.

31.3.4 Other Wooded Land and Trees Outside Forests

No NFI measurements are taken on other wooded land or trees outside the forests. Nevertheless, due to the increasing awareness of the importance of these trees and these landscape elements for the supply of woody biomass, the number of studies to determine the biomass availability is increasing. These studies began as desk studies, but have moved to the field to determine the woody biomass availability in the Dutch countryside. These studies are undertaken independently of the NFI and mainly consist of yield studies for individual types of plantations in the countryside, e.g. assessment of annual increment in linear planting along roads and the level of biomass amounts could harvested annually. These studies are on an ad hoc basis and are not expected to become structural.

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Chapter 32
Norway

Stein M. Tomter

32.1 The Norwegian National Forest Inventory

32.1.1 History and Objectives

The Norwegian National Forest Inventory (NFI) has been producing large-area forest resource information since 1919, as the world's first operational NFI. The first inventory was carried out from 1919 to 1930 (Landsskogtakseringen 1933). The main reason the inventory started at that time was due to concerns about the status of forest resources and the fear of a lack of forest resources in the future. Experience from regional inventories in Norway and Sweden was the basis for the first inventory. Although a lack of forest resources is no longer a major issue of concern, the NFI is still to a high extent used to assess availability of wood at regional and national level, in addition to international reporting (including carbon reporting), bioenergy and biological diversity issues and various research projects.

Over time, the NFI has gradually developed, as new designs and new variables have been introduced according to new scientific knowledge and new requirements. For example, the assessment of coarse woody debris and several ecological variables were introduced in the 1990s. Additional variables and adjustments to facilitate reporting of activities and carbon uptake and emissions from the LULUCF sector were introduced step-by-step from about 2005 until today. Prior to 2005, forest was assessed in the field according to the national definitions only, but from the 1990s with some additional variables to facilitate the reporting of forest area according to the international definitions. Since 2005, forest is directly assessed in the field according to the international definition to facilitate international reporting, while at the same time the national definition is maintained.

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32.1.2 Sampling Methods and Periodicity

Ten inventory cycles have been completed to date, the last one taking place from 2010 to 2014. From the beginning in 1919 until the mid-1950s, the surveys were organised as strip-sampling inventories and later on as plot sampling inventories with temporary plots only.

From 1986 to 1993, fixed-area circular permanent sample plots were installed in all counties except Finnmark. This inventory cycle, NFI6, was carried out on a county-by-county basis. In 1994 the concept of continuous forest inventory was introduced, with 20 % of the sample plots inventoried each year. Since 1995, inventories have been carried out together on a county basis with re-measurement of the permanent plots in such a way that temporary plots have been measured in selected counties and completed over a 5-year period. The temporary plots are, however, not relevant for international reporting and for preparation of statistics at the national level.

Limited inventory work in Finnmark, the northernmost county, was started in 2005, and the first cycle was completed in 2011. Afterwards, the permanent plots in Finnmark are re-measured according to the same system as in other counties. Also, during the period 2005–2009 the low productivity mountain forest was assessed for the first time. That means the development of the entire forest area, its growing stock and its biomass can now be monitored. Efforts have also been made to assess the land-use class of all sample plots in the national grid, and to track all land-use transitions of sample plots. This is an important requirement for the assessment of afforestation, reforestation and deforestation in the LULUCF reporting context. Plots in land-use classes not eligible for tree measurements are normally classified by means of aerial photo-interpretation.

The field sampling intensity for permanent plots is basically the same over the entire country; i.e. one sample plot represents the same forest area regardless of the location of the plot. There are, however, some exceptions in mountain forest and in the far north region. The distance between plots is normally 3 km, both in the north-south and in the east-west direction. If temporary plots used for county wise inventories are disregarded, all plots are installed in a regular grid without clustering. In mountain regions and in Finnmark county the distance is generally somewhat longer and may vary according to strata.

Stand description variables describe the forest stand where the field plot is located. Stand variables are assessed on a 0.1 ha plot around the plot centre (normally circular, but could also have some other shape depending on the location of the stand boundary). If a field plot is divided into two different stands or land use classes, the units are described separately. The minimum size of a partial plot to be described separately is 20 %. For tree measurements, the sample plot is a fixed-radius plot with a radius of 8.92 m (250 m^2). All trees with dbh $\geq$ 5 cm are measured on the entire plot, regardless of the diameter class. Trees with dbh < 5 cm are counted on four sub-plots inside the sample plot, representing in total 21.2 m^2.

The sampling grid consists of approximately 22,000 plots, of which about 11,700 are located on forest.

32.1.3 Data Collection

The NFI data consist of two main categories: area description and measured tree data. The area data content in broad categories is:

- Administrative data: location (county, municipality), field crew leader, assessment status, etc.
- Site description: land cover and land use class, vegetation type, slope, exposition, site productivity class, soil type, soil depth, bilberry cover, terrain properties, etc.
- Stand properties: stand size, crown storeys, species composition, crown cover, development class, age, damages, browsing by animals, naturalness, etc.
- Accomplished and proposed silvicultural measures: accomplished and proposed cuttings, silvicultural measures, soil scarification, drainage, pruning.

The tree data consist of:

- sample tree data: diameter, species, etc.
- subsample tree data: height, age, diameter, damages, crown density and discoloration (ICP), etc.
- data on deadwood (including decomposition).

Some of the variables are only relevant for "productive forest" and are measured only on plots located within this category. Others are measured for all forests, or for forest and other wooded land. Tree measurements for the assessment of growing stock and biomass are being carried out on all forest and other wooded land, in addition to a few other land-use categories. Complete data for trees outside forest (TOF) or other land with tree cover (OLwTC) are, however, not available.

Further details about the assessments and measurements made in the field can be found in the field instruction manual (Landsskogtakseringen 2014).

32.1.4 Data Processing, Reporting and Use of Results

The estimation of volume statistics consists of three main steps:

1. Estimation of stem volumes for sub-sample trees
2. Generalisation of volumes for sample trees
3. Summary of plot wise area and volume (or biomass) statistics.

Stem volumes of sub-sample trees are estimated with general volume functions using dbh and tree height as regressors (Bauger 1995; Braastad 1966; Brantseg

1967; Vestjordet 1967). Volume estimates are generalised for sample trees by calculating an average tariff (diameter-height relationship) for each sample plot and the occurring tree species group. Approximately 10 sample trees per sample plot are selected, when feasible. The average tariff is then used to estimate the volume of sample trees. When the volume of each tree is known, a height corresponding to this volume can be estimated for each of the sample trees. After these calculations, the following data are available in the database:

- Measured diameter and measured height of sub-sample trees;
- Measured diameter and estimated height of sample trees;
- Calculated volume of all trees.

Measured diameters, together with measured or estimated heights, are used to estimate the biomass of all trees.

The area represented by a sample plot is estimated by dividing the country land area by the number of sample plots. The land area is taken from the official statistics maintained by the Norwegian Mapping Authority. The area estimate for an arbitrary stratum is simply the sum of the areas represented by the number of sample plots within the stratum. If a sample plot is divided into two different stands or land-use classes, the represented area is distributed proportionally between the parts falling into each stand.

For each tree, the corresponding value per hectare can be estimated. The total volume estimate for an arbitrary stratum is obtained by multiplying the tree wise volume estimates per hectare by the area represented by the sample plot, then summing up for all plots in the stratum. Normally the volume represented by each tree and each sample plot is calculated and available in the database, so that the volume for a stratum or a group of trees can be performed by a simple summation.

Change estimates are obtained from the assessments of two consecutive inventories. The volume increment is calculated as the difference between the stem volume on the second occasion, and the volume one year earlier. That is accomplished by dividing the dbh difference of an individual tree by the number of growth seasons (approximately 5) between measurements. The volume tariff (diameter-height relationship) is assumed to be the same on the second occasion and one year earlier. Normally a value for volume increment is assigned to each individual tree on the second occasion, and a summary made to represent all trees inside a stratum or a region. For certain purposes, the volume of trees that have passed the minimum dbh-threshold between measurements are included in the increment estimate, resulting in a more complete estimate comprising all dbh classes. The accumulated volume of these trees provides an accurate estimate of the increment of trees below the dbh threshold.

The level of drain, consisting of the two components harvest and natural losses, can also be estimated by comparing data from two consecutive inventories. However, since the sample is small and variations are significant, reliable annual estimates cannot be provided from the NFI alone.

The results from the NFI are presented at various geographic levels. The smallest unit, for which reliable results can be given, is usually the county level. For bigger counties, the permanent plots will normally provide results of satisfactory quality, but for the smaller counties these data have to be supplemented by data from temporary plots. Results are published in reports presenting the most frequently requested data, for individual counties, regions or for the whole country.

The results of the Norwegian NFI are, to a bigger or smaller extent, used as basis for decision-making in forest policy, forest management, forest products industries, and for evaluating the consequences of decisions taken. Reporting obligations for many international processes and organisations are fulfilled using NFI data and results. Reporting processes include: the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO), the national reports on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Article 3.3 of the Kyoto Protocol, and the indicators and criteria for sustainable forest management in Europe (FOREST EUROPE, UNECE and FAO 2011).

NFI data are utilised as a data source for various research and development projects. Examples include: (i) a study on the possible influence of nitrogen and acid deposition on forest growth (Solberg et al. 2004); (ii) assessment of emissions and removals of CO_2 in forest (Nilsen et al. 2008); (iii) an evaluation to what extent afforestation may be a useful climate change mitigation measure (Haugland et al. 2013); (iv) assessment of the potential for using harvest residues for bio-energy (Bergseng et al. 2013); (v) analyses of the availability and future potential supply of forest resources from the coastal regions (Granhus et al. 2011). The data are also used as calibration and reference data for remote sensing projects, like recent projects on photogrammetry or 3D SAR applications.

32.2 Land Use and Forest Resources

32.2.1 Classification of Land and Forests

32.2.1.1 General Land Classification

Since 2005, the inventory system has been adjusted to facilitate international reporting, while at the same time maintaining the traditional national definitions. Forest is divided into two separate categories; productive forest and non-productive forest (Table 32.1). Together, these two categories normally correspond to the international definition of forest. However, there are a few other adjustments that are normally carried out to accommodate to the international definition. The NFI has specified a minimum area of forest and other wooded land of 0.1 ha, and a minimum width of linear formations of 4 m. Sample plots located on forests between 0.1 and 0.5 ha (or linear formations narrower than 20 m) are identified by

Table 32.1 Land use classes and forest area (2009–2013) from the NFI

Class name	Area (1000 ha)	Comment	Corresponding FRA classes (FAO 2004)
Productive forest	8658		Productive and non-productive forest generally correspond to FAO forest, except from some minor adjustments as described in the text.
Non-productive forest	3522		
Other wooded land	2087		FAO OWL
Barren land, bare rocks	14,201		FAO OL
Cultivated pasture	228	May have some tree cover	FAO OL, OlwTc
Agricultural land	931		FAO OL, OlwTc
Calluna spp. heath	194	Heathlands in coastal districts, historically managed by burning and pasture use.	FAO OL
Other land	614		FAO OL, OlwTc
Inland water	1944		
Total area	32,378		

Figures are not adjusted for minimum forest unit or for current land utilisation

a special variable and can be excluded for international reporting. Plots classified as forest, but located under power lines, land designated for holiday cabins, public roads, railways, etc. are normally also excluded. Finally, small openings in the forest related to infrastructure, landing sites, etc. are not classified as forest according to the national NFI methodology. These plots are reclassified and added to the forest area for international reporting. In total, these adjustments do not have any substantial impact on the area of forest. According to the most recent data, the sum of productive and non-productive forest is 12.180 million ha without adjustments, and 12.104 million ha with the aforementioned adjustments.

32.2.1.2 Forest Classification by Use

In addition to the basic land use classification listed in Table 32.1, each of these classes can be divided into maximum nine sub-classes of current land utilisation. These classes are:

- Forestry (no specific restrictions)
- Urban area, built-up land

- Area designated for holiday cabins
- Recreational area (not necessarily official designation)
- Military training field
- Nature reserve, national park
- Road, railway, airfield (non-forest road)
- Power line
- Other.

The term “productive forest” only means that the area has a productive capacity of at least 1 m^3 per ha and year. This type of forest can also e.g. be located in a nature reserve. To estimate how much is available for wood supply, “productive forest” has to be combined with the current land utilisation “forestry”. Under this limitation, the area is reduced from 8.658 million ha to 8.344 million ha. As some of the productive forest has poor access and/or a stocking of low quality, the actual forest area where wood harvesting is taking place will be less. Non-productive forest and other wooded land are normally not utilised for harvesting wood, although there may be some occasional cutting of firewood and other small-scale harvesting.

Protective forest that is productive, is normally available for wood supply, although with certain restrictions. Such restrictions may be to avoid large clear-cuts, or to practice selective felling. Protective forest is currently not a part of the NFI dataset, and information has to be derived from other sources, if needed.

The rule is that all forest plots should be visited in the field, whenever feasible. There are 27 inaccessible plots (including plots in military forest) in the productive forest and 117 plots in non-productive forest, representing 1.4 % of the total forest area. The majority of plots on other wooded land are also visited in the field. If photo interpretation and data from previous inventory shows that there are no trees of measurable size (≥5 cm dbh) on OWL, the sample plot may not be visited, but classified from aerial photographs. This is the case for plots representing 35 % of the total area under this category.

32.2.1.3 Classification by Ownership Categories

There is currently no complete classification of ownership directly linked to the NFI plots. It is possible to classify most of the plots (80–90 %) by using information from the cadastre and public registers. The completeness of data will probably improve over time.

The following distribution of forest land by ownership categories are taken from Statistics Norway, the national statistics office (Table 32.2). As the data are not totally harmonised with the NFI, the sum of the area categories does not correspond exactly to what is obtained from the NFI. The categories “common forest” and The Finnmark Estate represent community-owned forest and are normally included under private ownership.

Table 32.2 Productive, non-productive and total forest area by ownership classes (1000 ha)

Ownership category	Productive forest	Non-productive forest	Total forest area
Individuals	5668	2284	7952
Other private	267	96	363
Common forest	182	40	221
The Finnmark Estate	59	1047	1106
Municipality and county	218	56	274
Central government	633	580	1214
Unknown	28	29	56
Total	7055	4132	11,186

32.2.1.4 Forest Management and Cutting Systems

According to NFI data, nearly half of the forest area available for wood supply is considered even-aged, while the rest is uneven-aged. This feature is assessed for productive forest, with the exception of temporarily unstocked forest and young stands. If all stands falling into the two latter categories are considered even-aged, the percentage of even-aged stands would be about 55.

Clearfelling is the predominant cutting system. Every year an assessment is carried out on a representative number of sites where harvesting took place three years earlier. The latest assessment (Granhus et al. 2013) reported that on 65.5 % of the harvested area, clearfelling was used. Seed tree cutting was used on 21.7 % of the area, while shelterwood cutting and various types of selective felling were used on the rest of the harvested area. The same assessment concluded that 53.5 % of the sites had been regenerated by means of planting, 7.6 % by a combination of planting and natural regeneration, 27.1 % by natural regeneration and that 11.8 % was insufficiently prepared for regeneration. Results from the assessment for previous years show similar distributions.

Results from the NFI show that 70 % of the harvested volume has been felled in clearcuts, while about 15 % was harvested by selective fellings. Thinnings represented 11–12 % of the harvested volume. Harvesting as a result of land-use changes amounted to slightly above 3 %.

Through the Forestry Act, forest owners are required to provide for satisfactory regeneration, normally within three years after harvesting. However, due to climatic and other local conditions five years is also considered acceptable in certain instances (Skogbrukslova 2005).

32.2.1.5 Legal and Other Restrictions for Wood Use

The provisions of the Forestry Act (Skogbrukslova 2005) require that forests are managed according to the principle of sustainable management. Specifically described is the duty to take appropriate environmental considerations, to provide for satisfactory regeneration and to prevent damage to forests. Forestry operations are generally not permitted in nature reserves and national parks. In landscape protected areas, forest operations can normally be carried out, but with certain restrictions. Also a number of other circumstances may prevent, or significantly reduce, the availability of wood resources in an area with forest cover. Smaller forest patches inside or close to residential areas may be managed for recreation rather than for wood production, although not always with a formal designation. In an area with a high concentration of holiday cabins, it may be more important to preserve the scenic features and to maintain an attractive recreational area.

For more than ten years, environmental assessments (Baumann et al. 2002) have been an integral part of forest management planning. Selected key habitats (currently about 70,000) are to be managed in such a way that their environmental qualities are being maintained. This process is related both to forest certification and to enforcement of public regulations.

A rather complex issue is to what extent the forest formally available for wood supply actually is or can be used for wood production. Some forests are located on steep slopes and/or far away from a road, others may be of low productivity or include trees with inferior quality wood. Cable logging equipment has been used in a number of regions, but to a limited extent, as it makes harvesting significantly more expensive. Data from the NFI and previous studies (Aalde and Gotaas 1998) indicate that roughly 20–30 % of the productive forest and about half of the total forest area can be considered unprofitable for wood extraction.

32.2.1.6 Further Classification of Forests

For national and international reporting, forests are commonly classified into classes according to the dominance of tree species: spruce-dominated (34 %), pine-dominated (28.5 %) and forests dominated by broadleaved trees (35.5 %). Temporarily unstocked forest represents 2 % of the forest area. This distribution was calculated from the productive forest area which is formally available for wood supply. A more detailed grouping of the forest area, covering also less frequently occurring tree species, is shown in Table 32.3. This classification is based on the percentage of individual species on every sample plot, as classified by the NFI during the field survey. Temporarily unstocked forest areas are excluded due to the absence of tree species.

It is obvious that birch is by far the predominant broadleaved tree species. It spreads quickly and is often dominant in young stands before cleaning-thinning. It is also covering extensive forest areas at higher elevations.

Another very common type of classification is by development classes. This classification takes into account site quality, in addition to stand age. Site quality is defined as the dominant tree height at the age of 40 years on a location. The development class furthermore corresponds to a certain age interval for every site quality class. The system is used and defined for productive forest, and may be used both for even-aged and uneven-aged forest. In the latter case, the dominant layer of the forest should be decisive.

Table 32.3 Productive forest area available for wood supply by tree species (NFI 2009–2013)

Tree species	Forest area (1000 ha)	Area (%)
Norway spruce *(Picea abies)*	2683	32.8
Introduced spruce and fir (*Picea* spp., *Abies* spp.)	49	0.6
Scots pine *(Pinus sylvestris)*	2217	27.1
Introduced pine and larch (*Pinus* spp., *Larix* spp.)	16	0.2
Birch (*Betula* spp.)	2577	31.5
Aspen *(Populus tremula)*	131	1.6
Oak *(Quercus robur)*	57	0.7
Rich deciduous forest	57	0.7
Grey alder *(Alnus incana)*	164	2.0
Other broadleaves	229	2.8

The various development classes are defined as follows. Figures in brackets are valid for broadleaved stands, the others for coniferous:

- Class 1: Temporarily unstocked forest land (may have some seed trees or other individual trees)
- Class 2: Young forest. Include forest stands up to the age of 20 (15) years on the best site classes, and up to 55 (30) years on the poorest
- Class 3: Younger production stands. Include forest stands up to the age of 40 (25) years on the best site classes, and up to 85 (55) years on the poorest
- Class 4: Advanced production stands. Include forest stands up to the age of 60 (40) years on the best site classes, and up to 120 (80) years on the poorest
- Class 5: Mature forest: Include forest stands over the age of 60 (40) years on the best site classes, and over 120 (80) years on the poorest (Table 32.4).

32.2.2 *Wood Resources and Their Use*

32.2.2.1 Growing Stock, Increment and Drain

The estimates of growing stock and annual increment are based on measurements of sub-sample and sample trees on the sample plots. According to the national

Table 32.4 Productive forest area available for wood supply, by development classes (NFI 2009–2013)

Development class	Forest area (1000 ha)	Area (%)
Class 1	164	2.0
Class 2	1416	17.0
Class 3	1662	19.9
Class 4	1794	21.5
Class 5	3308	39.6
Total	8344	100

tradition, growing stock and increment are normally estimated and reported under bark. However, growing stock is estimated both under and over bark by the NFI, and both results can be provided. Statistics on increment have to be adjusted by using a fixed bark percentage if increment over bark is required.

National functions used by the NFI give the volume of stem above stump, up to a top diameter of 0 cm, including or excluding bark (Bauger 1995; Braastad 1966; Brantseg 1967; Vestjordet 1967). Branches are not included. The minimum dbh for national purposes is traditionally 5 cm. Since a simplified procedure for estimation of trees with dbh between 0 and 5 cm has been implemented, results are sometimes reported down to 0 cm dbh. Dead trees are not included in the volume estimates unless explicitly specified. Usually increment is calculated such as one year's increment is assigned to every tree with dbh ≥ 5 cm on the second occasion. This is estimated as a mean value of the increment between two surveys of the NFI. Trees not present (or not measurable) on the first occasion are given a value based on an average of similar trees in the same stratum. The ingrowth of trees with dbh below 5 cm is for some purposes added to the sum of the increment of individual trees to obtain a more realistic value of the total increment.

Forest drain consists of the volume of harvested trees and volume of trees that have died during the period between two inventories. It can be assessed by calculating the volume of trees that was present during the initial inventory, but classified as harvested or dead during the subsequent NFI, then adding an increment corresponding to half of this period. An average estimate over a number of years can be made, but as the sample is relatively small, it is not possible to create annual estimates or to analyse in detail the harvest or mortality of various tree species.

There are no official national definitions of drain and increment, but they are more based on custom and tradition. The NFI has also a leading role in defining various forest variables that are often adopted by other institutions.

The NFI also provides biomass estimates, primarily related to LULUCF reporting for the UN Framework Convention on Climate Change and the Kyoto Protocol, but they may also be used for assessment of biomass for bioenergy. A set of Swedish functions (Marklund 1988) for estimation of the various biomass components of individual trees is normally used.

The total growing stock on all forests in Norway is 1070 million m^3 over bark (2010), of which the majority (90 %) is located on productive forest land where harvesting is permitted. In addition, there is about 90 million m^3 of deadwood, of which standing deadwood represents 35 % and lying deadwood 65 %. The annual total increment (over bark) on productive forest land is approximately 29 million m^3. The total drain has been estimated at slightly above 16 million m^3, whereas the harvested volume amounts to almost 13 million m^3. That means there is an accumulation of stemwood, corresponding to between 1 and 2 % of the total growing stock every year. The harvest level has been reasonably constant for about 100 years, while the increment was increasing most of this period. However, over the last 10 years, the increment level seems to have been fluctuating somewhat more. A higher proportion of the increment of spruce is harvested, compared to pine and broadleaved trees.

The growing stock assessed according to the species classification used in the NFI is presented in Table 32.5. As the three most common species: *Picea abies, Pinus sylvestris* and *Betula pubescens*, represent 90 % of the growing stock and similar amount of increment, it is obvious that other tree species play a relatively minor role in wood supply.

Table 32.5 Growing stock on all forest land, by tree species 2010

Tree species	Growing stock over bark (1000 m^3)	Annual increment over bark (1000 m^3)
Norway spruce (*Picea abies*)	439,768	14,988
Scots pine (*Pinus sylvestris*)	317,757	6966
Downy birch (*Betula pubescens*)	181,536	4052
Aspen (*Populus tremula*)	18,789	481
Grey alder (*Alnus incana*)	18,479	786
Rowan (*Sorbus aucuparia*)	10,096	312
Goat willow (*Salix caprea*)	9824	424
Oak (*Quercus robur*)	9568	242
Silver birch (*Betula pendula*)	9126	338
Other *Picea spp.*	6834	417
Ash (*Fraxinus excelsior*)	2961	108
Black alder (*Alnus glutinosa*)	2266	62
Abies spp.	1803	65
Lime (*Tilia cordata*)	1632	40
Bird cherry (*Prunus padus*)	1458	71
Hazel (*Corylus avellana*)	1369	61
Elm (*Ulmus glabra*)	1368	40
Lodgepole pine (*Pinus contorta*)	1058	73
Beech (*Fagus sylvatica*)	943	37
Other conifers	822	34
Norway maple (*Acer platanoides*)	775	27
Larch (*Larix spp.*)	725	27
Sycamore maple (*Acer pseudoplatanus*)	580	28
Other broadleaves	375	13
Yew (*Taxus baccata*)	37	1
Sweet cherry (*Prunus avium*)	20	1
Crab apple (*Malus sylvestris*)	20	1
Other *Sorbus spp.*	11	–
Common holly (*Ilex aquifolium*)	7	–
Total	1,040,007	29,693

Trees with dbh ≥ 5 cm. (1000 m^3)

32.2.2.2 Tree Species and Their Commercial Use

Norway spruce is by far the most important tree species for industrial production. According to data from Statistics Norway, more than 75 % of the total harvest of wood for industrial production consists of spruce. About 50 % of the industrial spruce harvest is sawnwood, while the rest is pulpwood. Pine represents 20–25 % of the wood harvest for industry, while the proportion of sawnwood is slightly higher than for spruce. Harvest of broadleaved trees represents 1–2 % of the total quantity of industrial wood. Approximately 2–2.5 million m^3 is harvested annually for use as firewood. This amount, however, includes a substantial quantity of wood from broadleaved species, mainly birch.

32.3 Assessment of Wood Resources

32.3.1 Forest Available for Wood Supply

32.3.1.1 Assessment of Restrictions

Firstly, the most important restriction is related to site productivity and forest type. Almost 30 % of the forest is located on shallow soil or has unfavorable climatic conditions, meaning that the potential for wood production is practically zero. This has been defined as non-productive forest. The various restrictions on wood supply in productive forest are mostly related to the land utilisation classes listed in Sect. 32.2.1.2. Furthermore, there are a number of environmental considerations (like key habitats) that may reduce or restrict the harvesting level, but not necessarily exclude it completely.

The assessment of national parks and nature reserves is carried out by combining the location of sample plots with a GIS database, thus classifying plots into the category of protected areas where harvesting of wood is not allowed. The other types of restrictions are mainly assessed in the field. A very limited number of sample plots are assessed by watching the plot location from a distance, by means of aerial photographs or by means of maps.

To assess the plots which are formally available for wood supply, but economically assumed to be unavailable, additional information from the NFI may be used. These variables include distance to the nearest road, slope, site quality and tree species, and a separate classification of areas with specific constraints for wood extraction (e.g. islands, transport across lakes or rivers, areas enclosed by railways).

While results for productive forest without legal restrictions and other restrictions related to land utilisation are normally presented in all reports from the NFI, the assessment of economic unavailability is normally only carried out in special studies, like the previously mentioned Aalde and Gotaas (1998), Granhus et al. (2011) and Bergseng et al. (2013).

32.3.1.2 Estimations

The growing stock on non-productive forest and productive forest with land utilisation different from "forestry" represents about 10 % of the total. In a number of studies, the proportion of forest area, growing stock or maximum sustainable yield assumed to be available for wood supply, taking all restrictions into consideration, has been estimated. Vennesland et al. (2006) concluded that at this time, the potential harvest of industrial wood is 25–50 % higher than the current level. Søgaard et al. (2012) reported that about 31 % of the productive forest area in Norway had moderate to strong environmental restrictions on wood harvesting. A significant part of this area is on lower site qualities and has a correspondingly low stocking. At the same time, moderate wood harvest is allowed in some of the area with restrictions. Thus, a reduction of about 15 % on the availability of growing stock has been estimated. Since this reduction is only due to environmental restrictions, the effect of additional terrain constraints would have to be added.

32.3.2 Wood Quality

32.3.2.1 Stem Quality and Assortments

The Norwegian timber grading association "Norsk Virkesmåling" (NVM) has specified general requirements with regard to the quality of roundwood for sale. These include e.g. the occurrence of rot, knots, reaction wood, crooked stems and annual ring width. The main assortments would be first-class and second-class sawlogs of spruce and pine, and pulpwood of the same species. Furthermore, there are a number of special assortments, usually of high quality, such as veneer logs and logs for poles. Roundwood from broadleaved trees may also be classified into similar categories, although the harvested quantity is currently small. The detailed requirements, including minimum and length of logs, are normally specified according to local agreements. The allowable length of logs is normally between 3 and 6 m, but there may be local deviations from this. Cutting of the stem into lengths is today mainly accomplished in a semi-automatic way, in that a computer program in the harvester will propose an optimal division of the stem. Energy wood is a separate assortment.

32.3.2.2 Assessment and Measurement

The NFI does currently not assess stem quality or assortments. There was such an assessment for several years, but it was discontinued in year 2000. The classification at that time was rather simple. For conifers: "Normal quality", "special quality" and "few or no sawlogs". For broadleaves: "Normal quality" and "subnormal quality". These data were not widely used, and it was then concluded that it was difficult to make good estimates corresponding with other timber grading. However this may change if new and more reliable methods are found in the future.

Dead trees, standing and lying, are recorded by the NFI according to five different stages of decomposition. This information may be used to estimate the proportion of deadwood that potentially could be utilised. There are few or no other variables that could be used to assess stem quality.

32.3.2.3 Estimation and Models

The computer model "Avvirk-2000" (Eid and Hobbelstad 2005) allows for creating scenarios of the effect of various forest management options, including allowable fellings, assortment distribution, value of stands and future forest situation. It is based on a theoretical distribution of the stem according to its size, and possible assumptions of a less favorable distribution due to damages must be added separately. The distribution of assortments has been estimated for certain purposes, but is not a part of the normal NFI reporting.

32.3.3 Assessment of Change

32.3.3.1 Assessment and Measurement

The estimation of increment and drain in the Norwegian NFI is based on the field measurements on permanent plots at two consecutive points in time. Sample trees can be distinguished into trees present only at the first occasion, trees present at the first and the second occasion, and trees present only at the second occasion. Sample trees present at the first occasion and that are no longer present on the plot at the second occasion are recorded as harvested or otherwise removed during the field assessment, and the type of stand intervention since the previous survey recorded at the same time. All trees with a dbh ≥ 5 cm are measured according to the same methodology. On sample trees only dbh is measured, while on sub-sample trees both dbh and height are measured. Sub-sample trees are selected using a procedure similar to the relascope, and adjusted such as there will be about 10 sub-sample trees on every plot. A tariff (diameter/height relationship) is then estimated for each tree species on the sample plot, based on data from the sub-sample trees. Using a model, a tree height corresponding to the tariff is finally assigned to each of the sample trees.

32.3.3.2 Estimation of Increment

Normally the increment of individual trees is calculated by using the tariff estimated at the second occasion. Then the diameter difference between the first and the second occasion is used to estimate the diameter one year before the second occasion. The annual increment of a tree is then calculated as the difference between the volume at the second occasion and the volume one year earlier. Standard volume functions are used for this estimation (Bauger 1995; Braastad 1966; Brantseg 1967; Vestjordet 1967). The increment for national reporting is normally calculated only from the trees that were present at the second occasion. The volume of ingrowth trees that have passed the dbh threshold of 5 cm during the period between inventories, are for some purposes added to the total increment of trees with dbh ≥ 5 cm. Volume and increment estimates comprise all parts of the stem above stump height. The increment of trees that have died or are felled between the first and the second occasion is not taken into consideration, as it is assumed to be negligible.

Scaling up from the sample trees to increment per hectare and total increment, is carried out by multiplying with the number of trees represented by the sample trees at the time of the second measurement. The increment can afterwards be aggregated for individual tree species, diameter classes, site classes, development classes, etc., or basically any classification that can be used for grouping of individual trees or sample plots.

The increment obtained by using this procedure gives an estimate of the gross increment. Net increment can be calculated by subtracting an estimate of the annual natural mortality from the gross increment.

Increment in terms of biomass may in principle also be estimated, as the calculation has the same requirement of data (dbh and height) as for volume increment. However, this is not very relevant in our case, since the stock change method is employed for LULUCF reporting.

32.3.3.3 Estimation of Drain

Drain is the volume of trees that have been harvested between two field assessments, plus the volume of trees that have died during the same period. The volume of sample trees that are found to be harvested or dead is calculated by using the tree measurements at the first occasion. The standard functions and normal calculation method for tree volume estimation used at the first occasion are utilised. As the annual increment of individual trees is readily available in the database, an increment corresponding to half the period between the two occasions can easily be added to the harvested volume. The volume of felled trees on areas converted to other land-use classes is included in the drain estimates. Normally the drain is calculated as an average annual figure for the assessment period. Scaling up from the sample trees to drain per hectare and total drain, is carried out by multiplying with the number of trees represented by the sample trees at the time of the second measurement. In principle, the drain can be distributed by tree species, subcategories of forest, etc., however there are some practical limitations due to the rather small sample size. An advantage of assessing the harvest and mortality from NFI data is that it is possible to keep living and dead trees apart to avoid double counting of dead trees. If an already dead tree is harvested, it should previously have been included in the drain and not counted again.

Annual harvesting statistics of industrial wood are published by Statistics Norway. They cover by far the major part of the harvested quantity of wood. However, they have some limitations, in that the harvest of firewood is estimated by means of a consumer survey. Also, self-consumption by forest owner may be inadequately covered by these statistics. These statistics do also cover the removals, not the fellings. To obtain an estimate of fellings from these statistics, harvesting losses have to be added. On the other hand, the figures provided by Statistics Norway give a better picture of the fluctuations from year to year.

32.3.4 Other Wooded Land and Trees Outside Forest

32.3.4.1 Assessment and Measurement

The sampling grid of the Norwegian NFI covers all land-use classes and ownership categories. Since 2005, other wooded land has been assessed according to the international definition (FAO 2012). The measurement of trees on these plots is carried out according to the same methodology as for forest. On OWL plots located in remote areas, the plots are often not visited in the field if it is obvious from the photo interpretation that there are no trees of measurable size (≥5 cm dbh). This means that it is possible for trees below 5 cm dbh not to be assessed. However, this is not of significant importance.

Pasture lands and open areas not under any of the main land use classes are also inventoried according to the normal NFI methodology, with re-measurement at 5 years intervals. Agricultural lands and urban areas/built-up land were subject to a trial assessment about five years ago, when a sub-sample of the total number of plots under these categories was assessed. This assessment included visiting private gardens for detailed tree measurements. The measurements on agricultural lands and urban areas/built-up land have not been completed and were discontinued.

32.3.4.2 Estimation

Calculation of growing stock and increment on OWL and other land-use classes corresponds to the methodology described for forest. The area of other wooded land is given in Table 32.1. Total growing stock on OWL has been estimated at 7 million m^3, which is about 0.7 % of the growing stock in forest.

Based on the assessments a few years ago, the growing stock of the other land categories outside forest have been estimated at:

- Open areas + pastures: 4.8 million m^3;
- Agricultural land: 1.6 million m^3;
- Urban area/built-up land: 5.3 million m^3.

In total, the latter categories represent nearly 12 million m^3, which is about 1.1 % of the total growing stock in forest. Altogether, the growing stock of trees on land not classified as forest is hardly more than about 2 % of the growing stock in forest.

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Chapter 33
Perú

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33.1 The Peruvian National Forest Inventory

33.1.1 History and Objectives

The historical background of the current National Forest Inventory (NFI) of Peru began in the late 1960s when the need to complete a NFI was expressed through a project proposal developed by the Departamento Académico de Manejo Forestal de la Universidad Agraria La Molina (DMF-UNALM) (Forest Management Academic Department at La Molina National Agrarian University) (Malleux 1975). Support was provided by the Food and Agriculture Organization (FAO) and United Nations Development Programme (UNDP) through Project 116. According to this proposal, NFI should (i) promote forest inventories at national and regional level (ii) generate information for the forest development plan (iii) coordinate the activities of forest inventory in several forest institutions (iv) normalise and standardise methods, systems and terminology according to objectives (v) develop inventory

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methodologies and (vi) facilitate the generation of reliable information to public and private institutions.

In 1979 the Ministry of Agriculture made a request to the DMF-UNALM to execute the first phase of NFI in the “central jungle” and the forestry plantations in the departments of Cuzco and Huánuco. The planning and design took place in 1980 which was advised by Prof. Aarne Nyyssönen from Helsinki University, sponsored by the Finnish government (CEPID 1980). Although the field work was executed between 1981 and 1982, not all activities under this phase were completed due to the lack of economic resources and IFN was canceled (CEPID 1982).

After more than 25 years, in 2008, the Ministry of Agriculture (MINAG) and the Ministry of Environment (MINAM), requested support to FAO for the NFI implementation. In 2009 the project document was concluded and in 2010 was adjusted by the FAO/Finland Programme “Sustainable Forest Management in a Climate Change”. It should be noted that according to FAO (2010), 53 % (67.9 million ha) of peruvian lands are forests. Finally, the agreement between the FAO and the Government of Peru in early 2011 was signed to implement the “National Forest Inventory and Sustainable Forest Management in Peru to Climate Change” (GCP/GLO/194/MUL). The planning and design phase took place in 2012 and in March 2013 the evaluation of sample plots began (Proyecto INF 2014).

The “National Forest Inventory and Monitoring” project is in charge of implementing the NFI of Perú, which aims to “provide continuous, current and reliable information for planning the sustainable management of the forests of Perú and its resources, in the regions of Selva, Sierra and Costa (jungle, highlands and coast, respectively) including natural forests, forest plantations and secondary forests, collecting and processing data on biomass, biodiversity, carbon stocks, deforestation, emissions of greenhouse gases, state wildlife and socioeconomic information of the rural populations settled in their environment” (Proyecto INF 2014).

33.1.2 Sampling Methods and Periodicity

The population of interest of the NFI is the continental land area of Peru (1,285,256.6 km^2). Due to the diversity and complexity of Peru, six sub-populations have been determined with the objective of optimising the sampling design. In the determination of sub-populations five criteria were followed: physiographic, physiognomic, floristic, carbon storage capacity and accessibility. The sub—populations are *Selva baja* (low jungle), *Zona hidromórfica* (hydromorphic zone), *Selva alta accessible* (accessible high jungle), *Selva alta difícil* (difficult high jungle), *Sierra* (highlands) and *Costa* (coast).

These sub-populations were defined based on three natural regions: *Costa*, *Sierra* and *Selva*. In addition, *Selva* was divided into *Selva baja* and *Selva alta* due to its physiographic and ecological diversity. But in the Selva baja it differs also a great hydromorphic zone (*Zona hidromórfica*) characterised by having flooded forests that are more homogeneous. Finally, *Selva alta* was divided into *Selva alta* *accessible* and *Selva alta difícil* by the difficulties of accessibility that this region presents.

In the sampling design, the plots were distributed in systematic grids with cells of unequal sizes with regard to sub-population and divided into five annual panels. The NFI sampling approach will be continuous and permanent with a cycle of five year, where each panel will have 20 % of the total sample. Each sub-population has been treated independently with respect to the sample size; the number of sample plots was determined in each case according to their coefficient of variability, the size of its forests and the desired accuracy (from 12 to 20 %) and travel costs. The sample size of each sub-population resulted from an analytical process based on multiple combinations of shape and size of plot, its hypothetical variance, cost of evaluating different types of plots and the expected accuracy. For this purpose, a tool for planning, design and evaluation for the NFI was developed jointly with researchers from the United States Forest Service. The result of this analytical process was the selection of plots and sub-plots of different shapes and sizes according to the sub-population. The sample size estimated for the country is 7293 plots. Table 33.1 shows how plots were distributed by sub-population.

The high number of plots in *Sierra* is because in this sub-population, the forest are composed by relict forests of native species as forest plantations scattered and of small size, so to evaluate these forests increased sampling intensity is required. It is also noted that the sub-populations of the more inaccessible regions (*Selva alta difícil* and *Zona hidromorfica*) have the highest distance between plots due to the high cost of transportation for field-work.

For the distribution of these plots, each sub-population was divided by a grid; the grid cells are square with sizes that change according to the sub-population (Table 33.1). A grid contains the total number of plots allocated to each sub-population. Inside each grid cell, one plot was randomly located resulting in a non-aligned plot distribution.

Table 33.1 Number of plots by sub-population (Proyecto INF 2014)

Sub-population	Size of the side of the square grid cell (km)	Number of sample plots	Average distance between plots (km)	Field plots to be evaluate
Selva baja	24	808	24	803
Zona hidromórfica	31	91	31	87
Selva alta accesible	20	288	20	262
Selva alta difícil	34	101	34	101
Costa	18	460	19	112
Sierra	8	5545	8	511
Total		7293		1876

The plots were grouped to optimise and facilitate the logistics of field data collection, where one or two crews could evaluate a group of plots during a 4 week term. The number of plots within each group is different, depending of the time of access, displacement and recording field data, although the ideal number is 8.

Then, the coverage of the plots was analysed using Open Foris, an application developed by FAO, using information from Google Earth to verify forest cover on the plots. In total, 1876 plots were selected to be evaluated in the field due to their high probability of being located in a forest. Table 33.1 shows the number of plots to be evaluated in the field in each sub-population.

The configuration and size of the sample plots were determined by an optimisation process. This process had the following steps:

(a) determination of costs of evaluation of the plots: 9 cost models were developed based on the accessibility and type of transport; in these models the following cost-factors were considered: field staff, office staff, training, quality control, instruments, food, accommodation, travel between plots and sub-plots.
(b) development of alternate plots of different configurations with respect to: shape, size, number of sub-plots and distance between sub-plots.
(c) analysis of the relation variance-cost depending on the number and size of sub-plots and the distance between them by every possible configuration of plot.
(d) calculation of the number of plots to be evaluated with the sample size formula used for systematic sampling.
(e) calculation of the total cost for each scenario of plot design with a view to obtaining the best accuracy at lowest cost.

These results served as a basis to decide the configuration plot and the sample size. Two plot designs were chosen: (i) the first one for *Selva baja*, (ii) the second one for the other sub-populations*: Selva alta accessible, Selva alta difícil, Zona hidromorfica*, *Costa y Sierra*.

The plot in *Selva baja* has a total area of 0.7 ha, is compound of 7 rectangular sub-plots (SP) located 75 m apart from each other, along two perpendicular axes resembling an L configuration. The first axis, North-South oriented (375 m length), contains 3 of the SP, the second one (425 m length, West-East oriented) contains the 4 remaining SP (Fig. 33.1).

The sub-plot is divided into two units of register (UR) of 0.05 ha each and contains two other overlapping elements: a square and a circle, of 0.01 and 0.0025 ha, respectively. The four elements, identified with letters A, B, C, and D in Fig. 33.1, are intented for the mensuration of forest vegetation in 4 different growing stages (trees, polewood, low polewood, sapling) as shown by Table 33.2.

The plot in *Selva alta accesible*, *Selva alta dificil, Zona hidromorfica, Costa* and *Sierra* has a total area of 0.5 ha is composed of 10 circular sub-plots located 30 m apart from each other, distributed along two identically sized axes (276.2 m long)

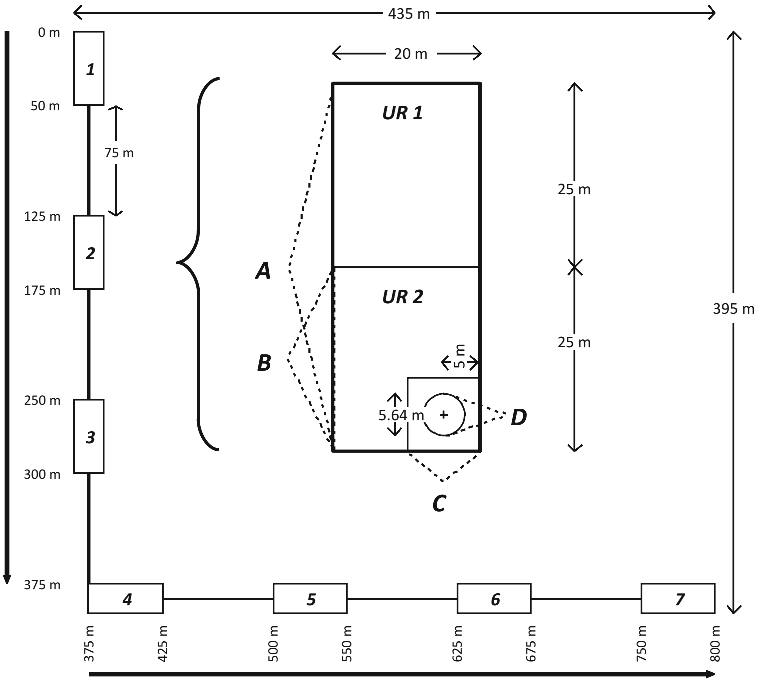

Fig. 33.1 Plot design to *Selva baja*

Table 33.2 Sub-plots and measurement of each of the forest growing stages, *Selva baja*

Forest growing stage	Definition	SP number/SP element application						
		1	2	3	4	5	6	7
Trees	dbh ≥ 30 cm	A	A	A	A	A	A	A
Polewood	10 cm ≤ dbh < 30 cm	B	B	B	B	B	B	B
Low polewood	dbh < 10 cm and h > 3 m	–	C	–	C	–	C	–
Saplings	1 m ≤ h ≤ 3 m	–	D	–	D	–	D	–

arranged perpendicularly, resembling a L-configuration, with orientation North-South and West-East (Fig. 33.2).

The 3 overlapping circular elements shown in the sub-plot (A, B and C) have 0.05, 0.01 and 0.0025 ha, respectively. In these plots forest vegetation is assessed in the 4 growing stages (trees, polewood, low polewood and saplings) (Table 33.3 for *Selva alta accesible, Selva alta difícil* and *Zona hidromórfica* and Table 33.4 for *Costa* and *Sierra*). It is worth noting that the definition of the forest growing stages varies according to the sub-population.

At present the Panel 1 plots in the sub-populations of *Costa* (the dry forests of the northwestern region of Perú) and of *Zona hidromorfica* have been evaluated. Panel 1 belonging to the Loreto's department have also been evaluated and

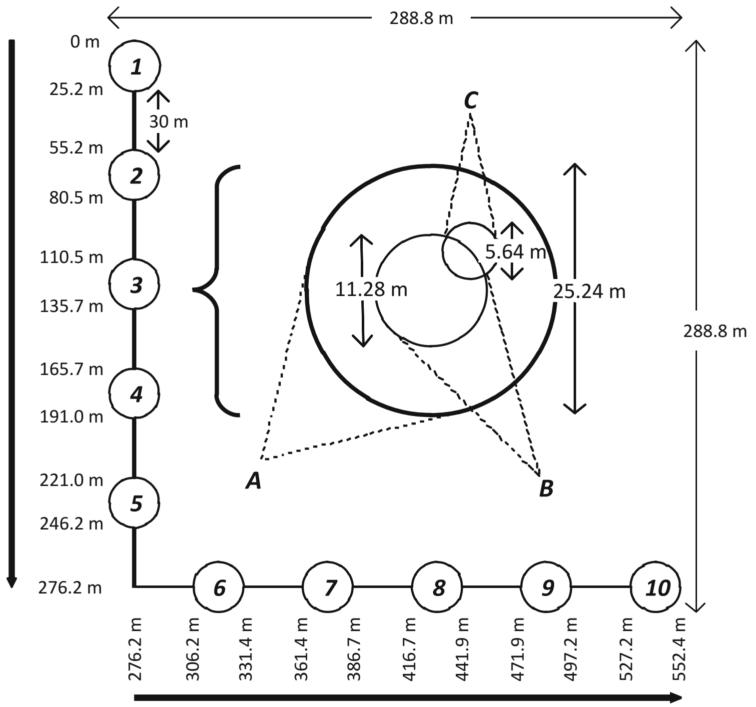

Fig. 33.2 Plot design to *Selva alta accesible, Selva alta dificil, Zona hidromórfica, Costa* and *Sierra*

Table 33.3 Sub-plots and measurement of each of the forest growing stages

Forest growing stage	Definition	SP number/SP element application									
		1	2	3	4	5	6	7	8	9	10
Trees	dbh ≥ 30 cm	A	A	A	A	A	A	A	A	A	A
Polewood	10 cm ≤ dbh < 30 cm	A	–	A	–	A	–	A	–	A	–
Low polewood	dbh < 10 cm and h > 3 m	–	–	B	–	B	–	B	–	–	–
Saplings	1 m ≤ h ≤ 3 m	–	–	C	–	C	–	C	–	–	–

Selva alta accesible, Selva alta dificil and *Zona hidromórfica*

Table 33.4 Sub-plots and measurement of each of the forest growing stages (*Costa* and *Sierra*)

Forest growing stage	Definition	SP number/SP element application									
		1	2	3	4	5	6	7	8	9	10
Trees	dbh ≥ 10 cm	A	A	A	A	A	A	A	A	A	A
Polewood	5 cm ≤ dbh < 10 cm	A	–	A	–	A	–	A	–	A	–
Low polewood	d30 < 5 cm and 1 m ≤ h < 3 m	–	–	B	–	B	–	B	–	–	–
Saplings	1 m ≤ h ≤ 3 m	–	–	C	–	C	–	C	–	–	–

Note d30 means “diameter 30 cm above ground” assessment is underway in the Ucayali's department, all of them being part of the sub-populations of *selva baja*. Work will then progress with the evaluation of plots of the sub-population of *Sierra*.

33.1.3 Data Collection

The data collected by the Peruvian NFI is referred to both plot and its surroundings as to measured trees. The variables evaluated at plot level describe both the plot and the forest stand in which the plot is located. These variables are:

- Sub-population
- Location
- Altitude (Elevation above sea level)
- Accessibility
- Land use
- Land use change
- Physiography
- Slope
- Natural disturbances
- Anthropic disturbances
- Fire damage
- Forest succession
- Vertical structure
- Wildlife evidence.

At tree level, the evaluated variables characterise the tree, natural regeneration, and stumps found in the plot. These variables are:

- Relative location
- Species
- Diameter at breast height (dbh)
- Stem height
- Dominance
- Stump diameter
- Stump height
- Stem quality
- Tree condition
- Phytosanitary condition
- Uses of the Species
- Standing dead trees
- Degree of wood decomposition
- Natural regeneration by species
- Individuals number (natural regeneration).

More information can be found on the fieldwork manuals for *Selva baja* (Proyecto INF 2013a) and for the *Zona hidromorfica*, *Selva alta accesible* and *Selva alta dificil* (Proyecto INF 2013b).

33.1.4 Data Processing, Reporting and Use of Results

The results of NFI will allow continuous updating of information about the status of forests products and services, the interactions of populations that benefit directly and indirectly from them, and the value of forests for their multiple functions, including mitigation to climate change. The NFI combines technologies of data collection in the field with remote sensing information. The information generated will be used for policy decisions, at level at the central government, the regional governments and as local governments and communities as well as for planning the sustainable management of Peruvian forests and its resources, for which the NFI takes and processes data about biomass, biodiversity, carbon stocks, deforestation, emissions of greenhouse gases, wildlife condition and socioeconomic information of rural populations settled in their environment (Proyecto INF 2014).

To calculate the NFI statistics, the EVALIDator tool developed in 2007 by the USFS NFI in the USA was used. This tool provides the estimators and sampling errors for the variables of the NFI (Miles and Hansen 2012).

The NFI results have not been disseminated to date as the evaluation of the Panel 1 plots is still underway. However data from the field plots in the sub-populations *Costa* (dry forests of north-west) and the *Zona hidromorfica*, were already used to estimate the carbon content of the forests of the country (MINAM 2014).

33.2 Land Use and Forest Resources

33.2.1 Classification of Land and Forests

33.2.1.1 General Use Classification

The NFI classifies the national territory under an approximation process of 4 levels. The first level discriminates between forest and non-forest; the second level distinguishes if the forest is disturbed or non-disturbed; the third level differentiate climatic condition, establishing if it is Dry or Wet; and the fourth level establishes classes according to the physiographic and floristic condition.

The forest definition is the basic determining feature in the classification of general land-use. Forest is a predominantly arboreal ecosystem that should be a greater area than 0.5 ha, with a minimum width of 20 m, and to have a minimum canopy cover of

10 %. The predominant vegetation is represented by woody trees with a minimum height of 2 m in its adult stage in the *Costa* and *Sierra*, and 5 m for the other sub-populations. In its integral conception, includes relief, soil, water, plants, wildlife and microorganisms that determine the floristic, edaphic, topographic and climatic associations with self-sustaining functional capacity to provide goods and services. In the case of dense forest is divided into several vertical layers. This definition includes secondary forests and forest plantations (Proyecto INF 2014).

This definition of forest harmonises different points of view and concepts for the forest management. It will serve as a basis for the planning of forestry development, at national and regional level, as well as its contribution to the agendas of Climate Change, REDD+, FRA, among others. To elaborate this definition the FRA 2010 criteria were used as well as definitions directly linked to the Peruvian NFI and the other two components of the Project, so the tree height criterion is 2 m in the sub-populations of Costa and Sierra while for *Selva baja*, *Zona hidromórfica*, *Selva alta accesible* and *Selva alta difícil*) the value of the tree height is 5 m equal to the FAO definition.

The forest stands that have been invaded by bamboo plants but where the trees are still dominant are considered forest, in a general way there are called "*pacales*". The areas fully covered with bamboo plants are called "*bambusales*" and naturally are considered Non-forest. In the same category are included: scrub that are extending in the humid areas of transition toward highlands; the grasslands located predominantly in the highlands (known as "*pajonales alto andinos*"); the deserts, usually located along the Pacific coast; the glacier areas in the highest mountains; and all water bodies (rivers, lakes and lagoons). Also are considered Non-forest all urban areas, buildings and another human infrastructures as well as agricultural and pastures lands (Table 33.5).

33.2.1.2 General Forest Classifications

The management of forest lands is governed since 2011 by the new Forest and Wildlife Law (LFFS), which provides the regulatory, development and supervisor framework of forestry and wildlife activities, which has jurisdiction over the forest and wildlife heritage (PFFF). This heritage also includes other natural vegetation ecosystems, its biodiversity and landscapes and the services they provide. They are lands that according to the System of Lands Use Capability Classification (CUM) belong to Group F (Land suitable for forestry production) and Group X (Protection Lands) groups; it means that such areas can not be dedicated to neither to agricultural nor cattle production, but can be used for timber logging, or due its limitations of use, these areas classify as protective land.

The Peruvian legislation establishes that the State maintains the domain of the PFFF but grants rights of usufruct of PFFF with limitations, so it can not be alienated from them. The LFFS excludes from the PFFF forest plantations on private and communal lands, and its products. The usufruct is realised according to the forest management (OF) established by law, which requires a prior process of

Table 33.5 Classification of Forests and other classes of land cover according to the NFI (Proyecto INF 2014)

Level 1 Forest/non-forest	Level 2 Intervention	Level 3 Climatic condition/physiognomy	Level 4 Physiographic/floristic
Forest			"*Aguajal*" (palm swamp)
	Natural	Wet	Wooded swamp
			Alluvial terrace
			Hills
			Mountains
			Bamboo ("*pacal*") in alluvial terrace
			Bamboo ("*pacal*") in hills
			Bamboo ("*pacal*") in mountains
			Andean relict
			Mangrove
		Dry	Coastal "*algarrobo*"
			Savannah type
			"*Lomas*"
			Hills
			Mountains
			Interandean valleys
			Secondary
	Anthropic		Plantation
Non-forest	Natural	*Bambusal* Bamboo plants stand	Bamboo forest (*Pacal*)
		Shrub	Shrubs
		Herbaceous	Hydrophytic grassland
			Hydrophytic savannah
			Coastal wetland
			Highland wetland (Bofedal)
			Highland grassland
			Paramo
		Bare soil	Desert
			Glaciers
		Water bodies	Lake/lagoon
			"*Albufera*"
			Oxbow lakes
			River, beaches,
	Anthropic	Others	Agriculture
			Livestock/grazing
			Agroforestry
			Fallow
			Mining
			Petroleum
			Infrastructure
			Village

forest zoning based on ecological-economic zoning that the local and regional governments must undertake in an obligatory and participative way. In the OF are also considered Natural Protected Areas (ANP), but these are established and managed according to the law of the National System of Protected Areas by the State (SINAMPE). The administrative management of forests is the responibility of to two ministries: of Agriculture (MINAGRI) and of the Environment (MINAM), the first one has a productive role and the second one, of conservation and protection. Besides the central government, the regional governments also have administrative jurisdiction over forests under their control and incorporate other forest lands to categories established by LFFS. The National Programme of forests conservation, created for MINAM in 2010, classified the Peruvian forest by administrative categories (Table 33.6). Permanent production in reserve is a class of forest that the State keeps in reserve so that, in the future they can be offered under concession to produce timber.

33.2.1.3 Classification by Ownership Categories

As mentioned above, the state is the owner of the forests and can grant concessions or licences of use to private users or recognise its management to "*Comunidades Nativas*" ("Native Communities") and "*Comunidades Campesinas*" ("Peasant Communities"). For such purposes, territorial units of Forest Management (FM) are established under one of the following categories: (a) permanent production forests, (b) local forest, (c) protective forest, (d) permanent production forests in reserve, (e) forest in "*Comunidades Nativas*" and "*Comunidades Campesinas*" Natives and Peasant Communities lands, (f) forests on private land.

It is necessary to mention that only one of the 23 administrative regions of the country has completed the process of territorial planning and now it is in process of inscription in the Public Bureau of Lands Register. This region is located in the Peruvian Amazon basin.

33.2.1.4 Further Classification of Forests

The first national forest map (NFM) dates from 1975 and was based on the use of panchromatic aerial photos, aerial-photographic mosaics and radar images SLAR,

Table 33.6 Forests land by administrative categories (MINAM 2013)

Class name		Area (1000 ha)
Forests	Protected natural areas	17,039
	Native and rural communities	14,190
	Territorial reserves	1755
	Permanent production	9187
	Permanent production in reserve	8785
Wetlands	Special zone	3327

all them in photographic paper or film of tones of gray. Both interpretation and classification were made with essential tools such as the mirror stereoscope, and the map was produced with photomechanic process. The classification used in this map was based on physiographic, physiognomic-floristic and potential forest criteria. It defines areas with homogeneous and heterogeneous productive forests, lands with forestry aptitude, lands suitable for forestry, protection forests, also the non-forests lands, reaching a total of 21 classes. In this map, the forest lands are divided in classes of forestry potential associated with the operability which is conditioned by the relief of the terrain and by the forest timber stocks (Malleux 1975).

The development of satellite sensors and availability Landsat program of images made possible the publication of the second NFM two decades later, in 1995, whose interpretation was made on false images printed on photo paper or colored bond, to check on computer screens. The map was created using a Geographic Information Systems (GIS), which facilitated the production of digital maps. The classification in this map was based on floristic physiognomic criteria, using an ecological approach. It describes 27 cartographic units differentiated indicating its location in the landscape and their predominant composition, and like the previous map distinguishes floristically homogeneous classes, but leaves the timber potential criteria that was present in the previous map (INRENA 1996).

A map was prepared in the year 2000, but it was never published. Satellite images were used to achieve a new physiognomy classification with ecological-climatic basis, which represents life zones or vegetable formations. The explanatory report of this map was produced and it describes the physiognomy of the vegetation, its composition and it does partial reference of the timber contents of 50 differentiated units but does not provide a systematic characterisation of their operating condition (Estrategia Nacional Forestal 2003).

In 2012, MINAM published the map Vegetation Cover Map of Peru, which uses bio-climatic, physiognomic and phyto-geographical criteria to map the distribution of 33 cartographic categories (28 of them are natural vegetation formations). Landsat images, from 2009 were used with the support of images of Google Earth for overflights and ground check. The largest class of this map is the “Rain Forest of Low Hill and Lomada” which extends over 28 million hectares of “Amazonian lowlands”, representing 21.8 % of the country (MINAM 2012).

33.2.2 Wood Resources and Their Use

33.2.2.1 Standing Stock, Increment and Drain

The NFI has not estimated of increment or drain as the first cycle has not been completed yet. Estimates of standing stock will be make from tree measurements made in the field plots. The estimation is done to trees from 30 cm dbh outside bark in the case of *Selva baja, Selva alta accesible, Selva alta difícil* and *Zona* *hidromórfica*. In the case of the *Costa* and *Sierra*, the standing stock will be estimated from 10 cm of dbh.

Also the biomass will be estimated for calculating the carbon content of the forests of Peru, as the information collected will serve to address the information needs of the Measurement, Reporting and Verification of Peru, as part of a future mechanism of Reduction of Emissions from Deforestation and Forest Degradation (REDD +) (Proyecto INF 2014).

For the first cycle of the NFI, the volume of standing trees will be calculated from the basal area measurements. The aggregation of volumes of individual trees will be obtained directly from measurements of variables of the sample unit; which is scaled to obtain the volume per unit area and the total volume. For total estimations, it will use the "Estimator for samples of unequal size" (SUUS) (Cochran 1977).

Additionally, other data will be registered to improve estimates of volumes in the future. The results will be delivered by dbh class, forest types and the more important land uses (Proyecto INF 2013a, b).

33.2.2.2 Tree Species and Their Commercial Use

From an economic point of view, information on the timber felled in Peru is based on the export of precious woods such as *Swietenia macrophylla* and *Cedrela odorata*. According to DGFF (2013), which presents the statistical information of the forest activity in Peru, of the total timber harvested in both natural forests and plantations, 90 % is dedicated to the production of fuelwood and charcoal and 8.9 % is destined for lumber. The species most commonly used in sawing is *Cedrelinga catenaeformis,* which represented 15 % of total sawn timber in 2012 in Peru.

33.2.2.3 Forest Management and Cutting Systems

The Peruvian government facilitates access to the forest resources to interested people who meet the requirements of LFFS and its regulations. These forests lands must be included within a Forest and Wildlife Management Unit (UGFFS) administered by the regional government that has competitive process for those who expressed an interest in the concession. The persons interested in obtaining a concession for timber must submit an application including a technical proposal of managing of the areas. The contracts of timber concessions are valid for up to 40 years, renewable for five years subject to the compliance with the obligations of the contract; such compliance is supervised by the State every five years during the contract period.

The timber concessionaires develop each year, a plan of annual cut; the basis for this annual plan is a complete inventory of the area to be cut, this area is usually 1/40 part of all concession. The trees to be cut must not have a dbh less than the "minimum cutting diameter" established by the authority for each species (e.g., the "minimum cutting diameter" for cedar (*Cedrela odorata*) and mahogany (*Swietenia macrophylla*) are 0.65 and 0.75 m, respectively). Another restriction to forest management is that 10 % of harvestable trees must be conserved as seed trees. It is possible to re-enter to the cutting area one time up to five years after the harvest was completed.

33.3 Assessment of Wood Resources

33.3.1 Forest Available for Wood Supply

33.3.1.1 Assessment of Restrictions

In the design of the NFI the factors that could affect the performance of the inventory crews or prevent its access to the location of the plots were identified. During the phase of planning access to the plots was evaluated considering the topography and the relative distance (steep slopes, flood zones, lack of access, terrestrial or aquatic), legal restrictions (areas where access is prohibited), and security situations (conflict in neighboring towns, violence or crime, among others). Thus, the plots that couldn't be visited in the field were identified.

The difficulty of forests for logging will be known after the fieldwork in a phase of post-stratification in which the information registered in the field forms about the slope, land form and accessibility of the plots. Information from GIS databases can be used post fieldwork to classify plots.

33.3.1.2 Estimations

Forests with the potential to provide timber and non-wood goods in Peru are distributed in one of the following administrative categories: Forest concessions (for timber, for non-timber products and for reforestation), Forests in reserves, communal Forest and Forests for permanent production in reserve; the remaining forests, those without a defined legal use, must be considered also. The NFI registers the attributes of site, tree species, biophysical measurements and the general condition of trees. With this information, the gross and commercial volumes by species will be estimated both by local use and by quality of stem; later, these volumes will be extrapolated using GIS for the different forest concessions (Proyecto INF 2014).

33.3.2 *Wood Quality*

33.3.2.1 Stem Quality and Assortments

The dbh classes to be used in the reports of NFI are: 5–10 cm, 10–20 cm, 20–30 cm, 30–40 cm, 40–50 cm and ≥50 cm. Also, up to 11 different uses of the species will be evaluated being the principals: sawn timber and logs (Proyecto INF 2013a, b). The data generated will be used to report the forest stocks according to the uses of wood that defines the Ministry of Agriculture as saw timber, flooring, plywood, etc.

33.3.2.2 Assessment and Measurements

In the field measurements of NFI, the stem quality of all trees with dbh ≥ 10 cm is evaluated. The same classes of stem quality are used for all species (Table 33.7). As already mentioned other parameters that determine the status of the forest were also evaluated: tree condition (living, dead standing or stump), health of the stem (healthy, burned, hollow, crushed, damaged by animals, sick, hurt by "matapalos" trees ("strangler" trees), with parasites, woody vines) or tree disease (healthy, mild, severe).

33.3.3 *Assessment of Change*

The NFI is in its early stage, so change assessments has not yet been performed. In the field, the features of natural regeneration, standing dead trees and stumps are recorded. This will provide useful information to analyse the dynamics of the forests.

33.3.3.1 Other Wooded Land and Trees Outside Forests

The distribution of the NFI field plots facilitates monitoring of all the classes of land use as well as the categories of property or tenure of the lands, with the exception of reserved territories for indigenous communities under voluntary isolation. For this, the NFI has developed a classification of current land use and forest types based on the vegetation map (MINAM 2012) which has a large intersection with the definition of forest land of the FAO (Table 33.5).

Table 33.7 Stem quality classes as assessed by the Peruvian NFI (Proyecto INF 2013a, b)

Stem quality	Value	Description
Optimum	1	Straight tree, without visible fire damage, tree pest, disease, etc.
Medium	2	Tree with small defects or damage due to fire, pest, disease, etc.
Low	3	Tree with severe defects or damage due to fire, pest, disease, etc.

Currently the fieldwork survey is implementation on forest lands, however it is possible to monitor other land uses exists. So both the sampling design and adopted classification allow measurements of trees in non-forest areas, which will improve the estimates of carbon emissions and sequestration by forests. This will be useful for analysing the dynamics of land use change, especially in areas with mosaics of secondary forests, abandonment lands and areas of agricultural productions (Proyecto INF 2014).

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Chapter 34
Portugal

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34.1 The Portuguese National Forest Inventory

34.1.1 History and Objectives

In Portugal, the first forest area evaluation dates back to the late XIX century, which predates the first NFI. Monteiro (2007) refers that in 1874 Gerardo Pery estimated a total forest area of 640,000 ha, which represented 7.3 % of the country mainland area. In subsequent decades, updated evaluations were published, namely in 1902 and 1928 by Mendes de Almeida and in 1956 by SROA (former Portuguese service for land planning), revealing a very significant increase in the Portuguese forest area. In 1956 the total forest area was 2.763 million hectares, corresponding to 31.0 % of Portuguese mainland area. The first evaluation to include a biometric characterisation of forest stands based on the measurement of a sample of field plots took place during the years 1965–1966, and was conceived as the first Portuguese National Forest Inventory (DGSFA 1965–66, 1966). Since then, four NFIs have taken place, and a new NFI (NFI6) is currently on-going. The sequence of the six Portuguese NFIs, detailing the time periods corresponding to land cover and field data collections, is presented in Table 34.1.

Since NFI5, the Portuguese NFI includes not only data for the mainland territory but also for Madeira's and Azores' Autonomous Regions. These two atlantic

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Table 34.1 Dates for the land cover and field data collections of the six Portuguese national forest inventories

NFI	Designation	Reference year	Land cover data collection period	Biometric field data collection period
NFI1	National forest inventory	1965	1965	1965–1966
NFI2	1st NFI revision	1974	1968–1980	1968–1980
NFI3	2nd NFI revision	1985	1980–1989	1980–1989
NFI4	3rd NFI revision	1995	1995	1997–1999
NFI5	5th National forest inventory	2005	2004–2006	2005–2006
NFI6	6th National forest inventory	2015	2010–2015	2014–2015

archipelagos have their own forest inventory programmes, which were initiated more recently. To date, the Azores had one single forest inventory (IFRAA in 2007) and the Madeira's has just concluded the second forest inventory (IFRAM1 in 2010 and IFRAM2 in 2015). The contribution of Azores and Madeira's to Portuguese forest area is relatively small, since these territories represent to approximately 3 % of the nation's terrestrial area. But the presence of "Laurissilva" subtropical forest, a pristine forest that represents the world's largest remaining area of the Tertiary forests that covered most of the south of Europe and the North of Africa (Capelo 2004), is a relevant aspect on Portugal's forest statistics.

All NFIs include estimations of forest area, based on data extracted from aerial photography by photointerpretation techniques, and the characterisation of the stands of the most representative tree species in the country. The NFI methodologies have evolved over the years to adapt to the needs of the forest industry and to national and international reporting requirements. NFIs use a land use/land cover nomenclature that has been modified through time. However, this evaluation has always included an assessment of: forest land use, forest composition with the identification of the two most abundant tree species, and crown cover classification. The forest and other wooded land definitions of the Food and Agriculture Organization of the United Nations (FAO 2004) have been used since NFI4. In the earlier NFIs, areas of forest strata, that included also stand structure, were evaluated based on photointerpretation of aerial photographs and resulted in the production of cartography. At that time, aerial photographs were captured by region. A wall-to-wall forest cartography at 1:25,000 scale is available for NFI2 (1968–1980), but photographs correspond to different time periods. The high dynamics of the Portuguese forests, due to a high incidence of wild fires and a significant increase of new plantations, justified the need to use whole country aerial photographs obtained in a single year. A more expedite methodology for forest area estimation was used, based on qualitative sampling, that enabled an estimate of forest strata areas closer to photography's data. The first full coverage of aerial photography was taken in 1990, followed by the aerial coverages taken in 1995, 2005 and 2010. Forest areas in 1995 were based on a sampling grid different to the one used in 2005 and 2010. The national commitment to consistently report the activities in land use, land-use change and forestry (LULUCF) sector led to the reassessing of land use/land cover of 1995 aerial photographs using the NFI5 grid. The current NFI is based on the same grid system, and a consistent time series of land use/land cover data for 1995, 2005 and 2010 is presently available. Within the framework of NFI6 it was possible, and for the first time, to compute land use/land cover transition matrices, which provided a relevant insight into Portuguese land use/land cover dynamics.

All NFIs included the measurement of a sample of field plots in order to characterise the forest stands with the most important forest tree species in Portugal. Standing volume estimation was the main objective of the first four NFIs, as well as the growing stock increment for maritime pine (*Pinus pinaster* Ait.). In the course of NFI4, stand structure was also evaluated taking into account the shrub strata and using vegetation diversity models, the production of non-wood goods such as cork, resin and acorn and the evidence of erosion and fire as well as forest vitality at the stand level (DGF 2001). Biomass and carbon stock estimations as well as volume of standing dead trees and shrubland biomass were included for the first time in NFI5 (2005–2006).

The scope of the current inventory (NFI6) has increased, with the following topics included within its framework: habitat identification and conservation status evaluation; soil characterisation and organic carbon evaluation; comprehensive deadwood evaluation for biomass and carbon quantification; shrubland species identification and carbon stock quantification; alien and exotic species quantification; and tree growth data collected with increment borers for biometric model development.

More detailed descriptions of the Portuguese NFIs can be found in the original reports that are listed on pages 231–233 of the NFI4 official report (DGF 2001 – in Portuguese) in the NFI5 report (AFN 2010) or in Tomé et al. (1997) and Barreiro et al. (2010).

34.1.2 Sampling Methods and Periodicity

The Portuguese NFIs occur in an approximately 10 year cycle (Table 34.1), and a new inventory (NFI6) is presently on-going. The first four NFIs were based on temporary sample plots. However, the importance of monitoring changes in the forest resulted in the establishment of a permanent sampling grid system during the NFI5 (2005–2006) increasing the photointerpretation sampling intensity from ca. 130 thousand points in 1995 to ca. 360 thousand points in 2005. This grid system is based on a 500 × 500 m grid that is used for photointerpretation and includes sub-grids of 2 × 2 km and 4 × 4 km that are the basis for field work in forests and shrubs, respectively. Temporary sample plots were concentric fixed-area circular plots with areas of 250, 500 and 1000 m^2, according to tree diameter at breast height (dbh) thresholds of 7.5, 17.5 and 27.5 cm, respectively. In NFI5, after realising that a large percentage of the Portuguese forests is even-aged, simple fixed-area circular plots were adopted, with an area of 500 m^2 for wood production species and 2000 m^2 for cork and holm oaks stands. In steep-sloped terrain, where trees are planted in terracing systems, special rectangular plots covering two terraces and a length adjusted in order to achieve an area of 500 m^2 were used. In all NFIs a cluster of five 10 m^2 plots (40 m^2 plots in cork and holm oaks), centred at the plot centre, was used to count trees below the dbh threshold of 7.5 cm (5 cm for *Eucalyptus* spp. since NFI5). The plot was considered to be part of a forest stratum, if the centre of the plot coincided with this forest stratum. When plots do not fully occur within the forest stratum, an estimation of the fraction of the area matching with the target stratum is made in the field. In NFI5 field plots were assessed on a 2 × 2 km grid that corresponds to 22,091 points of which 12,258 were classified as forest or shrubs. In the case of shrubs, only plots located on the 4 × 4 km grid were measured. In the previous NFI's the number of plots measured in the field was smaller (e.g. Barreiro et al. 2010).

34.1.3 Data Collection

This section focuses on the data collected in NFI5. The most important improvements implemented in NFI6 are also described. Besides basic data such as the plot coordinates, allocation of sample plots to administrative regions, land use, date of measurement, verification of the land cover photointerpretation, the Portuguese NFI assessed five main categories of variables: site, stand, plot, trees within the plot and sample trees.

To assess site conditions influencing the growth and development of trees and stands, site variables such as land use/land cover, elevation above sea level, terrain aspect, slope gradient, terrain location and soil erosion are considered. In order to characterise the forest stand where the sample plot is located, the two main species are identified and their structure, age class and method of age determination are registered. The stands' vertical structure, including shrubs, is assessed by estimating percent cover according to height layers. The species richness (area and number of species), the understory use (e.g. grazing, agriculture) and the percent cover of litter and respective thickness are also collected. Recent stand treatments (pruning, weeding, thinning, cork extraction, forest roads maintenance), the occurrence of harvesting and the percentage of trees removed during harvesting if not clear-cut and the cutting cycle (only for species managed with a coppice system) are assessed as well as the occurrence of tree tapping (pine resin), lichens presence and tree vitality. The occurrence of fire, year of fire and type of damage (partial or total) along with the Northern Forest Fire Laboratory fuel model identification. Finally, for the dominant and secondary species regeneration evidence and type (natural, planting, seedling or coppice) are recorded as well as, in plantations, the spacing (distance between and within plantation lines) and any evidence of site preparation.

At plot level, the plot shape and its size (500, 2000 m^2 or a fraction of those areas) are recorded along with the plot land-cover (same as the stand, forest gap, clump of other species, clearcut, burnt).

All trees within the plot and above the dbh threshold have two perpendicular dbh measurements recorded and the following variables are assessed: species; tree status; tree shape; tree health evaluation (classes of decolouration and defoliation); tree development stage classes (Kraft); tree age in even-aged stands (younger, equal or older than the stand); Boolean indicator variables for dominant limit trees and standing dead trees. Additional variables specific for cork oak trees are collected: year, type and debarking level, evidence of excessive pruning, excessive grazing or of inner-bark wounds.

Additional measurements are carried out for sample trees (per 5 cm dbh class, the tree with dbh closest to the class mid-point): two perpendicular diameters at stump level; tree height; height to the living crown base; tree age with an increment borer (for even-aged softwood stands in two of the dominant trees and in the average tree). Further for cork oak trees also stem height, height of bifurcation, debarking heights, number of 1st and 2nd order debarked branches.

Detailed and further information about the data collected in NFI5 is available in the field protocol (DGRF 2005).

In NFI6, most of the NFI5 variables were considered, but significant improvements were included at methodological level, namely by the inclusion of new variables and by an in-depth revision of NFI conceptual framework and data gathering procedures. A publication containing a detailed description of the biometric data gathering procedures for vegetation used in NFI6 will soon be made available to the public.

34.1.4 Data Processing, Reporting and Use of Results

In the Portuguese NFI, area estimates are obtained by qualitative sampling, based on the land use/land cover classification of the set of 360 thousand photo-points (500 × 500 m grid) using photointerpretation techniques. Land Use Maps and Stand Type distribution Maps for continental Portugal were produced (DGF 2001). The area of the Portuguese territory, and the administrative NUTS regions were obtained from the official cartography of Portugal (*Cartografia Administrativa Oficial de Portugal*—version 2009.0).

Field assessments and measurements in plots located at each point of the 2 × 2 km or of the 4 × 4 km grids, for forest and shrub plots respectively, were the basis for the estimation algorithms used to evaluate stand characteristics in NFI5. The estimation of the volume and biomass of standing stock and of growing stock is of particular interest for productive forest land, but also very relevant for carbon stock and sink evaluation on the whole forest land. The estimation procedure includes several steps, starting with the estimation of tree height for each non-sample tree using species-specific height-dbh curves (DGF 2001; Barreiro et al. 2010). The volume and biomass of each tree within the plot is then calculated using species-specific functions (DGF 2001; Barreiro et al. 2010). Tree volume and biomass estimations are summed up for each plot and expanded to per hectare estimates using the corresponding plot area.

During the inventory process, quality control procedures are applied to check data input and data processing. The consistency of data input is also checked in terms of compliance with the methodology.

Plot estimates per hectare are aggregated for each forest stratum to a mean volume or biomass per hectare and multiplied by the respective area to obtain the total volume or biomass of standing stock and growing stock of each forest stratum. Mean volumes and biomass per hectare and total volumes and biomass are also estimated for the Portuguese mainland as well as for the required administrative regions. Change estimations can be obtained by the use of existing forest regional simulators (e.g. Barreiro and Tomé 2011, 2012).

The Portuguese NFI provides official estimates at national level, NUTSII level, and Regions for Forest Planning (PROF) level. The estimates at NUTSII and PROF levels do not include all the statistics published at the country level due to the small sample sizes that lead to large percent errors. The FloreStat software, available from the internet site of the Portuguese Forest Service (http://www.icnf.pt/portal/florestas/ifn), allows users to obtain more detailed information, for smaller administrative regions (NUTSIII and larger municipalities) regarding the main NFI indicators.

The results of the Portuguese NFI are used as a basis for decision-making processes in forest and environment policy, forest management, forest products industries, and for evaluating the outcomes of the implemented plans and decisions. National reporting commitments with several national and international processes and organisations are fulfilled using the data and results of the Portuguese NFI. The main reporting processes include: the national economics accounts on forests, the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and under Articles 3.3 and 3.4 of the Kyoto Protocol, the criteria and indicators for sustainable forest management under FOREST EUROPE process (FOREST EUROPE, UNECE and FAO 2011), the evaluation of conservation status of natural habitat types under the Habitats Directive (Council of the European Communities, 1992), and the United Nations Convention on Desertification reporting. Besides that, NFI data are a valuable data source for numerous research projects, and for outlook scenario analyses to estimate current and future potential of Portuguese forests in wood and cork supply (e.g. Santos et al. 2013).

34.2 Land Use and Forest Resources

34.2.1 Classification of Land and Forests

34.2.1.1 General Land Classification

The land classification system used in NFI5 for photointerpretation (500 × 500 m grid) follows a hierarchical system of land use types (Table 34.2). At the top level, land area is divided into forest and non-forest. Forest is then sub-divided into forest and other wooded land. The non-forest land is presented separately for shrubs, agriculture, other uses and inland waters. The FAO definition of forest is used directly by the Portuguese NFI: land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 %, or trees able to reach these thresholds in situ. It includes windbreaks, shelterbelts and corridors of trees with an area larger than 0.5 ha and width larger than 20 m. It does not include land that is predominantly under agricultural or urban land use. All other land uses/cover require also a land spanning of more than 0.5 hectares and a width larger than 20 m. The land use types presented in the Portuguese NFI are compatible with the FRA 2015 terms and definitions (FAO 2012). The details of the land classification system applied in NFI5 are described in the photointerpretation manual (DGRF 2006) and the approaches used in NFI6 will be soon made available to the public by the Instituto da Conservação da Natureza e das Florestas (ICNF).

Table 34.2 shows the NFI5 areas for the forest and non-forest land classes, its description and a comparison with the Forest Resources Assessment of FAO (2004) definition. The area of Other Wooded Land (OWL) has been included under forest land, although it has always been estimated separately so it can be discounted from forest area for international reporting purposes. Similarly to OWL, shrubland area which has always been estimated within the NFIs framework, was only reported for the first time under FRA 2015.

34.2.1.2 Forest Land Classification

In NFI5, forest land was classified using a combination of photointerpretation, coupled with the information collected during the measurement of field plots. The photointerpretation registers the forest composition by indicating the main and the secondary tree species as well as the occurrence of other species. The tree species (or tree species groups) considered individually in the Portuguese NFI are: maritime pine (*Pinus pinaster* Ait.), eucalypts (*Eucalyptus globulus* Labill.), cork oak (*Quercus suber* L.), holm oak (*Quercus ilex* L. subsp. *ballota* (Desf.) Samp), other oaks (*Quercus* spp.), umbrella pine (*Pinus pinea* L.), chestnut (*Castanea sativa* Miller). All other species are grouped in one of the following groups: other hardwoods and other softwoods. Since NFI5 (2005–2006) *Acacia* spp. are considered as

Table 34.2 Land use classes according to the national definition and the respective area (NFI5, 2005–2006)

Land use class		Description	Area (1000 ha)	Corresponding FRA classes (FAO 2004)
Forest	Forest area	Production forest, protection forest, recent stands (planted or regenerated by broadcast seeding), sites prepared for plantation, nurseries, shelterbelts, forest roads, gaps, clumps, chestnut and umbrella pine orchards; it also includes burnt and clear-cut areas	3310	Forest
	Other wooded land	Land with tree species that, due to site conditions, will not attain a height of 5 m and land with tree species with a crown cover less than 10 %	148	OWL
Non-forest	Shrub-land	Land with shrubby or herbaceous vegetation, of natural origin, and where no forest or agriculture takes place	1927	(not reported as OWL based on 2004 definition)
	Agricultural land	Cropland, fallow land, horticulture lands, fruit orchards (except chestnuts and umbrella pine), vineyards and grazing land. This land use may contain “trees outside the forest”	2929	OL, OLwTc
	Other uses	Unproductive non-forest land, urban areas	432	OL, OLwTc
	Inland waters	Large rivers, estuaries, lakes, dams, reservoirs, marshes and salt marshes	162	OL
Total land area			8908	

a separate group, and in NFI6 carob trees (*Ceratonia siliqua* L.) were considered as an autonomous forest species.

The occurrence of trees outside forest in the agriculture, shrublands or other uses is also registered for the main species.

Besides species and stand composition, the following characteristics are also registered for forest stands during the photointerpretation: crown cover of forest stands and identification of young stands, burnt stands or recently clear-cut stands; dimension of the stand; and understory use. Crown cover of forest stands is registered using the following classes: <10 % or vegetation that will not attain a height of 5 m (OWL); 10–30; 30–50; >50; young stand; burnt stand; harvested stand (clear-cut). The stand's dimension is evaluated in 4 classes: <2; 2–10; 10–50; >50. The understory use classes considered are: crops (including grasslands); bare soil; low density shrubs (cover <50 %); dense shrubs (cover ≥50 %).

In NFI5 the percentage of stands managed as high-forest and coppice was estimated (but not published) and can easily be made available. Regarding wood resources characterisation, the distinction between productive forest and protective forest is particularly relevant. NFI5 includes the estimation of areas that are within Protected Areas and under the NATURA 2000 program. However, Forest Available for Wood Supply (FAWS) is not estimated as a separate category. All resource-related estimates like standing volume, growing stock, increment and harvest are calculated for the entire forest area.

34.2.1.3 Classification by Ownership Categories

The Portuguese NFI distinguishes forest ownership into two main categories: Private and Public. Public forests are subdivided into National Forests and Other Public Forests. The large majority of the Portuguese forest area is privately owned (97.2 %). Public forest area corresponds to a mere 2.8 % of the total forest area, of which 98.6 % are classified as "Matas Nacionais", i.e. National Forests.

34.2.1.4 Forest Management and Cutting Systems

Forests in Portugal are managed as even- and uneven-aged systems. The respective areas, as a total in the country and by dominant tree species, are estimated using the combination of the information obtained by photointerpretation and the stand structure registered in the field plots. Approximately 60 % of the Portuguese forests are uneven-aged. However the proportion of even-aged stands strongly depends on the tree species. More than half of the maritime pine stands (56 %) are managed as even-aged, while the majority of cork and holm oaks stands (62 and 73 %) are uneven-aged stands. Most of the *Eucalyptus* plantations (65 %) are even-aged stands.

Eucalyptus plantation management does not consider thinnings during the first cutting cycle (high-forest), but includes thinning during the 2nd and 3rd cycles to reduce the number of shoots regenerated between 2 and 3 years after harvest. Therefore, harvested wood results mainly from clear-cuts. Other even-aged forests, in particular the maritime pine stands, usually incorporate the following silvicultural practices for guiding stand development: stand establishment by natural regeneration or planting, cleaning and pre-commercial thinning, thinning, clear cutting or final cutting of all the remaining trees.

34.2.1.5 Legal and Other Restrictions for Wood Use

The forests in Portugal are predominantly privately owned (97.2 %) and are mainly owned by individuals (89 %). The Law on Forest Policy (Law nº 33/96) establishes that forest harvesting, conservation, land use change and expansion are of Public interest and that the Public Administration is responsible for defining the regulation for the use and fruition of the natural resources.

Therefore, harvesting in stands of wood production species (all, except cork and holm oak) is at the discretion of the forest owner's, but they have to comply with the Portuguese forest legislation, for instance the Decree-Law nº173/88 that inhibits premature cuts of forest stands, and ideally the operation should be foreseen in the respective Forest Management Plan. Harvesting of cork and holm oak stands can only occur due to land use transformation purposes and it requires a *Declaration of Indispensable Public Usefulness*, which is issued by three Ministers. Pruning and maintenance cuts on theses stands, also require authorisation from the Institute for Nature Conservation and Forests (ICNF).

Since 2014, the establishment of new forest areas, larger than 0.5 ha, requires the owner or manager to, depending on site dimension and location, to inform or request an authorisation to (re)plant from ICNF. These procedures will enable the national forest authority to have close to real-time data on human induced forest expansion and to more effectively monitor the degree of accomplishment with the objectives established in National and Regional Forest Plans.

34.2.2 Wood Resources and Their Use

34.2.2.1 Forest Area by Dominant Tree Species

According to NFI5, the main tree species in the Portuguese forests are maritime pine, eucalypts and cork oak (27.9, 23.3 and 22.5 % of the forest stands area, respectively). Note that the Portuguese NFI separates between stand area and forest area as the later includes the temporarily unstocked areas, namely burnt and recently clear-cut areas. The productive forest area and the coverage by the tree species is given in Table 34.3.

Table 34.3 Forest stands area (1000 ha and % cover) by dominant tree species in continental Portugal (NFI5, 2005–2006)

Tree species	Area (1000 ha)	Area (%)	Remark
Maritime pine	885	27.9	
Eucalyptus spp.	740	23.3	
Cork oak	716	22.5	Not reported as FAWS
Holm oak	413	13.0	
Other oaks	150	4.7	
Umbrella pine	130	41	
Chestnut	30		
Acacias	4		
Other hardwoods	82		
Other softwoods	25		
Total forest land	3175		

34.2.2.2 Forest Area by Tree Species, Stand Composition and Age Class

In NFI5 the areas were also presented by age class for even-aged stands (Table 34.4). The large areas of maritime pine and eucalyptus in young age classes are a consequence of the large forest fires that occurred in 2003 and 2005, whereas cork and holm oak stands, not managed for wood production, and less affected by these forest fires, present the bigger areas in the older age classes.

34.2.2.3 Standing Volume, Increment and Drain

NFI5 estimates of standing volume are based on field measurements, combined with the area information. Volumes are defined as stem volume over-bark including stump, and include all trees having dbh > 0. The volume of trees having a dbh greater or equal to 7.5 cm (5 cm for eucalypts), measured over bark, is calculated using species-specific volume equations (AFN 2010). Tree heights for the non-sample trees are also estimated with species-specific equations (AFN 2010). The volume of trees below the 7.5 cm threshold (counted, not measured) is included by estimating the volume of an average tree in each dbh class (dbh < 5 cm and 5 cm ≤ dbh < 7.5 cm), using the dbh of 2.5 and 6.25 cm respectively, the average height measured for the class and a form factor. The average tree volume is then multiplied by the number of trees counted in the five 10 m^2 satellite plots centred at the plot centre. In NFI5, standing volume can be disaggregated into the volume of growing stock and volume of standing dead trees. Increment and drain are not directly calculated from the NFI data. Increment may be estimated for the three most important tree species by using the regional simulators available for the country (Barreiro and Tomé 2011, 2012). For the Kyoto protocol reporting,

Table 34.4 Forest area (1000 ha) by dominant tree species, stand composition and age class (NFI5, 2005–2006)

Species	Stand composition[a]	Age classes (years)							
		<10	10–20	20–30	30–40	40–50	50–60	≥60	Uneven-aged
Maritime pine	Pure	133.67	79.66	59.41	50.41	41.86	19.80	16.65	279.94
	Dominant	15.56	9.33	10.37	16.08	6.22	5.70	2.59	78.82
	Secondary	21.18	12.36	8.24	5.88	5.30	1.77	2.35	61.77
Cork oak	Pure	6.38	6.38	43.52	44.68	15.67	20.31	86.47	324.39
	Dominant	1.39	2.77	4.85	4.85	1.39	3.47	19.41	83.18
	Secondary	5.99	0.80	3.60	2.40	2.00	3.20	7.19	60.32
Holm oak	Pure	0.53	1.59	7.40	13.22	12.16	16.39	53.39	255.84
	Dominant	0.00	0.47	0.47	2.80	0.00	0.93	4.67	36.90
	Secondary	5.49	0.00	2.74	0.00	0.00	2.19	1.10	52.12
Other oaks	Pure	0.77	1.92	4.99	2.68	2.30	1.15	1.53	87.05
	Dominant	0.00	0.00	2.01	1.00	2.01	2.01	0.00	37.16
	Secondary	0.00	1.49	1.49	0.74	0.00	0.00	0.00	54.33
Umbrella pine	Pure	2.10	10.00	8.42	5.79	2.10	2.63	1.05	21.57
	Dominant	0.98	2.95	1.47	2.46	0.49	0.49	0.98	20.64
	Secondary	2.01	3.36	0.67	1.34	2.01	1.34	1.34	30.88
Chestnut	Pure	0.00	4.03	0.00	2.01	2.01	0.00	0.67	15.44
	Dominant	*	*	*	*	*	*	*	*
	Secondary	0.34	0.34	0.00	0.00	0.00	0.00	0.00	3.44
Acacias	Pure	0.00	0.09	0.00	0.00	0.00	0.00	0.00	1.94
	Dominant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.07
	Secondary	*	*	*	*	*	*	*	*

(continued)

Table 34.4 (continued)

Species	Stand composition[a]	Age classes (years)							
		<10	10–20	20–30	30–40	40–50	50–60	≥60	Uneven-aged
Other hardwoods	Pure	0.00	12.50	1.79	0.00	0.00	1.79	1.79	37.51
	Dominant	*	*	*	*	*	*	*	*
	Secondary	*	*	*	*	*	*	*	*
Other softwoods	Pure	0.00	1.81	2.49	1.13	1.13	0.23	0.00	5.20
	Dominant	*	*	*	*	*	*	*	*
	Secondary	*	*	*	*	*	*	*	*
Species	STAND composition	Age classes (years)							
		<4	4–8	8–12	12–16	16–20	≥20	Uneven-aged	
Eucalyptus	Pure	97.31	113.02	98.83	58.79	14.19	10.14	174.34	
	Dominant	6.72	10.64	14.00	11.20	2.24	7.28	40.89	
	Secondary	4.11	9.58	11.64	5.48	0.68	8.21	47.23	

[a]*Pure* Pure stands; *Dominant* Mixed stands with the species as dominant; *Secondary* Mixed stands with the species as the secondary species; *sample size not large enough

Portugal uses average increment values per tree species, when multiplied by the area covered by each species, allow for the estimation of increment (Pereira et al. 2014). Drain is estimated based on information gathered in questionnaires to major forest producers and industrial associations and from the questionnaires to production industries (prodcom database—eurostat) using conversion coefficients calculated from forest inventory and industrial production data.

Besides volume estimation, the Portuguese NFI also estimates total biomass, aboveground biomass, root biomass and biomass by tree components (wood, bark, branches and leaves/needles) using allometric equations available for the country (DGF 2010).

The forest land in Portugal has a standing volume of 182 million m^3 of stemwood overbark of which 5 % corresponds to standing dead wood. Maritime pine is responsible for the majority of the standing volume (47 %), followed by eucalypts (25 %), cork oak (14 %), holm oak (4 %), other oak spp. (3 %) and umbrella pine (2 %). The remaining tree species altogether account for 4 % of the standing volume. Table 34.5 gives the estimates of standing volume and increment by tree species. The increment values are the ones used in the Portuguese National Inventory Report (PNIR) (Pereira et al. 2014).

34.2.2.4 Tree Species and Their Commercial Use

According to NFI5, the main tree species in Portugal are maritime pine, eucalyptus and cork oak which together represent 74 % of the forest area and 86 % of the total standing volume. From those species just maritime pine and eucalyptus, representing 51 % of the forest area and 72 % of the total standing volume, are relevant for wood production, as cork oak is mainly managed as an agroforestry system with cork as the principal product. In 2014 the total supply (removals) of roundwood amounted to 8.2 million m^3 for broadleaves and to 2.7 million m^3 for coniferous

Table 34.5 The volume of standing stock and increment on forest land (NFI5, 2005–2006)

Tree species	Standing volume (1000 m^3)	Increment (m^3 ha^{-1} $year^{-1}$)
Maritime pine	85,756	5.6
Eucalypts	45,828	9.5
Cork oak	24,773	0.5
Holm oak	7566	0.5
Other oaks	5405	2.9
Umbrella pine	4330	5.6
Chestnut	1631	2.9
Acacias	521	2.9
Other hardwoods	4325	2.9
Other softwoods	1639	5.0
Total	181,774	

(UNECE/FAO Timber Database). Eucalyptus is mainly used for paper and paperboard production (45.7 %), raw pulp (29.2 %) and corrugated paperboard (10.1 %), whereas maritime pine has been traditionally used for carpentry and construction (39 %), sawnlogs (26 %), fiberboard and particleboard (14 %) (Santos et al. 2013). More recently, maritime pine wood is also used to produce pellets.

34.3 Assessment of Wood Resources

34.3.1 Forest Available for Wood Supply

34.3.1.1 Assessment of Restrictions

In Portugal, and for reporting processes, the whole forest area is considered as forest available for wood supply, with the exception of cork and holm oak areas in which wood harvest has strict restrictions, the "Laurissilva" forest, and particular conservation areas where harvesting is strictly prohibited.

The field assessments of the Portuguese NFI5 includes all sample plots in the sampling grid, with the exception of plots in inaccessible terrain which are just classified using aerial photographs. The existence of legal restrictions is not assessed in the field, but rather obtained from a post-stratification approach by intersecting sample plot locations with a GIS database that contains the areas with restricted harvest. Any restriction available as geo-referenced GIS-layer can be considered in assessing the forest area available for wood supply.

With regard to other restrictions and in particular to site characteristics that may restrict harvesting, the Portuguese NFI assesses several relevant variables such as accessibility and slope. These attributes are decisive for the use of harvesting and logging technologies.

34.3.1.2 Estimations of Future Wood Availability

The Portuguese regional simulator SIMPLOT that projects national forests into the future taking into account several drivers—wood and biomass demand, forest fires, afforestation and deforestation—was first developed for eucalyptus stands (Barreiro and Tomé 2011, 2012). Subsequently, SIMPLOT was broadened to include maritime pine stands and used in a prospective study for the Portuguese forests that was carried out following a demand from the Portuguese Industry. This study (Santos et al. 2013) covered the period after 2012 (2012–2041 for eucalyptus; 2012–2071 for maritime pine and cork oak) and also projected cork oak stands, using an existing simulator specific for this species, the SUBER model (Tomé et al. 2015). No legal restrictions were used for wood harvesting. Restrictions on the establishment of new eucalypt plantations were introduced, by not allowing plantations of this exotic tree species in Natura 2000 areas.

34.3.2 Wood Quality

34.3.2.1 Stem Quality and Assortments

Wood assortments were considered for maritime pine and eucalyptus in NFI5. For maritime pine the assortment includes diameter classes and assortments according to the top diameter and the log length. The classification comprises three classes: class A—logs with a top diameter >20 cm and log length >2 m; class B—log with a top diameter between 12 and 20 cm or >20 cm with a log length <2 m; class C—logs with a top diameter between 6 and 12 cm. For eucalyptus the assortment just computes wood with a top diameter >6 cm.

34.3.2.2 Assessment and Measurement

During field data collection in NFI5 several variables relevant to stem quality were assessed for all trees within the field plot. The most relevant is the tree shape (good form, forked, thick branches, curved base, curved stem, leaning tree, dried top, broken top, shrubby tree, tree lying on the floor). Just the living trees above the dbh threshold are classified for shape.

In addition, several other variables assessed on individual trees may contribute to the evaluation of stem quality such as the tree status (alive, burned, dead, failure in a plantation, stump, burned stump), the height of the living crown base, if the tree is a border tree in the stand, and some other stand and site specific variables like management type and elevation above sea level.

34.3.2.3 Estimation and Models

In order to obtain volume estimates by assortments different systems of equations are used for the maritime pine and eucalyptus (AFN 2010). The system of equations for each species includes a volume equation (total volume over bark), a taper equation (upper-diameters over bark) and a volume ratio equation (volume under bark to an upper diameter, excluding stump) that are applied to each individual tree within the plot to estimate the respective merchantable assortments. Stem quality information was not considered in the computation of volume by assortments presented in NFI5.

34.3.3 Assessment of Change

34.3.3.1 Assessment and Measurement

During the photointerpretation phase of the NFI6 the aerial photographs of the two previous NFIs (1995 and 2005) were re-analysed and the photo-plots corresponding to the same grid of 500 × 500 m were photo-interpreted using a software that allows the simultaneous observation of each plot over time by the same photo-interpreter and applying the same rules. This methodology allowed a very good estimation of land use/land cover changes that led to the correction of the estimations of forest areas that had been published in the previous NFIs. As previously mentioned, changes of volumes and biomass have not been directly calculated from the NFI data as the field plots are not permanent.

34.3.3.2 Estimation of Increment

Increment has not been computed directly from NFI data. Increment may be estimated for the three most important tree species using the regional simulators available for the country (Barreiro and Tomé 2011, 2012; Tomé et al. 2015). When reporting for the Kyoto protocol, Portugal uses a different method (see Sect. 34.3.1.2).

34.3.3.3 Estimation of Drain

In Portugal, drain is estimated from different data sources, namely production statistics provided by industrial associations and reported production data in national surveys. Wood imports data are considered for data calibration for national production. Coefficients are then applied to production data for estimating removal, while natural losses are estimated from NFI data on tree mortality.

The Portuguese National Report on Greenhouse Gases (Pereira et al. 2014) uses a slightly different method based on several assumptions. It is not possible to classify by harvesting type, but the majority of harvested wood comes from clear-cuts. Major wildfire events contribute to a high amount of wood harvested in salvage logging. In maritime pine stands, large harvest volumes have also originated from sanitary measures such as a consequence of the pine nematode.

34.3.4 Other Wooded Land and Trees Outside Forests

34.3.4.1 Assessment and Measurement

The sampling grid of NFI5 covers all land-use classes of the Portuguese territory. As previously mentioned the plots coinciding with forest area are measured according to a 2 × 2 km grid and the ones coinciding with shrub-lands according to a 4 × 4 km grid. Shrubland has a broad intersection with other wooded land definition of FAO (2004). Measurements on Trees Outside Forest have been restricted to those occurring in the shrubland plots.

34.3.4.2 Estimation

Shrubland and Other Wooded Land areas were both assessed in NFI5 (see Table 34.2). These strata together correspond to the Other Wooded Land according to the FAO definition (FAO 2015). Information retrieved from photointerpretation analysis also enabled the estimation of the non-forest area with the presence of forest trees (Trees Outside the Forest).

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Chapter 35
Republic of South Korea

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35.1 The South Korean National Forest Inventory

35.1.1 History and Objectives

The South Korean National Forest Inventory (NFI) is carried out by the Forest Resource Information Division of the Korean Forest Research Institute. The institute is a division of the Korea Forest Service (KFS). The NFI has been conducted on a regular basis since 1972 at approximately 10 year intervals: NFI1 from 1972 to 1975 (first cycle), NFI2 from 1978 to 1981 (second cycle), NFI3 from 1986 to 1992 (third cycle), and NFI4 from 1996 to 2005 (fourth cycle). In past NFIs, the provincial based inventory results were reported to the KFS at the end of the year. The KFS collates the inventory data and publishes annually the Statistical Yearbook of Forestry.

The purpose of the NFI is primarily to provide basic information on national forest resources. Each year one of the nine provinces are assessed. The provincial basis of field data collection causes some difficulty when producing forestry statistics for the whole country as the NFI can only provide sample based inventory

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data for one province per year. The periodic nature of the cyclical inventory can be problematic due to fluctuating NFI budgets and the fact that the survey results do not accurately reflect forest dynamics between measurements (Scott et al. 1998). From the early 1990s, NFIs in many countries began to improve by changing from periodic to a continuous annual inventory system to address international demands for forest resource information as well as to monitor and assess national forest resources and ecosystem. Most climate change and forest sustainability agreements require periodic reporting of forest statistics such as national forest area.

In NFI5 (2006–2010) the assessment timeframe of the South Korean NFI moved from a periodic to a continuous annual inventory. The Forest Inventory Center (FIC) conducts the continuous NFI over a 5 year period to obtain precise and up to date data necessary for the formulation of sound forest policies. Due to the robust sampling base and accurate field surveys, the statistics produced have international credibility.

For NFI 6, the re-measurement of permanent plots began in 2011 and is due for completion in 2015. Prior to 2011, the FIC carried out two major assessments of the nation's forest resources: the NFI program and the Forest Health Monitoring (FHM) program. As a result of new legislation and a revised implementation strategy in 2011, these two programs are now being merged, whereby more intensive measurements using the former FHM indicators and methodology are now being applied to a subset of NFI plots.

The FHM program is a national initiative designed to determine the current status, change, and trends in indicators related to forest condition on an annual basis. In South Korea, several sources of forest damage have been identified during the last decades. These include; fire, wind, floodwater, insects, disease and climate change. In most cases, the damage at a national level has not been substantial. However locally, the impact has been severe in some instances. As a result of the sparse monitoring networks, it has been difficult to quantify the magnitude of damage and acquire useful data for mitigation programmes. Therefore, the forest health monitoring data needs to be multi-dimensional. The merging of the NFI and FHM has the potential to provide a comprehensive dataset to describe large forest damage outbreaks.

35.1.2 Sampling Design

Digital map information is used to separate forest land from other land classes, such as arable land, built-up areas, roads, urban areas and single houses (Tomppo et al. 2008). Panchromatic aerial photograph at a scale of 1:15,000 has traditionally been used in forest inventory for the initial assessment of the entire sampling grid and for the identification of plots to be surveyed in the field (FAO 2007). In addition, aerial photos are assessed to determine; forest types, primary tree species, diameter class, age class and crown cover. A digital forest type map is prepared for the whole country. While field plots provide detailed stand information such as volume, tree height, diameter at breast height (dbh), species composition and growth rate, the forest type maps provide statistics on the area by major forest types. Both volume and forest area data are combined to calculate national forest statistics.

The sampling design adopted in NFI5 uses permanent sample plots for the continuous monitoring of forest resources and ecosystem. About 4000 permanent sample plots are systematically established over the country (Korea Forest Research Institute 2011). The field plot design is based on a cluster plot, consisting of four circular subplots. The subplots 2, 3, and 4 are 50 m away from the subplot 1 at azimuths of 360°, 120°, 240°, respectively (Fig. 35.1).

Circular plots are easy to establish where the radius is not very large, and they are also less vulnerable to errors in plot area. The length of the perimeter increases as the radius increases, however so too will the number of trees on the edge of the plot. Thus circular plots with a large radius are not very efficient (Schreuder et al. 1993; Loetsch et al. 1973). In many cases combined circular plots can be established, i.e. plots that consist of several concentric circles, the smaller circles being used for smaller trees and the larger circles for larger trees (Annika and Matti 2009).

Each sub-plot has a concentric design, consisting of three different plots: a sapling plot of 30 m^2 (3.1 m radius), a small tree plot of 400 m^2 (11.3 m radius), and a large tree plot of 800 m^2 (16 m radius). The sapling plot is used to collect

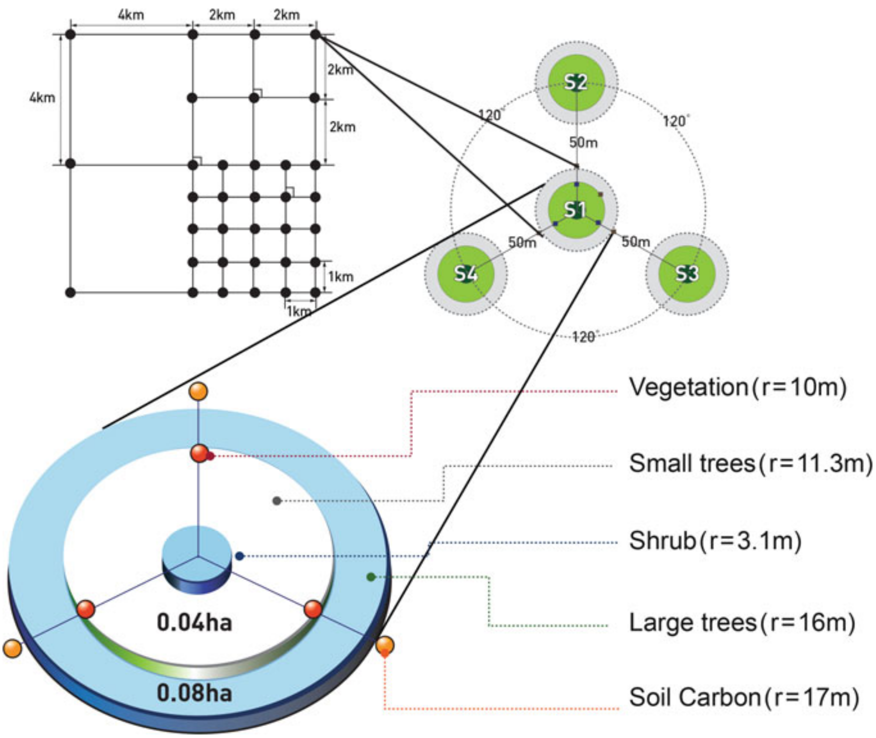

Fig. 35.1 South Korean NFI sampling design

data on trees with dbh less than 6 cm; the small tree plot assesses tress greater than 6 cm and large tree plot assesses trees with a dbh of more than 30 cm. In the new inventory system 25 % of the sample plots are permanent for the purpose of forest health monitoring. The centre sub-plot only contains six micro plots, three vegetation plots and three soil carbon plots, each with areas of 1 m^2. The centre of the micro plots are located at a distance of 10 and 17 m from the plot centre, on three lines radiating from the plot centre. These micro plots are only established on the 1000 permanent sample plots that are systematically sub-sampled from the total permanent sample plots for Forest Health Monitoring (Fig. 35.1).

35.1.3 Data Collection

During field data collection the following important attributes are assessed; forest type, species composition, diameter at breast height (dbh), age class, stand density, height, crown height, site quality, age class and defects of each sampling plot (Lee et al. 2014). From the data collected secondary attributes are calculated; the number of trees per ha, the basal area, the volume of trees in an area and the economic value of the timber. In particular, the biomass components of all living trees, in addition to the stem, were studied more intensively due to the increasing interest in using biomass as an energy source (Hakkila 1989). Also, the national forest inventory provides an overview of the resources available at a regional and national level, as well as information on the carbon balance of Korea’s forests.

35.1.3.1 National Forest Inventory Variables

The field crews determine the location of the subplot geographic centre using GPS receivers. There are a lot of variables assessed on the plot, including; species, dbh, height, growth, soil, mortality, damage, management activity, etc. Additional NFI measurements relate to forest stand condition and site description; and may be grouped into three categories:

1. Forest stand condition
    - Forest type: Conifer, Broadleaf and Mixed forest
    - Crown density: Assessed using a densitometer
    - Stand DBH class: Sapling tree stand (<6 cm dbh), Small tree stand (6–17 cm dbh), Medium tree stand (18–29 cm dbh), Large tree stand (>30 cm dbh)
    - Stand age class: Five sample trees to measure age
    - Forest ownership: National, Public or Private
    - Stand origin: Natural or Artificial
    - Forest land class: Forest practice area i.e. area where forest management is permitted
    - Stand renewal (Afforestation, Natural seeding, Regeneration).

2. Site description
   - Altitude: Altitude measurement at the sample plot centre
   - Slope: Slope is measured from two points (15 m apart), which are generally in the direction of the slope line below the sample plot center
   - Aspect: Aspect is classified into one of eight classes N, NE, E, SE, S, SW, W, NW
   - Topography: Aerial photographs are used to measure the topography
   - Soil: Soil is separately described in terms of depth (0–10, 10–20, 20–30, 30–40, 40–50 cm).
3. For each tree Species (where tree dbh is greater than 6 cm):
   - Live/Dead status: To estimate biomass
   - Diameter: Tree-level dbh data
   - Height: Height is assessed on 10 well-grown trees
   - Crown ratio: Percent of tree height represented by crown
   - Crown class: For example; dominant, co-dominant, suppressed.

35.1.3.2 Forest Health Monitoring Variables

The measurement of FHM indicators can be grouped into Tree Health, Vegetation Health, Soil Health and Atmospheric Health. Each indicator is evaluated, classified and analysed to provide conclusive information on the health of South Korean forests. Additional measurements for FHM relate to forest ecosystem function, condition, and health. These measurements are generally acquired during summer months and may be grouped into four categories:

1. Tree health
   - Crown: Crown health, crown class, crown density
   - Stem: Quality of stem, damage to the stem, damage type and damage severity
   - Defoliation: Damage resulting in the loss of leaves or needles
   - Growth: Stand dynamics.
2. Vegetation health
   - Overstorey: Tree species, species diversity, density, cover cover, number of exotic tree species
   - Understorey: Cover of the herbaceous layer, shrub species, sapling species
   - Forest floor: Thickness of litter on the forest floor
   - Mortality: Mortality (in small tree plot).
3. Soil health
   - Chemical properties: pH, Nitrogen content, Organic content, Available phosphate, Cation Exchange capacity
   - Physical properties: effective soil depth, consistence, humidity.

4. Atmospheric health
    - Lichens; Number of epiphytic and ground lichens.

If multiple factors affecting forest health are identified on a plot, field crews assign tallied trees to the condition class in which they occur and record the necessary information for estimating the portion of the plot that is within each condition.

35.1.3.3 Land Use Information

Forest is defined as land spanning more than 0.5 hectare with trees higher than 5 meters and a canopy cover of more than 10 %, or trees able to reach these thresholds in situ. The width of the interpretation area is at least 20 m. It includes areas with bamboo and non-stocked forest land provided that height and canopy cover criteria are met. It excludes land that is predominantly under agriculture, building site, road (national highway, local road, railroad) etc. Forests are divided into stocked forest land, un-stocked forest land and Miscellaneous. Non-forests are divided into residential area, cultivated land, others and Marshy land (Korea Forest Service 2011a).

35.2 Land Use and Forest Resources

35.2.1 Classification of Land

The total land area in South Korea is 10,003,308 hectares with 64 % of forests and 36 % of other land. Between 1990 and 2010, the total land area of South Korea has increased from 9.927 to 10.003 million hectares. The area of stocked forests have slightly decreased with industrialisation and urbanisation after 1990s. However, the unstocked forest and other land have slightly increased over the same period of time (Table 35.1).

Table 35.1 Land area of South Korea (Korea Forest Service 2011b)

Year	Total land area (1000 ha)	Forest (1000 ha)			Other land (1000 ha)
		Sub-total	Stocked	Un-stocked	
1990	9927	6476	6302	174	3451
2000	9946	6422	6268	154	3524
2010	10,003	6368	6171	197	3635

35.2.2 *Forest Land Classification*

The total forest area of Korea is 6.3 million ha, about 64 % of the total land. In recent decades, Korea has undergone rapid urbanisation and industrialisation which has expedited a population influx into the cities. This has increased the demand in land for factories and housing. This increased demand in land for development has led to a decrease in the total forest area from 1990 to 2010. The forest land area decreased from 6.47 to 6.36 million ha between 1990 and 2010, continuing a slight downward trend in area beginning in the 1990s. The forest areas were predominately coniferous in the 1990s but now the area is more or less equally divided between coniferous, deciduous forest and mixed species forest (Table 35.2).

35.2.2.1 Reforestation

In the 1950s, the forest area was left in a state of extreme devastation as a result of excessive cutting during and after the colonial period of 1910–1945 and the Korean War of 1950–1953. In order to rehabilitate the degraded forests, the government initiated a large-scale reforestation program, and set up a national forest plan, which has been renewed every 10 years from 1973 to present.

In 1973, the first 10-year forest rehabilitation project (1973–1978) was launched and proved to be a turning point in the evolution of forest policy affecting the management of the nation's forests. The main goal of the plan was to restore 1 million ha of forest over a short time period. As a result, this 10-year project was completed in 1978, four years in advance of its target year 1982. During this project, 1.08 million ha of forest land was reforested, representing a significant achievement in the national forest rehabilitation plan.

The Second National Forest Plan (1979–1987) was devised to establish large-scale commercial forests. To achieve this objective, the government initiated various forest policies relating to the; improvement of the national rehabilitation project and forest protection, promotion of forest development fund to support private forest management, grouping and expansion of national forests. Forest conservation projects were also implemented to improve the ecological benefits of forests for society.

The objective of the third national forest plan (1988–1997) was to harmonise the goals aimed at enhancing economic capacity of forests and improving common

Table 35.2 Forest land area (1000 ha) by forest type (Korea Forest Service 2011b)

Year	Total	Conifers	Broadleaves	Mixed	Bamboo Stand	Un-stocked
1990	6476[a]	3079	1389	1810	7.98	174
2000	6422	2711	1666	1885	6.09	154
2010	6369	2581	1719	1865	7.04	197

[a]Un-surveyed area (15,386 ha) is excluded from the total forest land area in 1990

benefits of forests. The plan also aimed to promote the effectiveness of forest management practices. Although the reforestation target was nearly achieved by the end of the second 10-year forest plan, timber supply in Korea was still dependent on imports for about 90 % of the domestic demands.

The primary objective of the Fourth plan (1998–2007) was to establish a foundation for sustainable forest management. Key strategies were included aimed at developing valuable forest resource, fostering a competitive forest industry and enhancing forest health and vitality.

The fifth national forest plan (2008–2017) is the latest government-driven reforestation initiative, and sets out further goals towards the implementation of sustainable forest management in pursuit of maximising forest functions. In particular, the plan highlights the importance of forest functions with respect to climate change. The overall vision of the fifth plan is "to realise a green nation with sustainable welfare and growth" by sustainably managing forests as key resources for strengthening national economic development, land conservation and improved quality of life.

35.2.3 Wood Resources

Korea's forests were devastated in the 1950s due to the Korean War and land use change for industrialisation. The Korean government has made diverse efforts to rehabilitate the forest area. These efforts have resulted in the dramatic increase in the growing stock volume. Forest resources of South Korea have continuously improved in general condition and quality, as measured by increased average size and volume of trees. Tree volume is estimated on those trees that have a dbh of 6 cm or larger. The growing stock volume of South Korea increased from 38.36 to 125.62 m^3/ha between 1990 and 2010 (Table 35.3). Currently estimates of increment and drain are not available. However, following the completion of NFI6 (2011–2015), it will be possible to produce such statistics.

Table 35.3 Growing stock volume of the South Korea by forest type (Korea Forest Service 2011b)

Year	Growing stock per ha (m^3/ha)	Growing stock (1000 m^3)			
		Total	Conifers	Broadleaved	Mixed
1990	38.36	248,426	113,868	64,509	70,048
2000	63.46	407,575	174,941	110,129	122,504
2010	125.62	800,025	336,337	215,369	248,369

35.2.3.1 Commercial Tree Species

Over the last 40 years, comprehensive efforts were made to rehabilitate degraded forests, to expand protected land, and to implement sustainable forest management. About 730,000 ha of degraded land was restored and extensive plantations were afforested on over 350,000 ha by planting about 11 billion trees. This plan has succeeded in restoring forest cover nationwide and is internationally recognised as an exemplary case of forest rehabilitation. Following the large-scale afforestation of plantations and rehabilitation of degraded forests and through natural succession, red pines (*Pinus densiflora*) have become dominant as a pioneer species in natural forests (Table 35.4).

35.2.3.2 Forest Management and Cutting Systems

Following the civil war, excessive and illegal cutting of trees was more severe compared to the levels previously experienced. The Korean Government introduced a policy that legally harvested timber should be marked. However, illegal cutting did not markedly decrease until the 1980s when a prohibition order from entering into forest was introduced (Kim and Kim 2005). Between 2005 and 2008, the average annual cutting area was approximately 22,000 ha (Table 35.5). However,

Table 35.4 Commercial tree species for NFI5 (2006–2010) (Korea Forest Promotion Institute 2013)

Tree species	Area (1000 ha)	Growing stock (1000 m^3)
Red pine (*Pinus densiflora*)	2220	317,839
Korean pine (*Pinus Koraiensis*)	235	25,240
Japanese larch (*Larix leptolepis*)	280	44,303
Pitch pine (*Pinus rigida Mill*)	313	40,065
Japanese cedar (*Cryptomeria japonica*)	14	2891
Japanese cypress (*Chamaecyparis obtuse*)	24	2307
Oak (*Quercus* spp.)	1078	157,235
Total	4164	589,880

Table 35.5 Annual cutting area (ha) of South Korea (Korea Forest Service 2010)

Year	Total	Clear cutting	Selective cutting	Shelter-wood cutting	Other
2005	23,703	15,970	1358	2178	4197
2006	23,349	14,394	805	1042	7108
2007	24,078	15,181	512	1829	6556
2008	22,183	15,079	200	1260	5644
2009	57,677	17,939	1706	811	37,221

the level of cutting increased in 2009 due to the implementation of a new forest policy that focused on increasing the quantity of timber harvested using clear cutting and selective cutting. The policy to increase harvest levels was aimed at stimulating economic growth and promoting environmental benefits from the forests. As the stand age class increases, the cutting area is also expected to increase continuously in the coming years.

35.3 Conclusion

The National Forest Inventory (NFI) produces valuable information on South Korean forests. The NFI program of South Korea has been enhanced by moving from a periodic to annual system from 2006 to assess and monitor the status of forest resources and changes to the forest ecosystem over time. Since 2006, the NFI has undertaken to collect various information for wood resources as well as environmental conditions in forests. National forest statistics are generated for a number of forest variables using NFI data.

Many variables assessed during NFI5 and NFI6 were selected to address specific criteria outlined by the Montreal Process working group for the conservation and sustainable management of temperate and boreal forests and is based on the concept of indicator variables. The indicator variables represent an index of ecosystem functions that can be monitored over time to assess trends. Indicator variables are used to monitor the status of ecological attributes such as vegetation diversity, fuel loading, regional air quality gradients, and carbon storage. The enhanced NFI of South Korea is expected to provide accurate and timely forest information at national level and to satisfy increasing domestic and international reporting requirements. This information is important for the formulation of government policy, public administration, the private business sector, the general public and the research community.

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Chapter 36
The Republic of Macedonia

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36.1 Forest Inventory in the Republic of Macedonia

36.1.1 History and Objectives

Following the chain of past historical, economic and political events that occurred within the region, a truly organised and functional forest management planning system and forest inventory was initiated in the Republic of Macedonia after the Second World War. Prior to 1941, 18 forest management plans were completed covering an area of 86,020 ha (Grujoski 1959) which was about 14 % of the total forest area. In 1946, the government of the Socialist Federal Republic of Yugoslavia adopted the Provisional Manual for Forest Inventory. The main goal was to establish as fast as possible the status of forest resources that remained following uncontrolled exploitation during the war (Meshtroviċ 1978), and to create a structure for future forest management (Klepac 1947). Those instructions, contained in the Provisional Manual, prescribe the use of a standardised forest inventory in all states of the federation, completed for forest management units, forest management district and forest management provinces. The result was an extensive inventory of all forest resources within the federation. Although the aim was for the inventory to begin quickly, the task was performed with some delay and it took two years to complete (1949/50) mainly due to the lack of skilled and trained

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professionals. In 1946, in the Republic of Macedonia there were only 14 forest engineers (Tasic 1959). The results from this inventory were reported in the Statistical Yearbook (SYb) in 1954 (State Statistical Office 1954). Since this 1949/50 inventory, only two assessments of forest resources have been completed, one in 1961 and one in 1979. The results from these inventories were published in the SYb in 1964 and 1982, respectively. The data collected in these inventories were gathered through Forest Management Plans and questionnaires, a method that has been continued by the state's statistical office for the yearly updates.

36.1.2 Sampling Methods and Periodicity

The assessments of forest resources have been conducted to provide information that satisfies forest policy requirements for the benefit of society. To date the three inventories that have been completed were based on self-registered questionnaires using data from Forest Management Plans (FMP), cadastres, local administrations and hunting associations. The periodicity of inventories was never officially prescribed. The surveys have not been probability based statistical inventories. The Federal Statistical Office (Statistical Office of the Socialist Federal Republic of Yugoslavia) prescribed a Methodology for Forest Inventory whereby only the stand variables were included (State Statistical Office 1963, 1982). With these inventories standing stock was determined either by the balance method or the estimation method. The balance method has been applied in managed forests (forests under FMP), where the standing stock is evaluated during the management inventory. In non-managed forests, an estimation method was applied, which used data from neighbouring managed forests. Where no such neighbouring data were available an estimate of standing stock was made using temporary sample plots established in the stand or using growth tables.

The periodicity and methodology of the forest management inventories (MI) which are made for the revision on the FMP are defined by Rulebook for contents of the Forest Management Plans (Ministry of agriculture, forestry and water economy 1971, 1975, 1998). FMP are revised every 10 years and a management inventory is conducted in the year preceding. Every year about 10 % of the forest area is inventoried. Management inventories are completed on a management unit level using temporary sample plots. Prior to the introduction of the 1971 Rulebook describing the contents of the Forest Management Plans, general guidelines for forest management on the whole territory of Yugoslav Federation were applied whereby the basic management unit was forest management district. The periodicity of 20 years was prescribed and the MI was completed using temporary sample plots (Meshtroviċ 1978; Ivanovski 1997).

The most recent Forest Law (2009) included a requirement to undertake a National Forest Inventory (NFI), but it did not define the periodicity between assessment dates. To date the NFI has not begun and the methodology describing its implementation remains to be prepared.

36.1.3 Data Collection

The input data in the three large forest surveys 1949/50, 1961 and 1979, as well as those used today for updating the statistical data on forest resources are collected within the framework of the forest MI. In uneven-aged high forests and in even-aged mature stands, sample plots have to cover between 5 and 10 % of the stand area and in even-aged younger stands and coppice stands, the sample should cover between 3 and 5 %. During the MIs, the stand characteristics are assessed on temporary sample strips or circular plots. The field assessor selects the most suitable plot type.

With the MI, three categories of variables are evaluated: tree, stand and site.

Trees variables are measured or estimated on temporary sample plots, with a diameter at breast height (dbh) threshold of 10 cm in high forests and 5 cm in coppice forests. The variables relate only to the living trees and they are:

- Tree species
- Diameter at breast height (dbh), where the dbh is assessed in 5 cm diameter classes; Tree height measured on a sub-set of tally trees selected in different diameter classes and stand locations
- Forked tree (below or above breast height)
- Stem damage (mechanical, pathological, insect)
- Stem quality (straight, curved on one side, twisted).

Stand variables describe the forest stands based on previous assessments and data collected on sample plots. They include:

- Management form (high forest, coppice, even-aged, uneven-aged)
- Stand age: the classes are 20 years and 10 years wide for high even-aged and coppice forests, respectively. If a stand consists of compartments larger than 1 ha in size and with an age difference of more than one age class, the stand is partitioned into sub-units
- Stand structure: layers (one or two layers stand), their coverage (in percent), and development stage (five phases)
- Stand stability: including damage, urgency and type of silvicultural treatment. Plant community (forest association) with an assessment of the occurrence and abundance of wooden, bush and herb species
- Composition: pure and mixed forests
- Regeneration: development stage and quantity
- Harvesting: species, quantity and assortment by year.

Site conditions are gathered in order to describe the factors that influence tree growth and stand development. Some variables are estimated in the field, others are derived from various external data sources. The following variables are included in this group:

- Altitude above sea level (m): minimum, maximum value
- Exposition: eight direction classes

- Slope: 5 categories (flat—up to 5°, slightly inclined—6 to 10°, medium inclined —11 to 20°, steep—21 to 30° and very steep more than 31°)
- Soil quality: type, depth, moisture, depth of mull horizon
- Non decomposed organic material: depth in cm
- Erosion: occurrence, type of erosion (superficial or line), place/location.

Although data about site conditions are gathered in the MI the data has not been used for the National Forest inventory or the yearly updates. A probability based inventory has recently been carried out in the National Park “Mavrovo” during 2009 and 2010 (Trajkov et al. 2011). During this inventory, 3542 permanent circular sample plots were established on a 300 × 300 m grid, where sample plots in neighbouring grid rows were displaced by half of the grid width (150 m). The size of the sample plots varies between 100 and 1256 m^2, with respective circle radii from 5.64 to 20 m. The size of the plots selected depends on the tree density in the stand, where the intention is to include at least 30 trees per plot. For the forest regeneration, 4 circular plots with a radius of 1 m each were established in each sample plot. The minimum dbh thresholds were 10 cm in high forests and 5 cm in coppice forests. In addition, dead standing trees were also measured; in contrast to MIs where this requirement is not prescribed in the regulations.

36.1.4 Data Processing, Reporting and Use of Results

Based on the MI field data, as well as data available from other sources (e.g. geological surface), every stand is described with its surface area, site conditions and stand variables, both in a narrative and numerical form. The stand area is obtained from topographic maps with a scale of 1:25,000. The volume of the stand is calculated by tree species and diameter classes. For this, the number of trees by tree species and diameter class is multiplied by the respective average single tree tariff volume, which is obtained from local or national volume tables. The number of trees per hectare is obtained from the number of trees in all sample plots in the stand and the ratio with the total area of the stand and the total area of the sample plot located in the stand. The volume of the stand is estimated using appropriate growth tables. Input parameters for these tables are tree species, age and height i.e. site condition. Due to the lack of national growth tables, tables from the neighboring countries are usually used.

The average dbh of a stand is the dbh of the mean basal area tree in the stand, and the stand’s average tree height is a weighted arithmetic mean of tree heights, where the weights are the basal areas of the trees (Lorey’s height). Wood increment is estimated using the percentage of increment calculated by Schneider’s formula (Klepac 1963). Increment is usually established for groups of stands with the same characteristics and with similar site conditions. The stand density is expressed as a volume density, i.e. the ratio between the measured volume and the normal volume of the stand obtained from growth tables (species, age, site condition). According to the proportion of different tree species in the total growing stock, stands are classified as pure or mixed. A pure stand is considered one in which more than 90 % of total growing stock is from one species. These stand characteristics are then used to compile estimates for the whole forest area under a management plan.

The data about forest area, harvesting and other activities in forests as well as the utilisation of wood and non-wood goods and benefits from forests, are recorded in the questionnaire by the forest managers. These questionnaires are submitted to the State's statistical office which were published in SYb prior to 2001 and since then have been published in the Statistical Review of Forestry. The report which presents the forest inventory data from 1979 (SYb 1982) includes information on forest area, growing stock, increment, ownership, tree species, type of management, stand age classes for even-aged forests, dbh classes for uneven-aged forests, purpose, afforestation and reforestation, forest damage (forest fire, insect infestation, disease, illegal cutting), hunting statistics, harvesting techniques and forest roads, etc. The annual statistic reviews from 2001 to date give relatively poor information on wood resources. In terms of the status of the forests, the annual statistical reviews present only the area of the forest by tree species and the rest refers to the works performed in the forests, e.g. planting, harvesting, employment, damage, etc.

The MI data serve different purposes (scientific papers, master and doctoral thesis, etc.) at varying spatial scales, and several reports on the state of managed forests have been published (Ivanovski et al. 1990; Nestorovski 2012). These reports on the state of managed forests comprise information about forest area, growing stock and increment, for the whole country and is broken down into forest management units, provinces and regions, the type of forest management and the type of forests (even-aged and uneven-aged forests, high forests and coppice forests), as well as the annual allowable cut.

36.2 Land Use and Forest Resources

36.2.1 Classification of Land and Forests

36.2.1.1 General Land Classification

Since there is no recent data from a national forest inventory available in the Republic of Macedonia, a general hierarchical system of land use is presented in this report. This land use information is derived from the Spatial Plan of the Republic of Macedonia for the period 2002–2020 (Eremeeva et al. 2004), adopted in 2004. In this plan, the territory of the state is divided into productive (2,241,000 ha) and non-productive (330,000 ha) land (Table 36.1). The productive land is then divided into agricultural and forest land with 1.244 million and 997,000 ha, respectively. Data about forests are based on data from State Statistical Office (SYb 2001) and classifies forests into high and coppice, managed and unmanaged. According to the most recent forest law, a Forest is defined as a piece of land of a minimum size of 200 m^2 where tree species and shrubs are present, as

Table 36.1 Land use classes according to the Spatial Plan of the Republic of Macedonia for the period 2002–2020 (Eremeeva et al. 2004)

Class name		Description	Area (1000 ha)	Area (%)	Correspondence to FRA classes (FAO 2004)
Productive land	Forest land (stocked forest land)	All categories forest	997	38.8	Forest, OWL, OlwTc
	Agricultural land	Cropland, fallow land, fast growing tree plantations, grassland with small groups of trees less than 0.02 ha, riparian forest vegetation outside the forest, orchards and vineyards, grassland, grazing land	1244	48.4	OL, OWL, OwlTc
Non- productive land		Natural land: water bodies, reed beds, bogs, heath lands, rocks, areas of gravel and debris, landslides, other natural lands, Built-up land: industry and commerce, mining, traffic and transport, disposal sites, tourist facilities, dwellings and parking sites, gardens and parks, buildings Other land: Inaccessible and unproductive non-forest land	330	12.8	Other land, other land with tree cover
Total land area			2571	100	

well as bare land in the neighbourhood or in the middle of the forest, forest nurseries, forest roads, seed plantations, wind shelters belts, fire breaks in forests, and forests in protected areas. The category Forest does not include small groups of trees on an area of less than 200 m^2, boundary trees on agricultural land, fast growing tree plantations, vegetation near river beds outside forest, recreational parks in inhabited areas.

36.2.1.2 Forest Classification by Use

Due to the fact that the main and most reliable source of information about forests is forest management plans, any classification of forests starts with the division between managed and non-managed forests. The total stocked forest land in 2012 amounted to 988.8 thousand ha (Ministry of Agriculture, Forestry and Water Economy 2012) of which 902 thousand ha were managed, i.e. for which forest management plans are prepared (Table 36.2). According to the most recent Law on forestry, further classifications of forests have been established according to use, management system, species, and stand characteristics.

Table 36.2 Forest classes by use within managed forest land according to the Forest Management Plans (Ministry of Agriculture, Forestry and Water Economy 2012)

Class name		Description		Area (1000 ha)	
Managed Forest land	Productive forests – high forests – coppice forests – shrub-lad	Forests that priority function is wood production	Forests available for wood supply without restriction	841	
	Protective forests – high forests – coppice forests – shrub-land	Forests with protective or other function and with yield	Forests available for wood supply with restriction in regards of the choice of the cutting system		
	Forests with special purposes			10	
	Forests in protected areas	National parks, Natural monuments	Forests without yield	5	51
			Forests available for wood supply with restriction in regards of the cutting system	46	
	Total stocked (covered) area				902
	Temporary or permanent Unstocked parts of the forests	Unstocked due to – Forest management (e.g. forest roads, timber yards) – Natural reasons			182
	Total managed forest land				1084

According to the purpose or the services provided, forests are divided into productive (economic) forests, protective forests, forests with special purpose (forest gaming reservations, park forests, memorial forests, forests for seedling production, scientific forests, etc.) and forests within protected areas. Productive forests are areas where the primary function is wood production which are available for wood supply. Parts of the forest (stands) with protective function (mostly forest around water bodies) in the context of the management units are distinguished as separate management classes. The primary function of these forests is protection but they are also used for wood supply, in a restrictive manner. According to the forests census from 1979 the surface area of such forests amounted to 17,617 ha. Forests on the protected land is partly managed which is allowed according to the Nature Protection Act. These areas are divided into management zones. The parts of the forest which are in the zone of sustainable development with some restrictions are considered available for wood supply.

36.2.1.3 Classification by Ownership Categories

The forest ownership in the Republic of Macedonia is divided into three main categories: private, state and religious communities. State owned forests are mostly managed by the public enterprise *Makedonski shumi* and other state owned institutions (national parks, reservations, etc.). Private forests are small, with less than 30 ha per owner on average. There is no obligation for owners with less than 30 ha to prepare management plan, as they are managed by special criteria prepared by the Ministry of Agriculture, Forestry and Water Economy (MAFW). Large forests over 30 ha have to complete a forest management plan. The total number of private forest parcels is around 220,000 so that the average size of the parcels in Macedonia is 0.45 ha. (Trendafilov et al. 2008). The number of large private forests estate is relatively small. Over 90 % of the forests are state owned, and only about 10 % have other type of ownership (Table 36.3). The increase of the area of private forests is not a result of afforestation, but is a result of the process of restitution of forest properties that has occurred since 1998.

36.2.1.4 Forest Management and Cutting System

The forests in the Republic of Macedonia are managed under even-aged and uneven-aged silvicultural systems. According to the last forest inventory from 1979 (Dimitrov 1983), the total covered forest area amounted 906 thousand ha of which 745 thousand ha have been managed and 161 thousand ha non-managed forests or forests without management plans. The largest part of the managed forests are coppice forests, occupying 63.2 % (Table 36.4). The proportions of high forests within managed forests are 20.4 % for uneven-aged and 8.6 % for even-aged forests, respectively. The remaining 7.8 % are other categories of forests. Total coppice forests as managed and unmanaged occupies 61.6 % of the forest area. However when the area of "other categories of forests"is added, which are also of vegetative origin (9.4 %), the total cover of coppice forests raises to almost 71 % of the forest area. A separate category called "other" includes bushes, shrubs, maquis or pseudo-maquis and low productive forests. This other category has a total area of 85,000 ha.

According to the latest update of forest management plans (FMP's) in 2012 managed forests cover an area of 902,000 ha of which high forests (uneven-aged and even-aged) cover an area of 276,000 ha, coppice with standards an area of 3000 ha, coppice forests an area of 561,000 ha, artificial established stands up to age of 20 years an area of 8000 ha, and other categories of forest an area of 54,000 ha.

Table 36.3 Forest area according to ownership categories (Dimitrov 1983; State Statistical Office 2012)

Ownership category	Area (1000 ha)	
	NFI 1979	Statistics 2012
State forests	816.6	888.5
Private forests (including forests owned by religious communities)	89.0	100.3
Total forest area	905.6	988.8

Table 36.4 Forest management system according to the census from 1979 and Forest Management Plans, state 2012 (Dimitrov 1983; Ministry of Agriculture, Forestry and Water Economy 2012)

Management system	Census 1979				FMP's State 2012	
	Total forests		Managed forests			
	1000 ha	%	1000 ha	%	1000 ha	%
High forests	263	29.0	216	29.0	276	30.6
Even-aged	96	10.6	64	8.6	Not available	
Uneven-aged	167	18.4	152	20.4		
Coppice with standards	Not separated				3	0.3
Coppice forests	558	61.6	471	63.2	561	62.2
Artificial forests (up to 20 years)	Not separated				8	0.9
Other (shrubs, maquis, etc.)	85	9.4	58	7.8	54	6.0
Total	906	100	745	100	902	100

36.2.1.5 Legal and Other Restriction for Wood Use

Forests in the Republic of Macedonia have to be managed according to the Forestry Law and other Acts regulating in this area. They ensure the sustainable management of forests by specifying limits on rotation age in even-aged forests and on the diameters of trees to be cut in uneven-aged forests. Harvesting in pre-mature stands is restricted by prescriptions on the intensity of tending activities. The regulations also contain specifications for protective forests (land and water protection areas) and forests in protected areas, specifically with regard to sustainable forest management. The availability of wood resources is also restricted to forests with special purposes such as military training areas, research, forests in protected areas, etc. Certain restrictions are present from environmental policy initiatives such as the promotion of habitat preservation.

An important point regarding the availability of wood resources are the low productivity forests such as shrubs with an area of 54,000 ha. These forests have an extremely low growing stock of 12 m^3/ha on average, and largely remain unmanaged. Other restrictions on wood resource availability, particularly in winter, are the long distances from productive forests to customers. Steep slopes combined with a poor network of forest roads and other infrastructure also restrict wood resource availability.

36.2.1.6 Further Classification of Forests

Forests are also categorised by other variables, such as tree species composition. The dominant tree species in Macedonian forests are different oak species (*Quercus* spp.) with a share of 29.3 % of the total forest area, followed by the European beech (*Fagus sylvatica* L.) with a share of 23.2 %. Coniferous forests occupy 7.3 % of the forest area and the dominant coniferous species is black pine (*Pinus nigra* Arn.) with a share of 4.8 % of the total forest area and 65 % of coniferous forests. In this classification, degraded forest stands occupy 44,800 ha or 4.5 % of the forest area (Table 36.5). Degraded forests are characterised by their poor quality and lack of vitality, which is the result of adverse impacts, such as biotic, abiotic and anthropogenic factors. They are mainly natural mixed broadleaved stands.

In the 1979 inventory the structure of even-aged forests was detailed in 20 year age classes for high forests and 10 year age classes for coppice forests. In uneven-aged forests, the structure was shown in diameter classes 10–30 cm, 31–50 cm and above 51 cm, but for today's needs, these classes do not have a practical relevance.

36.2.2 Standing Stock Wood Resources and Their Use

Standing stock and increment is calculated as the above-ground over bark volume of trees with a dbh above the minimum threshold including stump, stem and branches with a minimum top diameter of 2 or 3 cm depending on the volume table. The management inventory does not provide the amount of biomass, nor is the volume of standing dead trees assessed. Therefore, the volumes given below refer to growing trees. The increment is calculated as a percentage of the volume as explained in Sect. 36.1.4. The volume of drain includes only the volume of living trees that are removed by logging. The amount of harvest, such as cutting inside and

Table 36.5 Forest area by species according to statistical review (State Statistical Office 2012)

Tree species	Area (1000 ha)	Area (%)
Broad-leaved species	574.6	58.1
Fagus sylvatica	229.7	23.2
Quercus spp.	290.0	29.3
Castanea sativa	2.7	0.3
Other hard broad-leaved species	48.7	4.9
Other soft broad-leaved species	3.5	0.4
Coniferous species	72.2	7.3
Picea abies	1.1	0.1
Abies alba	5.7	0.6
Pinus nigra	47.5	4.8
Pinus sylvestris	9.9	1.0
Pinus peuce	4.3	0.4
Other conifers	3.7	0.4
Mixed forests	297.2	30.1
Degraded forests	44.8	4.5
Total Forest Area	988.8	100

outside forests, cutting by state and private forests and the amount of illegal cutting, and the amount of harvest by assortment of state forests, are detailed in the statistical review *Forestry 2012* (State Statistical Office 2012).

According to the forest management plans, the total growing stock in the Republic of Macedonia in 2012 was 88.67 million m^3 and the annual increment 1.785 million m^3 (Table 36.6). The volume of trees cut in forests with different cutting system (clear cut—meaning cut on coppice forests, regeneration cut and selective cut) was 744,000 m^3, volume of harvested trees outside the forests 34,800 m^3 and the volume cut illegally was 26,000 m^3. Over the last decade, the

Table 36.6 The volume of standing stock and increment on forest (*Source* actual forest management plans state 2012) and the amount of cut timber volume (State Statistical Office 2012)

Tree Species	Standing (growing) stock	Increment (1000 m^3)	Harvested timber volume (1000 m^3)				
			In pure stands	In mixed stands	Outside forest	Illegal cut	Total
	Million m^3		Within forest				
Fagus sylvatica	51.65	841	353	29	35	26	805
Quercus petraea	12.29	283	289				
Quercus frainetto	4.88	121					
Quercus pubescens	2.85	76					
Carpinus orientalis	1.02	33	6				
Ostria carpinifolia	0.55	14					
Quercus coccifera	0.05	2					
Other broad-leaves	3.89	97					
Total broad-leaves	77.17	1467	648	29			
Pinus sylvestris	2.19	50	28	18			
Pinus nigra	5.75	182	13				
Abies alba	1.84	37	7				
Picea abies	0.03	1	+ [a]				
Pinus peuce	0.36	8	nd				
Other conifers	1.32	40	1				
Total-Conifers	11.49	318	49	18			
Total	88.67	1785	697	47	35	26	805

[a]Harvested symbolic amount (70 m^3)

volume cut illegally has drastically increased. In 2008, the volume cut illegally was estimated to be 7164 m^3. Assessment of the harvest volume from trees outside of forest and illegally cut is estimated from periodic reports to forest managers and forestry inspectors.

36.2.2.1 Tree Species and Their Commercial Use

European beech (*Fagus sylvatica* L.) is the most economically important species in the Republic of Macedonia. In 2012 European beech occupied 58 % of the total growing stock, 47 % of the total volume increment and 51 % of the annual yield (Table 36.6). Conifer species represent 13 % of the total growing stock, 18 % of the annual increment and 9 % of the annual yield. The large difference between growing stock and increment in the conifer forests, and the amount of harvested wood is due to the large amount of young forests which are the result of important afforestation during the 1970s and 1980s where black pine (*Pinus nigra*) was the most predominant species planted (Dimitrov 1992; Trajkov et al. 2006). Some species such as spruce (*Picea abies*) and Macedonian pine (*Pinus peuce*) have only symbolic significance. These species are taken into account here, because spruce is at the southern border of its natural extent and Macedonian pine is a relict species.

36.3 Assessment of Wood Resources

36.3.1 Forests Available for Wood Supply

Legal restrictions on wood supply are mostly directed towards assuring the sustainable management of forests in Macedonia. In the productive forests, those restrictions are directed towards environmental and soil protection. There is also an obligation to harvest less than the annual increment, to harvest mature stands and to ensure silvicultural activities enhance the conditions of young and pre-mature stands. In the protective forests as well as in the forests in the protected areas where sustainable management is accomplished, there are also legal restrictions on the choice of the silvicultural system, such as no clear cutting. In the core zone of the protected areas silvicultural operations are completely forbidden.

Other restrictions on wood supply concerns the availability of harvesting technology and forest accessibility. Technological restrictions evidently exist as old machinery are used in harvesting wood. Due to the lack of investment in machinery, chain saws are used for tree felling, while old adapted agricultural tractors and specialised forestry tractors from the 1980s are used for skidding. Horses are also still used for skidding. Old forest roads with acute bends and limited quality allow only the use of trucks that have low capacity.

Accessibility restrictions are due to the low road density of forests as well as terrain conditions, which involve steep slopes that restrict the use of heavy duty machinery. The average road density of Macedonian forests is 10.55 m per ha (Trajanov and Nestorovski 2008), even if forest roads and public roads that pass through the forests are included in the calculation. Skidding distances to the forest roads are too long and making this operation very expensive.

36.3.2 Assessment and Assortment of Wood Quality

The wood assortment classes, quality and dimensions are regulated by the Macedonian standard for wood (MKS), that include different classes for roundwood, sawnwood, firewood and waste. The assortments are based on minimum length and diameters of logs, as well as certain quality characteristics or faults. The roundwood is divided into sawn veneer logs, peeled-veneer logs, sawn logs and other combined logs, as well as industrial roundwood. Other categories are small roundwood, firewood, pulpwood, and wood for special purposes, (dictated by the customer) resonance wood or wood for xylography. Veneer logs are the most valuable assortment, with best quality and minimum of 2 m length and 30 cm diameter. Sawn logs are divided into three classes I (best quality), II and III (lowest quality). The quality specifications differ between conifers and broadleaved species. According to the 2012 forest statistical data, harvested timber volume in state's forest is 558,800 m^3 (Table 36.7). The difference from the total volume harvested of 744,000 m^3 is the result of harvested wood in the private forests which is about 10 % and for which there are no data about assortment and the waste that remains after filling in the forests.

Table 36.7 Assortment of cropped timber volume in state forests (State Statistical Office 2012)

Assortment of cropped timber	Volume (1000 m^3)	Volume (%)
Logs, coniferous (m^3)	35.9	6.4
Mining wood, coniferous	6	1.1
Other long coniferous wood	10.6	1.9
Stack coniferous wood	1	0.2
Fuel wood, coniferous	3.4	0.6
Logs, broad-leaved	64.9	11.6
Mining wood, broad-leaved	0.2	–
Other long broad-leaved wood	0.2	–
Stack broad-leaved wood	–	–
Fuel wood, broad-leaved	436	78.1
Other wood in the rough, including chopped wooden poles and stakes	0.6	0.1
Total wood in the rough	558.8	100.0

The assessment of wood quality and assortments is also done during the MI. Trees to be felled are also marked at this time. During the MI and for the formulation of management plans the wood volume is divided into four classes: technical wood, chemical processing wood, firewood, and waste wood after logging. The assessment carried out with assortment tables and through expert judgement. Assortments of standing wood are produced at the management unit level.

During the marking of trees for harvesting, stem quality is assessed using three quality classes:

- 1 Stem is upright, full-bodied, free of knots, continuously without faults from stump to top
- + Stem is upright, full-bodied, some knots, no continuity from stump to top, with a higher amount of faults
- 0 stem crooked, with knots, no round stem, no dimensions, and significant faults.

The assessment also includes other parameters related to stem quality (height of the living crown base, upper stem diameter and other variables). During the marking of trees for harvesting the following attributes are also assessed: dbh under bark, stem length, tree height and tree species.

36.3.3 Assessment of Change

As explained in previous sections, no large scale forest inventory has been made in the Republic of Macedonia since 1979. During the FMP revision, changes in forest area, growing stock and increment on Forest Management Unit level are analysed. Changes are calculated as the difference between two successive estimations of these variables. The Statistical Office annually presents forest area statistics, which are based on changes observed in approximately 10 % of forests assessed annually by the MI. The data are collected through regular statistical enquiries. Data on forest operations are collected throughout the year based on accounting records. Questionnaires are completed by PE "*Makedonski śumi*" (Macedonian forests) or its branches, as well as the head of the national parks and other entities which manage forests. The estimation of change at a particular spatial level or about all forests in the country, are made by comparing information from statistical reviews for some years or by summarising data from management plans in a particular region.

Information presented in the annual SYb are mainly systematic data about: the forest operations performed to harvest timber, the value of services performed in forestry, afforestation, reforestation, care and amelioration, energy consumption in forestry, mechanisation, road infrastructure, forest damage, forest area, game population and the number of game shot. Due to a lack of data on growing stock and increment in the statistics, data from management plans is used to assess change.

36.3.4 Other Wooded Land and Trees Outside Forests

Information about other wooded land and trees outside the forest such as groups of trees on areas smaller than 200 m^2, boundary trees around the agricultural land, protective belts, parks, etc., are currently not available. A particular problem is the cutting of boundary trees around agricultural land for which a definition is missing. The only source of information about these boundary trees in the category of trees outside forests is produced by Statistics based on the reports issued by the PE Macedonian Forests as they also issue approvals for cutting trees in these areas.

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Chapter 37
Romania

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37.1 The Romanian National Forest Inventory

37.1.1 History and Objectives

Forest inventory in Romania started in 1959 by aggregating management planning information from forest districts assessed during the period 1948–1958 for all Romanian forest fund land. Forest fund land comprises land which is classified as forest in the national management planning books and maps. The aim was to assess Romanian wood resources, particularly for the development of forest industry at the end of 1950s. Subsequently, the national inventories of forest fund were periodically completed in 1965, 1973, 1980 and 1984 based on information from forest management plans, according to the tradition in Eastern-European countries prior to 1990.

In 2006 the National Forest Inventory (NFI) was initiated covering all of Romania's forests, which included the forest fund and also forests outside the forest fund. After a pilot study in 2007, the first sample-based NFI cycle was conducted in the period 2008–2012. The NFI design was adapted to the size and the landscape

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conditions of Romania and to the new forest reporting requirements associated with climate change, biodiversity, protective functions of forest, etc.

The main objective of the Romanian NFI is to provide accurate national and regional forest statistics on the current state of forests. The NFI information is used to guide national forest policy, which is used to formulate laws and national forest programmes. The NFI also aims to provide essential information for LULUCF reporting for UNFCCC, Kyoto protocol, Forest Resources Assessment conducted by FAO and for FOREST EUROPE reporting. Information on forest biodiversity is also collated. The NFI assesses the forest land according to national definitions, but also according to FAO definitions for forest, other wooded land and trees outside forest.

37.1.2 Sampling Methods and Periodicity

According to the forest law, the Romanian NFI is a continuous forest inventory, and the inventory cycle is five years. The sampling was designed as a two-phase system, where the first phase consisted of the interpretation of aerial photographs while the second phase was based on field measurements. The field plots cover the entire country territory based on a 4 × 4 km systematic grid (Marin et al. 2010). The grid density is doubled in lowlands (2 × 2 km) due to low forest cover. There are 31,202 clusters used in the NFI, consisting of 124,804 sample plots. The NFI field measurements are recorded on sample plots arranged in quadratic clusters with 250 m between each plot. During the first NFI cycle more than 8700 forest clusters and over 28,000 sample plots were visited in the field.

The NFI sample plot consists of three concentric circular plots of 7.98, 12.62 and 25 m radius, respectively. The sample trees with a dbh of between 56 and 285 mm, lying deadwood and ground vegetation are measured in the plot of 7.98 m radius, and the sample trees with dbh > 285 mm are measured on the plot of 12.62 m radius. The assessment of forest site, forest type, soil characteristics and tree cores occurs in the 25 m radius plot.

Trees with a dbh of less than 56 mm are recorded in three classes, by counting the stems in two concentric circular plots. For small trees, 10–50 cm in height, measurements are recorded on a circular plots of 1.0 m radius. Small trees over 50 cm height and under 56 mm dbh are assessed on a 1.78 m radius plot. Both plots are located at 10 m east and 10 m west of the sample plot centre.

When forest plots of 12.62 m radius (500 m^2) are covered by different forest stands, forest ownership, land use, etc. they are divided into sub-plots and described separately. The minimum area of a sub-plot is 100 m^2.

37.1.3 Data Collection

The NFI collects data related to sample trees, forest stands, forest sites, forest regeneration, forest management, forest edges, forest accessibility, etc. The instructions for NFI field data collection contain detailed information on data collected, measurements and assessments performed by the Romanian NFI.

The main variables measured or assessed on the sample standing trees are:

- Species
- Diameter at breast height
- Tree height
- Height to the living crown base
- Height to the dead crown base
- Length of broken stem
- Living/Dead standing tree
- Type of tree regeneration
- Social position
- Stem quality
- Tree defects
- Tree damages
- Tree biodiversity (nesting tree, degree of decomposition of standing dead tree, place of food).

The forest stand data collected aim to describe the forest stand in which the sample plot (subplot) is located. They include:

- Forest stand management regime
- Forest stand age
- Forest stand layers
- Forest stand structure
- Canopy closure
- Number of species and dominant species
- Forest stand development stage
- Forest stand regeneration
- Shrubs and ground vegetation

For describing the forest site conditions, the main variables assessed are

- Relief (lowland, hills and mountains)
- Elevation
- Slope
- Exposition
- Soil (type, humus, moisture, layer thickness etc.)
- Soil erosion, landslides
- Forest type (natural)
- Forest site type.

37.1.4 Data Processing, Reporting and Use of Results

37.1.4.1 Tree-Level Estimations of the Volume

The tree-level data processing involves limited modelling since the total tree height is being measured in the field for all the trees. Hence, the dbh and height are both available for the estimation of volume. For standing dead trees, the models applied are the same as for living trees but the volume of the branches is removed.

For broken trees, the volume is computed based on the probable height before breakage, then reduced proportionally to the difference between the current height and the height before breakage. The height before breakage is obtained by imputation from the nearest tree (of the same species) in the plot having the closest diameter. The volume function from Giurgiu et al. (2004) is implemented in two steps:

$$\log Volume = a_0 + a_1 \cdot \log_{10} dbh + a \cdot \log_{10}^2 dbh + a_3 \cdot \log_{10} h + a_4 \cdot \log_{10}^2 h \tag{37.1}$$

$$Volume = 10^{\log Volume}, \tag{37.2}$$

where *dbh* is in cm, and h is the height in m and a_i are species-specific coefficients (for 43 tree species).

Unfortunately, log-corrections factors for these log-log equations were not developed and no error assessment is possible.

For conifers, the volume refers only to the stem (from ground to top), and needs to be expanded to the entire above-ground component using species-specific coefficients, provided by the same authors.

37.1.4.2 Stratum-Wise Estimation

Tree-level data are aggregated to plot level using the specific tree weight. Plots are assigned to a stratum: typically 18 strata are distinguished. They represent the intersection of three primary strata:

1. Relief
   Three relief zones are used: lowland, hill and mountains. These classes are used to vary the grid density, which in the lowlands is twice as high as that of hill and mountain. This stratification also satisfies the need to produce reports per relief zones. Furthermore, it has the great advantage to divide the plot population according to the probable vegetation types (i.e. lowland tree species are very seldom encountered in mountains).

2. Regions
   Bearing in mind the need to report at a regional scale, the second stratification is also geographic and GIS based, consisting of three main regions that divide the country in roughly equal parts.
3. Forest cover
   Conversely, the last stratification is a post-stratification, based on the photo-interpretation, whereby the clusters are classified in two categories according to the presence/absence of forest vegetation on the images.

These predefined strata are GIS based and hence their area is known without sampling error. This leads to 18 strata: 3 regions × 3 relief zones × 2 photo-interpretation strata. The country-level estimates therefore result from summing the values and the variance obtained at stratum level.

37.1.4.3 Area Estimation

The estimators used for the estimation of the area were developed specifically to cope with the sampling design implemented: a two-phase sampling where the second phase is based on both clustered and mapped plots. Clusters have a constant size, $N = 4$ subplots, with some rare exceptions of plots that straddle country's borders. Subplots are mapped and can be divided into sectors to reflect differences in conditions.

The estimation of the area covered by a given condition k at country level is the sum of the area covered by the condition in each stratum s:

$$A_k = \sum_s A_{s,k} = \sum_s A_s \cdot \hat{\bar{a}}_{s,k} \tag{37.3}$$

where A_s is the area of the stratum s, defined by the first phase (s in [1, 18]), and $\hat{\bar{a}}_{s,k}$ is the mean cluster-level area covered by the condition k defined as:

$$\hat{\bar{a}}_{s,k} = \frac{\sum_i^{N_i} \bar{a}_{s,k,i}}{N_i} \tag{37.4}$$

where $\hat{\bar{a}}_{s,k,i}$ is the mean proportion occupied by the condition k in cluster i, estimated on the field. N_i is the number of clusters in stratum s. Indeed, clusters are considered as the primary sampling unit.

As described in the previous section, the strata are defined after photo-interpretation as the intersection of 18 predefined strata (3 regions × 3 relief zones × 2 photo-interpretation post-stratification strata). These predefined strata are GIS-based and hence their area is known without sampling error. Therefore, the area of a given stratum, A_s, is defined as:

$$A_s = A_{predifined-strata} \times \widehat{p}_s \tag{37.5}$$

where $A_{predifined-strata}$ is the GIS-based area of the predefined stratum, and $\widehat{p}_s$ is the proportion of photo points (i.e. phase 1 points) falling in the category s for this stratum, which is a binary indicator of the presence (s = 1) or not (s = 0) of forest vegetation.

37.1.4.4 Volume Estimation

The estimation of volume follows the same principle as the area estimation, except that the cluster-level mean is not a proportion covered by a category but the mean volume estimated for a given category k. Thus, the cluster-level mean volume (cluster i in stratum s) is defined as the mean of the volume observed in category k on the N_j subplots:

$$\widehat{\bar{v}}_{s,k,i} = \frac{\sum_j^{N_j} \bar{v}_{s,k,i,j}}{N_j} \tag{37.6}$$

where N_j = 4 except for rare situations. Thus, $\bar{v}_{s,k,i,j}$ is set to 0 where no tally trees contributed to the category k.

The total volume at country or regional level of category k (V_k) is the sum of the volume at stratum level, estimated as:

$$V_k = \sum_s V_{s,k} = \sum_s A_s \cdot \widehat{\bar{v}}_{s,k} \tag{37.7}$$

$$\widehat{\bar{v}}_{s,k} = \frac{\sum_i^{N_i} \hat{\bar{v}}_{s,k,i}}{N_i} \tag{37.8}$$

for the N_i clusters in stratum s (s in [1, 18]), where $\widehat{\bar{v}}_{s,k}$ is the mean volume over the clusters in stratum s and condition k, and $\widehat{\bar{v}}_{s,k,i}$ is the mean volume in condition k for each cluster i in stratum s, as defined above. The stratum area, A_s, is defined in the previous section.

This estimator is very versatile, since it can be used to compute areas or volumes, and can be used with no change to compute any other statistic: the total number of trees, the basal area, the biomass, etc. The only changes are the cluster-mean values which should reflect the total number of trees, or the sum of basal area, etc. Thus, it offers the possibility to answer a great variety of demands without the need to define new estimators.

37.1.4.5 Estimation of Ratios

Many estimations necessary for the inventory are a ratio of two measurements, for instance, the volume per ha, any proportion of species or another given category. The estimation in this situation is based on the computation of a ratio of means.

The estimations are made by default at stratum level. The mean for several strata is a weighted mean, the weight being the relative area covered by each stratum. For instance, the volume per hectare of a category k (e.g. for *Fagus sylvatica*) in one given stratum s, is estimated as:

$$\frac{V_{s,k}}{A_{s,k}} = \frac{A_s \times \hat{\bar{v}}_{s,k}}{A_s \times \hat{\bar{a}}_{s,k}} = \frac{\hat{\bar{v}}_{s,k}}{\hat{\bar{a}}_{s,k}} \quad (37.9)$$

where A_s is the stratum area, $A_{s,k}$ and $V_{s,k}$ are the total area and volume for the category k in stratum s, $\hat{\bar{a}}_{s,k}$ and $\hat{\bar{v}}_{s,k}$ are the mean area and the mean volume represented by the condition k in stratum s, estimated according to the formulas presented in Sects. 37.1.4.3 and 37.1.4.4 respectively.

For multiple strata, the ratio (Rk) representing the mean volume over the strata is estimated by:

$$R_k = \frac{\sum_s A_s \times \hat{\bar{v}}_{s,k}}{\sum_s A_s \times \hat{\bar{a}}_{s,k}}, \quad (37.10)$$

where A_s, $\hat{\bar{a}}_{s,k}$ and $\hat{\bar{v}}_{s,k}$ are defined as above.

The variance of the estimation is simply the sum of the variance on each stratum, since the strata display no overlap by definition.

37.2 Land Use and Forest Resources

37.2.1 Classification of Land and Forests

37.2.1.1 General Land Classification

The Romanian NFI uses the land classification according to five Cadastre and Real Estate Law categories (agricultural land, forest land, lands under waters and ponds, intra-urban lands and lands of special destination). The NFI assess forest resources on all categories, if at least one sample plot of a NFI cluster is located in forest.

Since there are some differences between national and FAO definition of forest (FAO 2004), the Romanian NFI uses both definitions in order to be able to answer to national and international requirements on forest resources.

According to national definitions, the forest categories are: national forest fund (NFF) and forest outside the national forest fund (FVONFF). The FVONFF comprises all the land covered with forest vegetation outside the NFF. Romanian Forest Law (2008) defines the forest as a land of minimum 2500 m^2 covered with trees able to reach a minimum of 5 m height at maturity in normal vegetation conditions. The Romanian NFI uses the FAO forest categories as forest, other wooded land (OWL) and trees outside forest (TOF).

The areas of national land classification categories and the corresponding FAO Forest resources assessment categories are presented in Table 37.1. According to the national definition, agricultural land contains some areas that belong to forest, OWL and TOF as defined by the FAO (2004); TOF are located also on land under water and lakes and Intra-urban land classes.

37.2.1.2 Forest Classification by Use

Forests are classified by management system and forest function. According to management system, forests are classified in two classes: high forest and coppice forest. More than 95 % of forests are managed on the high forest system. Forests have productive and/or protective functions (Table 37.2). Productive forest contains all forest areas available for wood supply, with no restrictions in applying specific forest treatments. Protective forests have mainly protective functions, as water or soil protection, but some of them are used for wood supply with restriction on applying specific treatments. Information like growing stock and increment are

Table 37.1 Land use classes according to the national definition with area estimates of the first NFI (2008–2012) and correspondence with FRA categories

Land use Class	Description	Area (1000 ha)	Corresponding FRA categories FAO (2004)
Forest land	Productive, protective and protected forests, permanently unstock parts of the forest lands	7013	Forest, OWL, OL
Agricultural land	Croplands, vineyards, orchards, pasture, hayfields, permanently unstock agricultural lands	14,911	OL, Forest, OWL, TOF,
Land under waters and lakes	Rivers, lakes, ponds	834	OL, TOF
Intra-urban land	Inner perimeter area of urban and rural lands	594	OL, TOF
Land of special destination	Inaccessible and unproductive non-forest land	487	OL
Total land area		23,839	

Table 37.2 Classes within forest land and their areas according to first NFI (2008–2012)

<table>
<tr><th colspan="2">Class name</th><th>Description</th><th>Area (1000 ha)</th></tr>
<tr><td rowspan="4">Forest land</td><td>Productive forest</td><td>Forests available for wood supply (includes protective forests available for wood supply)</td><td>4627</td></tr>
<tr><td>Protective forest</td><td>Forests with protective function, where there are legal or economical restrictions on wood supply</td><td>2234</td></tr>
<tr><td colspan="2">Permanent unstocked parts of the forest</td><td>152</td></tr>
<tr><td colspan="2">Total forest land area</td><td>7013</td></tr>
</table>

calculated for all the mentioned categories. Permanently unstocked parts of the forest belong to both productive and protective forest areas.

37.2.1.3 Classification by Ownership Categories

Romanian Forest Law (2008) specifies four main ownership categories: state public forest, municipality public forest, private forest (individuals, forest owners associations and legal entities) and municipality private forest. From the total forest area, 50 % are public state forest managed by National Forest Administration Company (Romsilva), 33 % are private forests, 16 % are public municipality forests and 1 % are private municipality forests. It is worth noting that the medium size of forest ownership area for more than 82 % of private forest owners is less than 3 ha, which is a serious issue in the management of the forest.

37.2.1.4 Forest Management and Cutting Systems

In Romania, a forest management planning system has been implemented for the entire forestry fund since 1948. Therefore all forest fund area is managed in accordance with management planning stipulations. Depending on tree species characteristics, forest stand composition and structure, forests are managed in even-aged, relative even-aged (the differences of tree ages in a forest stand are more than an age class), relative uneven-aged (the differences of tree ages in a forest stand are more than two age classes) and uneven-aged management systems. According to NFI estimates, 15 % of forests are managed in even-aged system (mainly Norway spruce (*Picea abies*) plantations, black locust (*Robinia pseudacacia*) and hybrid poplars (*Populus* spp.), 61 % in relative even-aged system, 19 % in relative uneven-aged system and 5 % in uneven-aged management system.

The cutting system is closely related to the management system. Clear cuts are allowed only in even-aged forests, seldom in relative even-aged stands, and on a maximum area of 3 ha. The clear field area must be regenerated within 2 years after cutting. The uniform shelterwood felling and group shelterwood felling are applied mainly in relatively even-aged stands. There are some restrictions on the maximum area on which these silvicultural treatments can be applied, and after the final cut, the natural regeneration must cover at least 70 % of the area. The group selection felling is applied in relatively uneven-aged stands, and selection felling by individual tree is applied in uneven-aged stands.

37.2.1.5 Legal and Other Restrictions for Wood Use

Forests in Romania are managed in accordance with the Romanian Forest Law (2008) and the Technical Norms for forestry elaborated by the Ministry responsible for forests. They ensure that forests are managed in accordance with the principles of sustainable forest management and contain specifications related to protected forest area (natural forest reserves, forests with special natural habitats, etc.) and forests with protective functions (soil, water, infrastructure, recreation, etc.). The protected forest areas are considered not available for wood supply, because of the legal restrictions for wood harvest which in many situations completely forbid the harvest of wood. In forests with protection functions, there are some restrictions for timber harvesting (forest on steep slope, forest around the drinking water sources, etc.) or for the type of silvicultural treatment to be applied.

An important restriction for timber use in Romania is forest accessibility, particularly in the mountainous region. The density of the forest road network is very low (about 6 m per ha) and the forest roads are not in good condition for timber transportation. Long logging distances make it economically inefficient to harvest wood. In forests situated on steep slopes, harvesting has the potential to cause damage to soil and is also associated with an increase in the hauling costs of wood. On these steep sites, cable crane logging is necessary, but this technology is more expensive than conventional harvest method.

37.2.1.6 Further Classification of Forests

The forest area is usually further stratified by tree species and age classes. The main tree species in Romanian forests are European beech (*Fagus sylvatica*), followed by Norway spruce (*Picea abies*) and *Quercus* spp. (Table 37.3).

The forest structure by age-classes is assessed in intervals of 20 years for high forest, 10 years for coppice forest (black locust) and 5 years for poplar and willow forest (Table 37.4). The NFI estimates tree age using cores or other auxiliary information such as management plans. In Table 37.4 the forest area by 20 year age-classes is presented, including coppice poplar and willow forest.

Table 37.3 Forest area by tree species (first NFI 2008–2012)

Tree species	Area (1000 ha)	Area (%)
European beech (*Fagus sylvatica*)	2111	31
Norway spruce (*Picea abies*)	1356	20
Sessile oak (*Quercus petraea*)	585	9
Oak spp. (*Q. robur, Q. cerris, Q. frainetto, Q. pedunculiflora, Q. pubescens*)	540	8
Hornbeam (*Carpinus betulus*)	476	7
Silver fir (*Abies alba*)	290	4
Black locust (*Robinia pseudacacia*)	257	4
Lime spp. (*Tilia tomentosa, Tilia cordata, Tilia platyphillos*)	184	3
Acer spp. (*Acer platanoides, Acer pseudoplatanus, Acer campestre*)	161	2
Poplar spp. (*Populus nigra, Populus alba*)	160	2
Fraxinus spp. (*Fraxinus excelsior, Fraxinus angustifolia, Fraxinus ornus*)	133	2
Other conifers	112	1
Other broadleaved hardwood	409	6
Other broadleaved softwood	87	1
Total forest area	6861	100

Table 37.4 Forest area by age-classes (first NFI 2008–2012)

Age class (years)	Area (1000 ha)	Area (%)
1–20	580	9
21–40	1290	19
41–60	1245	18
61–80	1320	19
81–100	1041	15
101–120	636	9
121–140	274	4
>140	192	3
Uneven-aged	283	4
Total forest area	6861	100

37.2.2 Wood Resources and Their Use

37.2.2.1 Growing Stock, Increment and Drain

The growing stock is estimated using the dbh and height measurements of sample trees as stem volume over-bark of all living trees (Table 37.5). Stem volume includes all overbark stem parts from the stump to top. The minimum dbh threshold

Table 37.5 The forest growing stock, increment (first NFI 2008–2012) and drain (official statistics 2012)

Tree species	Growing stock (million m^3)	Increment (1000 m^3/year)	Drain (1000 m^3/year)
European beech (*Fagus sylvatica*)	740.8	21,642	6390
Sessile oak (*Quercus petraea)*	151.0	4313	1690
Oak spp. (*Q. robur, Q. cerris, Q. frainetto, Q. pedunculiflora, Q. pubescens*)	131.6	3684	
Hornbeam *(Carpinus betulus)*	96.3	3071	–
Black locust *(Robinia pseudacacia)*	23.0	1055	–
Lime spp. (*Tilia tomentosa, Tilia cordata, Tilia platyphillos*)	54.6	1524	–
Acer spp. (*Acer platanoides, Acer pseudoplatanus, Acer campestre*)	36.6	1062	–
Poplar spp. (*Populus nigra, Populus alba*)	32.1	1478	–
Fraxinus spp. (*Fraxinus excelsior, Fraxinus angustifolia, Fraxinus ornus*)	25.6	829	–
Norway spruce (*Picea abies*)	454.6	13,501	7740
Silver fir *(Abies alba)*	132.9	3857	
Other conifers	14.9	837	
Other broadleaved hardwood	27.2	1959	2020
Other broadleaved softwood	9.1	564	1440
Total	1930.3	59,376	19,280

for sample tree measurements in the Romanian NFI is 56 mm over-bark. The volume of standing dead trees is also estimated.

To estimate the increment of the forest estate, tree sample cores were collected and analysed. The official statistics reports about 19.3 million m^3 per year of drain. In the future, the drain will be estimated based on the comparison with the outcomes of the second NFI cycle.

37.2.2.2 Tree Species and Their Commercial Use

Norway spruce, European beech and Oak are the most important tree species in Romania. According to the Forest Statistics provided by the Ministry of Environment and Forest, of the total timber harvested in 2011, Norway spruce accounted for 40 %, beech 33 % and oak 9 %. They are mainly used for industrial round wood and sawn wood production. The very high quality Norway spruce timber is used as resonance timber for musical instruments and the very valuable oak, cherry or beech timber is used for veneer. A large amount of timber is used as fuel wood as more than 45 % of the population live in rural area.

37.3 Assessment of Wood Resources

37.3.1 Forest Available for Wood Supply

37.3.1.1 Assessment of Restrictions

In the first phase of the NFI all sample plots of the sampling grid are assessed using aerial photographs. In the NFI second phase all sample plots assessed as being in the forest are visited in the field. When a sample plot is inaccessible, this information is registered in the field computer.

The restrictions related to wood harvest refers to forest with protective functions, mainly for soil and water, and protected forest areas. Forests situated on steep slopes (>35°) or natural forest reserves, for example, are considered not available for wood supply.

The distance to the nearest forest road is another factor for assessing if a forest is available for wood supply or not. In field assessments, according to the national rules, only sample plots located less than 1.2 km from the nearest forest road are considered available for wood supply.

37.3.1.2 Estimation

Until now, estimates of the forest available for wood supply were based on the management planning information. All the legal restrictions of wood harvest not allowed or severely restricted were taken into consideration. According to forest management plan estimates, more than 4.6 million ha of forest are considered available for wood supply. The second NFI cycle will assess the forest available for wood supply, as NFI sample plots can be classified to provide information on availability for wood supply, i.e. forests with no restrictions for wood supply, forests where wood harvest is partly restricted, and forests where cuttings are not allowed.

37.3.2 Wood Quality

37.3.2.1 Stem Quality and Assortments

Tree stem quality is assessed in the NFI by four quality classes (I, II, III and IV) according to the proportion of the wood volume able to be used as industrial wood from the total volume of a tree (Table 37.6). For example, the first quality class represents healthy trees with straight boles, no defects and no damage.

For the assessment of assortments, the total industrial wood volume is divided into percentages of different dimensional wood assortments using specific tables

Table 37.6 Tree quality classes

Group species	Quality class	Proportion of total tree height suitable for industrial wood
Conifer	I	More than 0.60
	II	0.40–0.60
	III	0.10–0.40
	IV	Less than 0.1
Broadleaved	I	More than 0.50
	II	0.25–0.50
	III	0.10–0.25
	IV	Less than 0.10

elaborated for 46 tree species. Classification of the dimensional wood assortments is made according to the top diameter of the log. There are three dimensional wood assortment classes: large dimension wood class (with three sub-classes), medium dimension wood class (with two sub-classes) and small dimension wood (pulp wood and fuel wood).

37.3.2.2 Assessment and Measurement

The assessment of stem quality is made for all NFI sample trees. Quality is assessed visually in relation to defects or damage and is registered the one of the four quality classes. A conifer tree, for example, is registered in first quality class (I) if the ratio between the tree stem height suitable for industrial wood and the total height of the tree is more than 0.60. For a broadleaved tree, the ratio must be more than 0.50. For a fourth quality class (IV) tree, the ratio must be less than 0.10 for both conifer and broadleaved trees.

There are several additional tree parameters that are assessed in the field for stem quality assessment, including the tree status (dead or living), information whether a tree is forked or broken, stem damage, the height of the living and dead crown base, etc.

37.3.2.3 Estimation and Models

In Romania, there are models of dimensional assortments for 46 tree species and industrial assortments for the most valuable six tree species (Giurgiu et al. 2004). The models require information on tree species, tree quality class and dbh. In the case of valuable tree species, there are specific models to estimate the timber that could be used for veneer, resonance wood, etc. but only for very large trees. A spruce tree, for example, contain resonance wood assortment only if dbh is larger than 40 cm.

37.3.3 *Assessment of Change*

37.3.3.1 Assessment and Measurement

Since the Romanian NFI has completed only its first cycle, no inventory comparison is available for the estimation of the increment and drain. However, increment cores were taken on all forest plots during the first NFI cycle in order to assess volume increment.

The cores were taken outside of the largest inventory circle in order to limit the potential damage to trees within the plot that will be re-measured periodically. The trees were sampled among the co-dominant and dominant layer, with a diameter larger or equal to the plot-average diameter. The number of trees sampled varied according to the species diversity: four trees in pure stands, three per species for stands dominated by two species, two cores per species otherwise.

37.3.3.2 Estimation of Increment

The diameter increment of the core sample trees was used to estimate the diameter increment of all trees in the plot. The historical diameter was estimated by multiplying the over-bark current diameter of the tree by the plot-level average diameter increment rate. The measurements enable the estimation of the increment in the last 5 years but could be extended to 10 years. The outer most ring from the year of coring was discarded if coring occurred prior to November, in order to keep in the analysis only fully grown rings. If they were too few usable collected cores on a plot (less than 6) to produce a reliable diameter increment rate estimation, the rate was inferred from the average value estimated based on the region, relief and species combination.

37.3.3.3 Estimation of Drain

Annual statistics on the wood harvest in Romanian forest are provided by the Ministry responsible for forestry. The drain was not estimated in the first NFI cycle, but it will be estimated at the end of the second NFI cycle, based on the volume of the sample trees measured in the first cycle, but harvested at the second field assessment.

37.3.4 *Other Wooded Land and Trees Outside Forests*

37.3.4.1 Assessment and Measurement

The Romanian NFI uses both national and FAO forest definitions, so it is possible to produce estimates on area, volume and increment of other wooded land and trees outside forest. The other wooded land is assessed in all sample plots photo-interpreted in first phase as belonging to this category and the field measurements are the same as in forest. Trees outside of the forest are assessed on all sample plots belonging to a NFI forest cluster, where at least one sample plot is located in forest or other wooded land. There are fewer measurements than in the two forest categories, as there is no assessment of forest stand, forest management, soil, etc.

37.3.4.2 Estimation

The estimation of area, volume, increment and other indicators of other wooded land follow the same methodology as in the forest category. The NFI provide the most important estimates for trees outside forest category (area, volume, increment etc.) but not all estimates as for forest and other wooded land categories.

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Chapter 38
Russian Federation

Oleg N. Solontsov, Alexander A. Martinuk and Alexander V. Bukas

38.1 National Forest Inventory of the Russian Federation

38.1.1 History and Objectives

The National Forest Inventory (NFI) is conducted on the basis of article 90 of the Russian Federation forest code and in accordance with the national program of forest development for the years 2013–2020 (Resolution of the Government of the Russian Federation 2014).

The NFI is a new instrument for the assessment of the sustainability of forest management, which has not been used previously on the territory of the Russian Federation. The preparation work for the NFI began in 2007 with the adoption of a new forestry code (Anon 2014; Order Rosleshoza 2011a, b), which set a significant new strategy for the management of forests and for the provision of forest ecosystem services. The national forest inventory meets accepted international standards for sampling based large-area forest inventories, employing similar techniques to many other countries.

The NFI is a sophisticated instrument for forest resources assessment which uses various data sources and methods to provide the required information. Currently, the main activities are carried out within the NFI are: the evaluation of the

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quantitative and qualitative characteristics of the Russian forest, the assessment of forest measurement activities in the field, remote monitoring of forest management activities and the compilation of output tables and reports at regional level. The regional reporting units are the constitutional entities, federal states.

The main focus is on the assessment of the current state of forests expressed by a variety of quantitative and qualitative characteristics, and the establishment of a network of permanent sampling units (plots) allowing inference through the methods of mathematical statistics.

Information about the forest land of Russia is available from forest management planning inventories, which have been carried out periodically in the past. At the time of the NFI introduction, a terrestrial stand-level forest inventory was already operational for 42 % of the state's forests, which was reduced during the past 40–50 years. Other different methods of forest assessment were implemented in a further 57 % of the forest land. For the remaining 1 % of the forest land, remote sensing technology was applied. Due to this non-standardised approach nationally, it was considered best to establish a statistical sampling approach to assess the quantitative and qualitative attributes using harmonised definitions. This was considered the most effective way to achieve the main goals of the NFI formulated in the forest code, for large regions and the entire territory of the country, namely to:

- detect, in a timely manner, and predict the development trends of processes which have adverse impact on forests
- evaluate the forest protection and renewal activities
- provide information on the management in the area of forest use, protection, renewal and state forest inspection and oversight.

NFI information will be used by the federal state authorities and by the wider forestry and related sectors, regional authorities and administrations, and by local authorities and administrations responsible for forest management and ecology. The scientific NFI results are also made available for non-governmental organisations and the public.

38.1.2 Sampling Methods and Periodicity

The size of the National Forest Inventory is substantial. In the period between the years 2007 and 2014, a network of 41,700 permanent plots were established in the forest covering a total land area of 273.4 million ha, which covers 30 constituent entities of the Russian Federation (Fig. 38.1).

The NFI is carried out in all forests of the Russian Federation, and in all federal states. Ground-based sampling, coupled with aerial and satellite techniques were used. The federal state body mandated for the implementation of the NFI is the

Fig. 38.1 The constituent entities of the Russian Federation with the time schedule for NFI permanent plots establishment. *Light green* sampling planned for the year 2015; *dark green* terrestrial NFI plot sampling completed 2011–2013; *orange* terrestrial NFI plot sampling completed in 2014

Federal Agency of Forestry, which in turn acts through its territorial bodies and subordinated organisations.

The NFI work is conducted in accordance with the methodology approved by the Federal Agency. These regulations are generally sufficient to carry out the complex NFI work. However, from the experience gained so far, some improvements of methodology are required. This work will be carried out by leading scientific organisations and forestry specialists.

The assessment of quantitative and qualitative characteristics is a fairly complicated process, which can be divided into six stages:

- a basic digital map of forest land is created based on existing topographic maps and forest management plans
- the digital maps are updated with data from forest registers and earth observation satellites, for effects of anthropogenic and natural disturbances in forests
- the digital maps are the basis for a stratified random selection of NFI plot locations (coordinates)
- terrestrial (ground-based) plot measurements and assessments
- updated forest maps are used to estimate strata areas
- estimation of quantitative and qualitative characteristics of forests, combining strata and plot data.

The stratified selection of terrestrial NFI plots starts from existing digital forest maps and attributes from stand-wise databases. The data sources for the maps are the state's registers of forests and satellite images with a spatial resolution of at least 5 m. The aim is to identify forest sites with similar characteristics, and ultimately to minimise the sample size and the optimisation of the allocation of permanent sample plots to the strata. The criteria for strata building are dominant species aggregated into species groups, land-use category, site class groups and age class groups. In total, 49 different strata types exist. Permanent plots are selected at random within strata aiming at a uniform distribution of sampling plots on operation units (Fig. 38.2).

The permanent plots of the NFI consist of three concentric circular plots for tree measurements. Two smaller circles for assessment of forest regeneration (trees <6 cm of dbh) and strip for assessment of the ground vegetation cover. A soil sample is taken close to the plot boundary (i.e. out of the plot). A diagram of the permanent plot layout of the NFI is shown in Fig. 38.3, and a summary of measurements in Table 38.1.

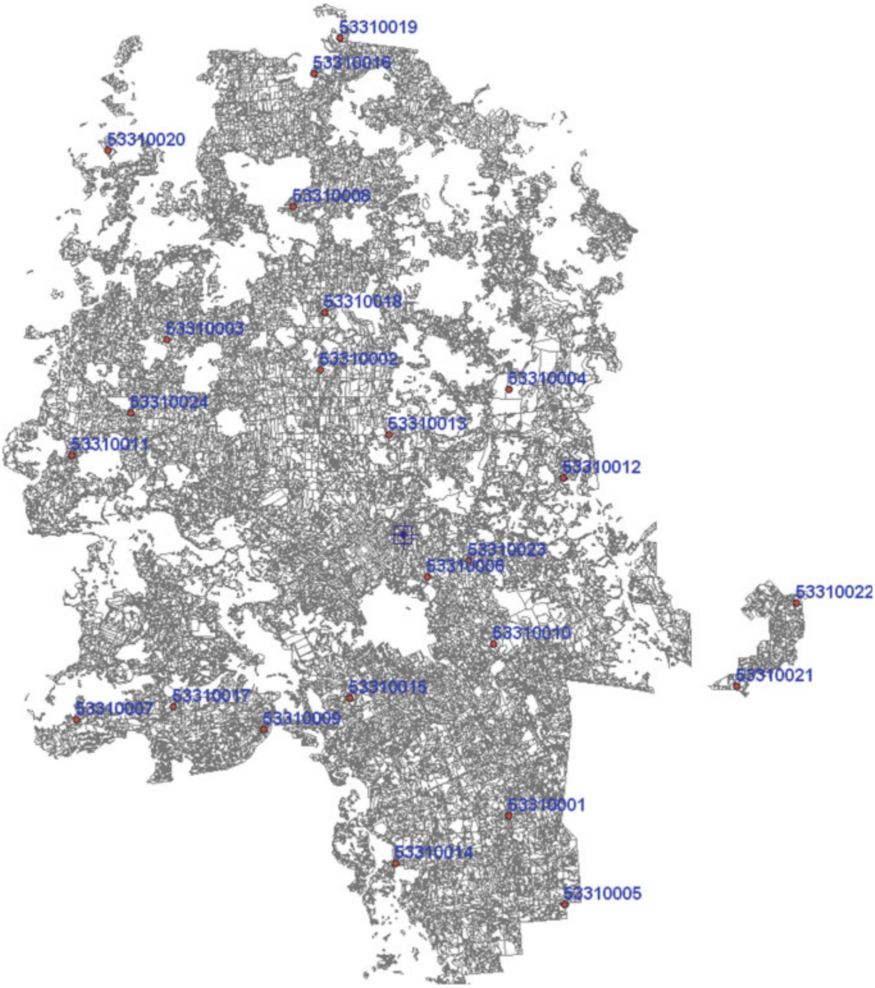

Fig. 38.2 Example of the placement of the permanent plots within an operational unit

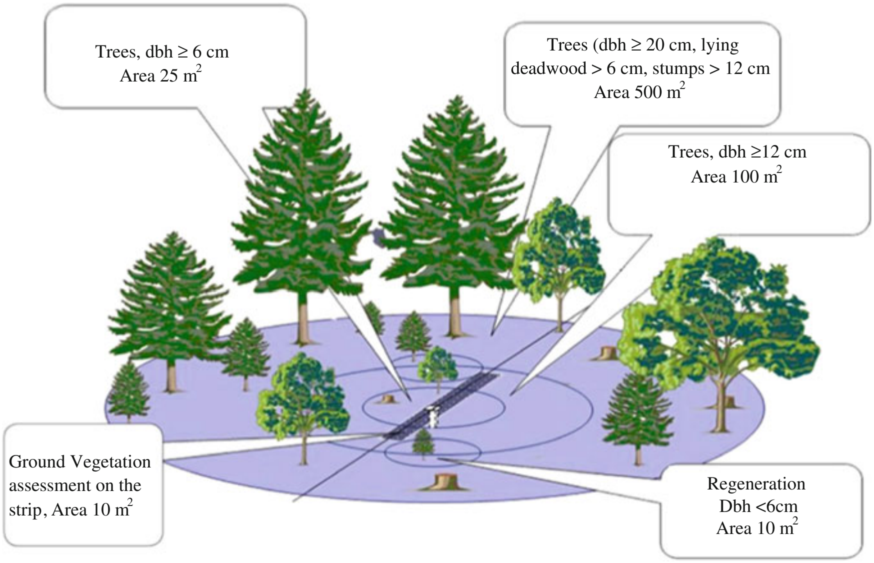

Fig. 38.3 Permanent plot layout of the National Forest Inventory

Table 38.1 Permanent plot details of the National Forest Inventory

Radius (m)	Area (m^2)	Threshold values of diameters of trees, stumps and lying dead wood, measured on separate concentric inventory circles
12.62	500	Trees with a diameter at breast height of 20 cm or more Lying deadwood wood with a diameter of 6 cm or more Stumps 12 cm diameter or more
5.64	100	Trees with a diameter at breast height of 12 cm or more Lying deadwood wood with a diameter of 6 cm or more Stumps 12 cm diameter or more
2.82	25	Trees with a diameter at breast height of 6 cm or more Lying deadwood wood with a diameter of 6 cm or more Stumps 12 cm diameter or more
1.78 two circles	20	Natural and artificial regeneration with a height of at least 0.2 m up to a diameter at breast height to 5.9 cm, young tree species and species of non-timber resources

Ground vegetation is assessed on a strip of 10 m in length and 1 m in width, passing through the centre of the plot in west-east direction

38.1.3 Data Collection

In total there are 117 different variables assessed and measured on the permanent plots, which can be divided into 8 categories:

- Plot and site data (ID plot; center plot co-ordinates; federal state; municipality; forest ecology zone; forest district; land-use type; ownership type; subject entitled for management and exploitation; forest enterprise; compartment identification, sub-compartment identification, area of forest compartment; forest designation category; forest protection category; type of inventory plot establishment; relief; aspect; slope; elevation; strata; site type evaluation, forest health status; biodiversity; forest vertical structure; canopy closure; forest stability; degradation of forest soil; management measures)
- Trees data including standing dead-trees (tree ID; co-ordinates; tree status; age; dbh; height; live crown base; fork; bread; IUFRO social status; tree ecological status; stem quality; living/dead tree information; tree top description; tree damage, location of the damage and damage intensity)
- Soil and ground vegetation data (erosion presence/absence; erosion type and intensity; soil type; soil structure; soil humidity; humus presence/absence; humus thickness; humus type; ground vegetation cover by different types of vegetation groups; ground vegetation cover of berry producing species; ground vegetation cover of medicinal species; ground vegetation cover of non-timber production tree species and shrubs)
- Forest diversity data (species diversity; species share; species distribution; tree distribution; dimensional diversity)
- Shrub layer data including non-timber tree species (species; height class; individuals count; average age)
- Forest regeneration data (regeneration presence/absence; regeneration vitality; height class; species, regeneration origin; individuals count; average age; average height; average diameter; damage type; damage intensity; number of damaged trees)
- Stumps and dead-logs data (dead-logs distribution; species; log length; log central diameter; log decay stage; rot type; stump height; stump diameter; time of cutting (classes); stump decay stage; rot type; rot intensity; branch cover)
- Stem profile and assortment structure data (stem form; stem profile; stem quality sections; stem branching and forking; stem damage)

The work on the permanent plots is performed by a unique technique using NFI software and measuring devices. The field equipment consists of a suite of instruments for high-precision measurements, a navigation equipment and integrated software (Fig. 38.4).

38.1.4 Data Processing, Reporting and Use of Results

The total sample of permanent forest plots in the Russian Federation consists of 82,500 permanent plots in forest. In accordance with the State's forestry development program, 80 % of the country's forest area is aimed to be surveyed by the NFI the year 2020.

Fig. 38.4 The field data measurement and equipment used in the NFI

For the calculation of the required number of permanent plots, the forest management database was used, which includes data about the distribution of growing stock in forests. The accuracy which should be achieved for total stock estimates was fixed to be between 1 and 5 %, depending on the intensity of forest use (Table 38.2). The accuracy ranges from 5 % in the Tundra region to 1 % in the EU and Southern Taiga parts.

The complete network of permanent plots has been completed for 19 constituent entities of the Russian Federation. For these, analytical reports on the state of the forests has been prepared. Table 38.3 shows the results of the calculations for the total growing stock based on the National Forest Inventory.

In addition to the information on growing stock, the reports from the National Forest Inventory include information on forest area, the wood quality, reforestation, soil cover, soils, non-wood goods from forests, biodiversity, carbon pools, forest ecological conditions and an assessment of the resource potential. The reports have been distributed to the state authorities, the scientific community and public organisations.

38.2 Land Use and Forest Resources

In 2015 the total area of forests was estimated to be 814,930,500 ha, representing 48 % of the global forest area (FAO 2015). The growing stock is estimated at 81.5 billion m3, with the an annual increment in excess of 1 billion m^3 per year

Table 38.2 Expected accuracy of total growing stock estimates (%) under the NFI by forest districts of the Russian Federation

The name of the forest district	Accuracy of stock estimates (%)
Tundra forests and sparse Taiga in the European Ural region of the Russian Federation	5
North-Taiga in the European part of the Russian Federation	3
Middle-Taiga in the European part of the Russian Federation	2
South-Taiga in the European part of the Russian Federation	1
Forests in the European part of the Russian Federation	1
Forest-Steppe in the European part of the Russian Federation	2
Steppe in the European part of the Russian Federation	2
Semi-Desert regions in the European part of the Russian Federation	5
North-Caucasian mountainous region	2
North-Ural Taiga region	3
Middle-Ural Taiga region	2
South-Ural steppe areas	2
West-Siberian Tundra forests and sparse Taiga regions	5
North-District of the West-Siberian Plain-Taiga	3
Middle-District of the West-Siberian Plain Taiga	2
South-District of the West-Siberian Plain Taiga	2
West-Siberian Forest-Steppe area	2
Central-Siberian Tundra forests and sparse Taiga area	5
Upland Central-Siberian Taiga region	4
Priangarskij Taiga region	2
Central-Siberian Forest-Steppe region	2
East-Siberian Tundra forests and sparse Taiga region	5
East Siberian Taiga region	3
Altai-Sayan Mountain-Taiga region	3
Altai-Sayan Mountain-Steppe district	4
Baikal mountain forest region	3
Baikal mountain-permafrost area	4
Baikal mountain forest region	3
East-Baikal Steppe area	3
Far east Tundra forests and sparse Taiga region	5
Kamchatka Taiga region	3
Far east Taiga region	2
Priamursko-seaside Conifer-Broadleaved Forest district	2
Far east Steppe region	4

(FAO 2015). The total growing stock by tree species group and for the regions where NFI data collection has been completed between the years 2007–2012 is presented in Table 38.3.

Table 38.3 Total growing stock by tree species group and for the regions in which NFI data collection has been done in years 2007–2012

Constituent entity of the Russian Federation	Total growing stock by tree species groups in million m^3				Accuracy of the total stock estimate (%)
	Total	Conifer	Broadleaved-hardwood	Broadleaved-softwood	
Altayskiy Kray	724.5	386.3	0.1	338.1	4.1
Bryanskaya oblast′	315.6	139.7	22.9	153.0	1.8
Vladimirskaya oblast′	318.5	165.2	11.7	141.6	4.0
Voronezhskaya oblast′	107.1	31.4	52.4	23.3	1.9
Jewish Autonomous Oblast	204.4	65.5	24.0	114.9	6.1
Kaluzhskaya oblast′	376.5	109.0	27.4	240.1	2.1
Leningradskaya oblast′	1270.8	666.7	2.7	601.4	2.0
Nizhegorodskaya oblast′	872.0	382.6	26.3	463.1	3.2
Altai Republic	701.4	570.7	0.0	130.7	6.2
Smolenskaya oblast	548.8	142.2	16.8	389.8	4.5
Tambovskaya oblast′	86.7	40.4	13.7	32.6	3.3
Tverskaya oblast	1047.6	475.5	8.9	563.2	1.8
Yaroslavskaya oblast′	417.1	149.5	0.9	266.7	4.0
Lipetskaya oblast′	45.1	18.2	13.3	13.6	2.8
Novgorodskaya oblast′	632.8	255.6	12.4	364.8	5.6
Orlovskaya oblast′	57.5	8.1	14.6	34.8	5.8
The Republic Of Karelia	1572.6	1122.7	0.0	449.9	2.0
Ryazanskaya oblast′	285.7	80.4	13.2	192.1	4.0
Tul'skaya oblast′	361.7	18.9	76.2	266.6	5.1

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Chapter 39
Serbia

Damjan Pantić, Milan Medarević and Dragan Borota

39.1 The Serbian National Forest Inventory

39.1.1 History and Objectives

The evolution of forest functions and their significance for human society has changed from a production focussed role to a more multi-functional role, with ever-increasing demands on forest resources. This has lead to a progressively greater demand for information on this natural resource. Information is required in terms of the quantity and quality of wood resources at all levels of planning and decision-making, from the local to the global. In this respect, Šmelko (1991) reports: "In addition to the data which characterise wood production (diameters, age structure, tree species, timber supply, increment and the expected felling volume), our attention has been increasingly directed to forest quality characteristics and forest health, as well as to the inter-relationship of forest functions and ecological characteristics. Taking this into account, the permanent monitoring of the trends of forest state and development is increasingly significant". The above change in forest function was followed by the permanent development of forest inventory to provide baseline information on forest production and the sustainable use of all forest resources. The development of forest inventory proceeded in three directions: (i) methodological (implementation of the principles of mathematical statistics,

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particularly sampling methods), (ii) technological (development of instruments used in forest measurement, application of computer technologies, aerial and satellite images) and (iii) increasing the scope of information acquired by the inventory. Thanks to its dynamic, multilateral development and flexibility, forest inventory can now meet the demands of numerous users of information on forest ecosystems. The union of the national organisations dealing with forest inventory (primarily large scale inventory) in different regional and global associations is also one of the characteristics of its development. The activities of such associations are reflected in the exchange of experiences, harmonisation of information and definitions of criteria for their acquisition, processing, and presentation within the National Forest Inventories (NFI). Their objective is to create a database for the monitoring of forest ecosystems using different ecological and economic indicators at the regional and global level. This database will inform professional and political decisions.

In the past thirty years or so, forestry in Serbia was characterised by the application of a methodologically and technologically modern stand inventory, but without a NFI. Stand inventories were conducted in Serbia for many years and focused exclusively on collecting data relating to the estimation of growing stock. To satisfy information needs for forest management planning, stand inventory methods were enhanced and modernised, in the 1980s by the:

- introduction of new forms of sample plots with partial measurement
- establishment of statistical based sampling methods
- classification of forest stands into homogenous units
- development of software for the processing of forest inventory data.

The methodology was fully adopted by the Serbian forest sector soon after its formulation, which resulted in the creation of a more reliable and more complex database for the elaboration of forest management plans and private forest management programmes, based on stand inventory data. In the absence of a national inventory, stand inventory data were also used for the elaboration of general forest management plans and macro-economic plans. The application of this unique methodology of stand inventory, computer data processing and the creation of a uniform database have been implemented since the 1980s in the Republic of Serbia. However, due to organisational and financial problems and inconsistent enforcement of the Law regarding forest management records, the requirements were not satisfied. Therefore in the past it was necessary to estimate data where information was missing, which facilitated the calculation of quantitative stand inventory data for higher level planning. This estimation process resulted in statistics with a high level of error in volume, volume increment and unreliable felling records. Overall, this made the information untrustworthy from the aspect of real multi-functional planning, particularly planning at a national level.

The first National Forest Inventory in the Republic of Serbia (excluding Kosovo and Metohija) started in 2004 after the methodology was defined in terms of scope of information and the training of field teams. The Kingdom of Norway provided financial support, and the Norwegian Forestry Group (NFG) provided expert support for the implementation of the NFI1 in Serbia. Field data collection, data processing and database development was finalised at the end of 2006. By forming a national database on forests and through periodic updating (planned inventory cycle is 10 years), it is possible to overcome the previous problems related to higher-level planning, i.e. to elaborate more realistic and reliable macro-economic plans and National Forest Programmes. Also, the cooperation with international organisations dealing with forest ecosystem monitoring at the regional and global levels has been improved. Data is available to numerous users such as commercial sectors, nongovernmental organisations, professional societies, individuals, etc., as well as different ministries, in agreement with the Law on Free Access to Information of Public Importance (Official Gazette of the Republic of Serbia 12/04).

39.1.2 Sampling Methods and Periodicity

The concept of the NFI1 in Serbia includes the application of a systematic sample in the form of clusters, distributed in a 4 × 4 km grid (Fig. 39.1a, b). The term cluster refers to a set of sample plots which are surveyed in order to assess the state of the growing stock and to evaluate its development. Each cluster consists of 4 sample plots, with the centre of the first one being the reference point (i.e. intersection point of the cluster network). The other three sample plots are distributed at the corners of square with 200 m sides (Fig. 39.1c). The sides of the sample plot clusters are oriented in a north-south and east-west direction. The plot area consists of three concentric circles with radii of 3, 10 and 15 m (Fig. 39.1d). The following diameter thresholds are used in the concentric circles:

- 3 m circle, all trees of diameter below 5 cm are recorded, and all trees above 5 cm are measured
- 10 m circle, the dbh of all trees above 10 cm are measured
- 15 m circle, the dbh of all trees above 30 cm are measured.

Trees which qualify for diameter measurement are also assessed for height and other tree specific data as well. Azimuth and distance from the centre of the circle are surveyed as well. The data on the general identification of clusters and sample plots, site description, stand description and information about trees are collected in each plot.

Due to the absence of experience in large-scale inventories, more detailed research should be undertaken regarding the optimal distance between cluster centres in the districts with different forest cover percentages. The most appropriate sample plot form should be assessed and recommendations made for the next NFI, for a possible correction to the methodology applied in the NFI1 (Banković et al. 2009). Although the planned inventory cycle is 10 years, financial problems have delayed the implementation of the second NFI, which is now planned for 2017.

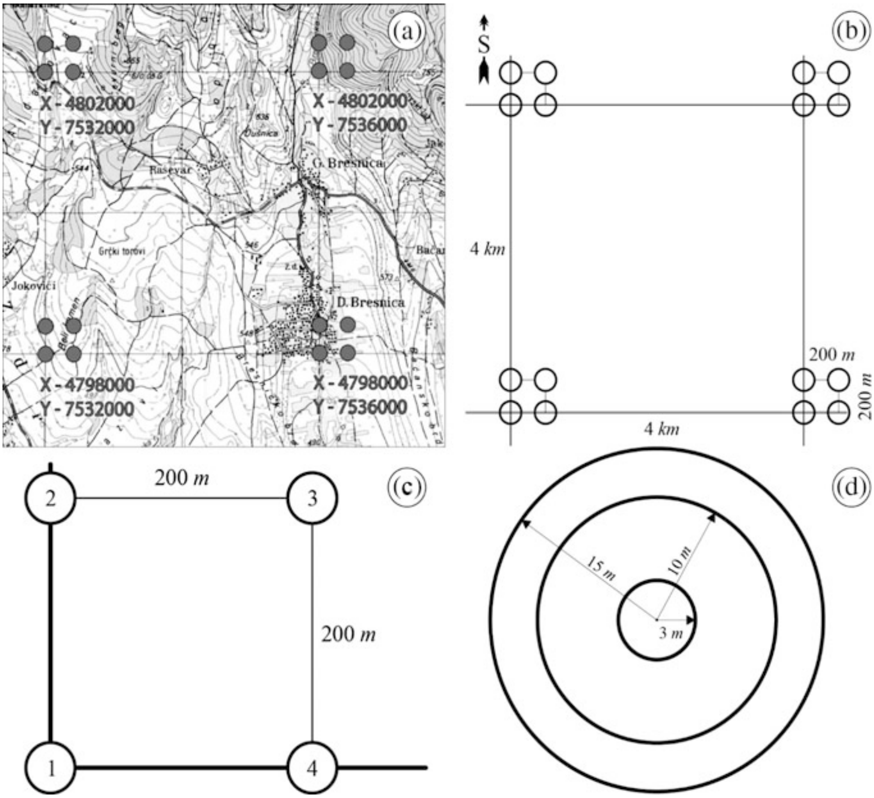

Fig. 39.1 Sampling plot system of Serbian NFI1 (2004). **a** Systematic sample in the form of clusters; **b** network (grid) 4 × 4 km; **c** distribution of sample plots on the cluster; **d** plot area of three concentric circles

The cluster and sample plot network was designed on four-colour topographic maps at the scale 1:25,000. Some maps were already in digital form, and the other maps were first scanned in *TIF* format, with a resolution of 300 dpi, and then georeferenced using the software package *Wingis 2003*. The prepared maps were upgraded with administrative boundaries of districts and political municipalities, and the boundaries of state forests by forest areas. The cluster network (grid) was also created using the above software, and the starting reference points (centre of the first cluster) were the coordinates of the plots used for monitoring for the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forest). The clusters were numbered (each reference point) and their coordinates were entered. Also, the numbers and coordinates of reference points were entered into a GPS receiver, which made their identification in the field easier. Using the described procedure, the territory of Serbia (excluding Kosovo and Metohija) was covered with 19,371 sample plots. The use of satellite imagery in Vojvodina (the northern part of Serbia), to acquire preliminary data on clusters led to a reduction in fieldwork. This positive experience points to its wider use in the future National Forest Inventories of the entire territory of the Republic of Serbia.

39.1.3 Data Collection

The volume and definition of the information collected during NFI1 in Serbia is in compliance primarily with national standards, needs and available financial resources. As a result, the database contains accurate information about the growing stock of Serbia. However, the information is largely incompatible with the requirements of COST Action E43 (2010) standards and Global Forest Resources Assessment (FAO 2010). One of the reasons for this was the lack of experience with large-scale forest inventory. Due to this, and unlike other countries with a long NFI tradition, it is difficult for Serbia to fully meet the criteria of various international questionnaires. Therefore, this report is compatible with current reporting abilities on the forests of Serbia. The experience gained with the NFI1, combined with the knowledge gained from being a member of the European National Forest Inventory Network (ENFIN), and participating in international projects, will allow Serbian experts to eliminate the above-mentioned information gaps during the second NFI.

The qualitative and quantitative data of the NFI1 are structured as follows:

Group A. GENERAL IDENTIFICATION OF CLUSTERS AND SAMPLE PLOTS determines the position and inventory status of each cluster and sample plot, and includes the following information:

- cluster identification number
- sample plot identification number
- inventory status
- sample plot status
- district
- municipality.

Group B. SITE DESCRIPTION determines land use, land ownership, conditions of the development of forest vegetation, also including some risk factors, as well as the following data:

- land use
- altitude
- slope
- aspect
- land ownership
- erosion
- litter
- humification process.

Group C. STAND DESCRIPTION provides a comprehensive information on forests, including preliminary definition of management goals. It includes the following data:

- tree species
- age
- age class identification number
- forest categories (defined according to the principal tree species in the stand)
- forest origin
- forest structure
- development stage in even-aged stands of high origin
- preservation status;
- mixture
- canopy (crown cover)
- main characteristics of the young crop
- naturalness
- potential silvicultural treatment.

Group D. INFORMATION ON TREES provides the data on individual trees on sample plots, such as:

- diameter at breast height (dbh) or diameter at half of the length of the stem if the tree is fallen
- height (h) or length of a part of a fallen tree
- distance and azimuth from plot centre
- health status
- usability of dead trees (classes defined according to whether or not a dead tree can still be used in mechanical or chemical processing)
- biological (social) position of a tree
- wood quality
- cause and degree of damage.

All the information with the codes, definitions and the procedures can be found in the Technical Guidelines and the Code Manual for the National Forest Inventory of the Republic of Serbia (Banković et al. 2009). Based on these data, the values of the basic inventory elements (number of trees, basal area, volume and volume increment) are obtained both per unit area (1 ha) and at municipality, district, and the Republic level. Additionally, stand health and technical quality of timber can be evaluated. In the future, based on the principles of permanent inventory, it will be possible to monitor the evolution of individual trees, stands and larger forest areas.

39.1.4 Data Processing, Reporting and Use of Results

As already stated, a cluster of 4 plots are positioned on a 4 × 4 km grid, representing 1600 ha and containing 4 sample plots, each covering the area of 400 ha. In cases where a sample plot is divided into different segments in different situations (for example, forest and barren land, high and coppice forests, even-aged and uneven-aged forests, etc.), the area of every segment in ha is obtained on the basis of the percentage of their share of the 400 ha area. Recapitulations at the level of municipalities, districts and the whole of Serbia were generated by adding areas represented by circular plots or their individual segments by various characteristics.

The validation of fieldwork was conducted in parallel with the NFI, which aimed to minimise systematic measurement errors. Due primarily to the overall number of sample plots assessed, the control was conducted on a single sample (Stojanović 1985; Banković et al. 2002b). The size of the control sample accounted for 2–5 % of the total number of sample plots (clusters). On the control sample plot, all the data were collected and all cruising measurements were taken in the same way as during the regular inventory, considering the same types of field forms. The control was conducted by an experienced field worker from NFG, under the supervision of representatives of the responsible Ministry. A lot of information was controlled, such as sample plot status, stand origin, stand structure, preservation, mixture, canopy, etc. The proportion between the number of circular plots with errors data and the total number of circular plots in the control sample did not exceed 5.5 %. Therefore, it can be concluded that there was a high degree of conformity between the field teams and the control. The errors in diameters at breast height and tree height account for 0.28 and 0.13 % respectively, of the average values of these elements. Also, there were no statistically significant differences between the field teams and the control results at the 99 % level of significance (Hadživuković 1975), which implies a high degree of reliability in the cruising data (area, volume, volume increment) per unit area, and altogether, at the level of individual Districts, i.e. Serbia.

The volume was calculated following the procedure for concentric circles, outlined by Banković and Pantić (2006). Two-way—model type V = f (d,h) volume tables were used, i.e. three-way volume tables for some tree species in even-aged forests—model type V = f (d,h,t) local area of validity (Pantić 1995, 1996, 1997a, b; Banković et al. 2003a, b). In these models d is diameter at breast height, h is tree height, and t is age of stand. In this way, volume per ha is distributed by diameter classes and was calculated for every tree species registered at a sample plot. Multiplication of this volume by 400 ha resulted in the total volume of every tree species in the area represented by one plot, distributed by diameter classes. Knowing the spatial position of every plot allowed the generation of summary statistics for volume at the level of a municipality, district or the whole Serbia.

The data were processed in specially developed software (for internal use only) and the database was established, followed by the drafting of a report on the results of NFI1 of Serbia. The NFI1 data were used in reports for the SORS (Statistical Office of the Republic of Serbia), the Government of the Republic of Serbia, the commercial sector, nongovernmental organisations, professional associations, etc. In order to avoid preparation of standard reports in the future, and to unburden experts, the intention after the second NFI is to make the database available online and to allow numerous users to create their own required statistics through a higher number of queries.

39.2 Land Use and Forest Resources

39.2.1 Classification of Land and Forests

39.2.1.1 General Land Classification

Forest cover in Serbia is 29.1 % of the total area (in Vojvodina 7.1 %, and in central Serbia 37.6 %). Other Wooded Land (OWL), which also includes thickets and bushes, includes 4.9 % of the territory. When combined, OWL and forest represents 34.0 % of the total land area (Table 39.1).

The percent forest cover nationally is close to the global percentage of 31 % (FAO 2010), but it is considerably lower than the European (including Russian Federation) percentage, which is 45 % (FOREST EUROPE, UNECE and FAO 2011). In Serbia, the forest cover per capita is 0.3 ha and is half the world average, which amounts to 0.6 ha per capita (FAO 2010).

The national land use definitions are:

- Forest—Land with canopy cover of more than 10 % and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. May consist either of closed forest formations, where trees of various storeys and undergrowth cover a high proportion of the ground, or open forest formations with a continuous vegetation cover in which canopy cover exceeds 10 %. Young natural stands and all artificially established stands that have not yet reached, but are expected to reach, a canopy cover of 10 % and tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked, as a result of human intervention or

Table 39.1 Land use classes according to the national definition with area estimates (first NFI, 2004-2006)

Class name	Area (1000 ha)	Area (%)	Correspondence to FRA categories (2010)
Forests	2252	29.1	Forest
Other wooded land	382	4.9	OWL
Barren land	92	1.2	OL
Agricultural land	3595	46.4	OL
Meadows and pastures	1030	13.3	OL
Built-up area	312	4.0	OL
Inland water	85	1.1	Inland water bodies
Total	7748	100	

natural causes, and that are expected to regenerate (felling units, burned areas, etc.). It also includes forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas within the forest; forest in national parks, nature reserves and other protected areas, such as those of specific environmental, scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and width of more than 20 m. Excludes: Land predominantly used for agricultural practices.

- Other Wooded Land (OWL)—is the land either with a canopy cover of up to 10 % of trees able to reach a height above 5 m at maturity in situ; or a crown cover of more than 10 % of trees not able to reach a height of 5 m at maturity in situ, and a combined cover of maquis, shrubs and bushes. The category of Other Wooded Land does not include those areas with tree, shrub or bush and maquis cover of less than 0.5 ha and width to 20 m, which are classed under “other land”, or land predominantly under agricultural or urban land use.
- Barren land—includes infertile areas which are not used as forests, or for agricultural production (public roads, rocky land, stock piles, waterlogged land, pools, etc.).
- Agricultural land—includes the areas used for agricultural production (farmland, orchards, vineyards, etc.).
- Meadows/pastures—are grassland areas which are used exclusively for livestock and wild animal pasturage.
- Built-up land—includes the areas under buildings (towns, villages) and other urban structures.
- Inland water—includes lakes and reservoirs, major waterways, larger pools, etc.

39.2.1.2 Classification by Ownership Categories

According to the national forest definition the total forest area in Serbia amounts to 2,252,400 ha, of which state forests cover 1,194,000 ha or 53.0 %, and private forests cover 1,058,400 ha or 47.0 %.

The share of private forests in the total volume is 38.9 and 40.6 % in the total current volume increment. Average volume in private forests is 133 m^3 ha^{-1}, and volume increment is 3.5 m^3 ha^{-1}. In state forests the average volume is 185 m^3 ha^{-1}, and volume increment is 4.5 m^3 ha^{-1}. They are predominantly of coppice origin, corresponding to FRA classes (FAO 2004), but their structure is defined as thinned, clear-cut and even-aged as well. The average size of a private forest plot in Serbia is 0.27 ha, which is a burdening factor with regard to the preparation of planning documents for these forests. Despite the planning challenges in the private forest sector, these are highly important from an environmental, social and production aspect, due to the significant area they represent.

39.2.1.3 Forest Management and Cutting Systems

Forest management systems used in Serbia can be grouped as follows:

– regeneration management system (area or stand management), which is applied in even-aged (regardless of origin) and uneven-aged forests (in case of regeneration felling of long regeneration period)
– selection management system (single-tree or group selection), which is applied in selection forests
– group management system, which is applied in difficult stand conditions, commonly in beech and spruce forests at the border of forest vegetation, whereby silvicultural units (groups) must be no larger than 3 ha.

All forests in Serbia are classified into four categories by structural form. Even-aged stands dominate with 91.6 % of the total forest area, followed by uneven-aged stands with 7.5 %, selection stands with 0.8 % and virgin forests with 0.1 % (Table 39.2). A long-term strategic problem which is evident from Table 39.2 shows the need to restructure the even-aged stands that dominate to an extent that limits the bio-ecological characteristics of the species, site characteristics and goals of forest management.

39.2.1.4 Legal and Other Restrictions for Wood Use

The forests of Serbia are zoned according to global and primary functions. The global purpose refers to the entire complex of forests as a natural unit that synchronises and integrates the condition of sites and stands with societal requirements for forests into unique-general forest management goals. Global purposes and general goals of forest management are normally legally defined. According to Banković and Medarević (2003), 18 global purposes are defined in Serbia (for example, forests and forest sites with production function, forests with priority protection function, forests intended for recreation, general cultural and educational functions, nature reserve, game park, etc.). The primary function is a lower legal category, which may be established in advance as a legal obligation, or established subsequently on the basis of specific criteria. Areas designated by legal acts (Forest Law, Law on Environment Protection, Law on Waters, Law on National Parks, etc.) implies also the definition of protection regimes, which provide guidelines and

Table 39.2 Forest area by stand structural form (first NFI 2004–2006)

Stand structural form	Area (1000 ha)	Area (%)
Even-aged stands	2063	91.6
Uneven-aged stands	169	7.5
Selection stands	19	0.8
Virgin forest	1	0.1
Total	2252	100.0

limitations with regard to management (Medarević 2006). The following three categories are differentiated:

- degree I of protection regime—strict protection (excludes any human activity, other than scientific, and only with special authorisation from the competent ministry);
- degree II of protection regime—active protection;
- degree III of protection regime—sustainable use.

In addition, limitations in using wood also result from extreme terrain conditions which make difficult, or prevent access for, mechanised forest operations. However, these are smaller areas, as most of the forests in these sites are protected forests under the first or the second degree of protection.

39.2.1.5 Further Classification of Forests

Forests by origin
In Serbia, high stands occupy 27.5 %, coppice regenerated stands 64.7 %, artificially established stands 6.1 % and plantations (poplar and willow clones) 1.7 % of the total forest area. The above forest categories differ significantly in terms of production. The average volume in high forests is 254 m^3 ha^{-1}, in coppice forests 124 m^3 ha^{-1}, plantations of conifers and broadleaves 127 m^3 ha^{-1} and in poplar and willow clonal plantations 172 m^3 ha^{-1}. Current volume increment in naturally regenerated high stands is 5.5 m^3 ha^{-1}, in coppice forests 3.1 m^3 ha^{-1}, plantations 6.5 m^3 ha^{-1}, and in clonal plantations 9.0 m^3 ha^{-1} (Table 39.3). Regarding the differences in production effects, it can be concluded that the loss in increment associated with coppice forests is about 3.5 million m^3 per year compared to high forests, and there are also differences in the quality of actual production of both forest categories. The percentage of plantations is a concern only at the local level and in state forests.

The high share of coppice forests is a consequence of poor economic conditions during most of the twentieth century (particularly after World War I and World War

Table 39.3 Area, volume and volume increment of forests by origin (first NFI 2004–2006)

Stand origin	Area		Volume			Volume increment		
	1000 ha	%	1000 m^3	%	m^3 ha^{-1}	1000 m^3	%	m^3 ha^{-1}
Natural high stands	621	27.5	157,511	43.5	253.6	3388	37.3	5.5
Natural coppice stands	1456	64.7	181,189	50.0	124.4	4458	49.1	3.1
Artificially established stands	175	7.8	23,787	6.5	136.1	1234	13.6	7.1
Total	2252	100	362,487	100	160.9	9080	100	4.0

II) and, as a result of that, a strong and often unplanned anthropogenic impact on forests. The recovery of such a situation requires an extremely long period of time as well as high technological and financial resources.

Forests by mixture
Mixed stands are defined as stands in which the percentage of other species have a high proportion of volume exceeding 25 %. All forests in Serbia are classified into five categories as follows: pure broadleaf stands dominate with 59.0 %, mixed broadleaf stands cover 29.3 %, pure coniferous stands cover 8.7 %, mixed broadleaf and coniferous stands cover 2.4 % and mixed stands of conifers that cover only 0.6 % of the total forest area (Table 39.4).

The highest productivity has been identified in mixed conifer forests (mostly fir and spruce) and mixed broadleaf and conifer forests (beech-fir-spruce in different combinations). Furthermore, these forests occur in uneven-aged and selection structural forms; they are biologically more stable and more valuable functionally in terms of the modern understanding of the role of forests in a human society. In this respect, increasing the level of mixture is one of the imperatives of forest management in Serbia.

Forests by tree species
The first NFI in Serbia identified 39 broadleaf and 8 conifer tree species. Although the number of species present is higher, considering that some species are grouped as "other broadleaves" and "other conifers", the high number of species indicates that the there is a diverse range of tree species in Serbia's forests. However, most of the volume and current volume increment is related to only 9 broadleaf species, primarily European beech (*Fagus sylvatica* L.) and 4 conifer species, primarily spruce (*Picea abies* (L). *Karsten*). In that respect, it is necessary to increase the level of mixture in the forests of Serbia. One of the measures for achieving this long-term goal is the introduction of rare broadleaves in the area under beech forests

Table 39.4 Area, volume and volume increment of forests by mixture (first NFI 2004–2006)

Stand mixture	Area		Volume			Volume increment		
	1000 ha	%	1000 m^3	%	m^3 ha^{-1}	1000 m^3	%	m^3 ha^{-1}
Pure broadleaf stands	1328	59.0	227,074	62.7	171.0	5158	56.9	3.9
Mixed broadleaf stands	661	29.3	84,527	23.3	127.9	2046	22.5	3.1
Mixed broadleaf and coniferous stands	54	2.4	11,693	3.2	216.5	310	3.4	5.7
Mixed stands of conifers	14	0.6	4028	1.1	287.7	128	1.4	9.1
Pure coniferous stands	195	8.7	35,165	9.7	179.8	1438	15.8	7.4
Total	2252	100.0	362,487	100	160.9	9080	100	4.0

and to avoid the removal of rare tree species. Although the number of introduced species is substantial (8 species), their share in the total volume and volume increment is minimal, and it can be stated that the natural composition of Serbian forests is preserved to a certain extent. Further processes introducing allochthonous species must be minimised and strictly controlled.

Forests by stand categories

All forests, according to the National Forest Inventory Manual, differ also by stand categories, defined according to the principal tree species in the stand, regardless of the percentage of other species. Pursuant to this criterion, NFI1 identified 20 stand categories in Serbia, from the linear willow forests in the riparian areas to spruce forests at the upper altitudinal belt of forest communities. The dominant stand category is beech (*Fagus sylvatica*) forests, which cover 29.3 %, followed by turkey oak (*Quercus cerris* L.) forests with 15.3 %, forests of black locust (*Robinia pseudoacacia* L.), aspen (*Populus tremula* L.) and birch (*Betula pendula* Roth.) with 9.9 %, sessile oak (*Quercus petraea* (Matt.) Liebl.) forests with 7.7 %, Hungarian oak (*Quercus frainetto* Tenore) forests with 7.1 %, hornbeam (*Carpinus betulus* L.) forests with 5.3 %, pine (*Pinus* spp.) forests with 5.6 % and spruce (*Picea abies*) forests with 3.8 % of the total forest area. Alder (*Alnus glutinosa* (L.) Gaertn) forests have a minor percentage of only 0.3 % (Table 39.5).

Even-aged forests by age classes

Age classification was determined on the basis of the age of principal tree species and the age class span. The age class span is defined in advance:

- for all high forests, whose rotation is longer than 80 years, the age class span is 20 years
- for all high and coppice forests, whose rotation is 40–80 years, the age class span is 10 years
- for all high and coppice forests, whose rotation is 15–40 years, the age class span is 5 years
- if the rotation is shorter than 15 years, age classes are not established.

Even-aged forests, irrespective of origin, are characterised by the distribution of age classes and in particular the domination of areas under middle-aged and maturing forests and substantially lower share of areas under young and mature stands (Table 39.6). This situation is undesirable from the aspect of sustaining yield and indicates that it will be achieved in the future primarily through thinning. This statement is also confirmed by the distribution of areas under high even-aged forests by development phases (Table 39.7). The representation of individual development phases is a result of intense exploitation and premature felling, primarily of beech stands, in the first half of the last century, caused by the increased demand after World War II.

Table 39.5 Area, volume and volume increment of forests according to stand category (first NFI 2004–2006)

Stand categories	Area		Volume			Volume increment		
	1000 ha	%	1000 m^3	%	m^3 ha^{-1}	1000 m^3	%	m^3 ha^{-1}
Beech forests	660	29.3	153,837	42.4	232.9	2929	32.3	4.4
Turkey oak forests	345	15.3	49,565	13.7	143.6	1162	12.8	3.4
Sessile oak forests	173	7.7	21,596	6.0	124.7	542	6.0	3.1
Hungarian oak forests	160	7.1	21,087	5.8	132.1	533	5.9	3.3
Spruce forests	86	3.8	18,926	5.2	219.1	607	6.7	7.0
Pine forests	126	5.6	16,451	4.5	130.6	888	9.8	7.0
Forests of birch, aspen and black locust	223	9.9	13,402	3.7	60.0	617	6.8	2.8
Hornbeam forests	119	5.3	13,267	3.7	111.7	298	3.3	2.5
Common oak forests	32	1.4	10,119	2.8	312.3	178	2.0	5.5
Fir forests	26	1.1	9839	2.7	384.3	226	2.5	8.8
Poplar forests	48	2.1	7816	2.2	162.8	398	4.4	8.3
Lime forests	30	1.3	6134	1.7	201.8	121	1.3	4.0
Forests of narrow-leaved ash	25	1.1	5979	1.6	237.3	163	1.8	6.4
Forests of oriental hornbeam, hop hornbeam and flowering ash	87	3.9	4795	1.3	55.0	133	1.5	1.5
Forests of other broadleaves	54	2.4	3284	0.9	61.3	102	1.1	1.9
Willow forests	22	1.0	2175	0.6	97.1	52	0.6	2.3
Forest of ash and maple	13	0.6	1583	0.4	123.7	43	0.5	3.4
Forest of other conifers	5	0.3	1054	0.3	202.8	42	0.5	8.1
Pubescent oak forests	10	0.5	907	0.3	87.2	28	0.3	2.6
Alder forests	6	0.3	673	0.2	105.2	19	0.2	3.0
Total	2252	100	362,487	100	160.9	9080	100	4.0

39.2.2 Wood Resources and Their Use

39.2.2.1 Standing Stock, Increment and Drain

Volume and current volume increment include trees dbh ≥ 5 cm with bark, including the above-ground part of the stump, and branches with a diameter above

Table 39.6 Area under even-aged forests by age classes (first NFI 2004–2006)

Stand origin	Area	I	II	III	IV	V	VI	VII	VIII	Total
Width age-class (year)		0–20	21–40	41–60	61–80	81–100	101–120	121–140	141–160	
High natural stands	1000 ha	10	44	108	87	55	102	19	6	432
	%	0.5	2.2	5.2	4.2	2.7	4.9	0.9	0.3	20.9
Width age-class (year)		0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	
Coppice natural stands	1000 ha	49	90	299	310	279	196	107	127	1456
	%	2.4	4.4	14.5	15.0	13.5	9.5	5.2	6.2	70.6
Artificially established stands	1000 ha	12	32	58	34	22	6	7	4	175
	%	0.6	1.6	2.8	1.6	1.0	0.3	0.3	0.2	8.5
Total area (1000 ha) of even-aged forests in Serbia										2063

Table 39.7 Area under high even-aged forests by development phases (first NFI 2004–2006)

Stand development stage	Area (1000 ha)	Area (%)
Regeneration	18	3.0
Sapling	100	16.5
Middle-aged stand	333	54.9
Mature stands	156	25.6
Total	607	100.0

3 cm. Since this is the first NFI, it was not possible to calculate drain. However, according to the principles of permanent inventory, the centre of every circular sample plot is fixed permanently by a metal pole positioned below the ground surface and the position of every tree was surveyed, which will also allow for the calculation of drain after the second NFI. The volume and current increment by tree species are presented in Table 39.8.

An important parameter for the assessment of forest qualitative structure is also the tree and volume distribution by the main diameter classes. For this reason, total volume is presented by 20 cm diameter class intervals (Table 39.9).

The proportion of the total volume thinned (10–30 cm) is 51 %: mid strong (31–50 cm) is 30 %: strong (>50 cm) is 19 %. This indicates an opportunity for future felling, both with regard to quantity and quality (potential assortment structure). Regardless of the dominant share of thin trees, it should be pointed out that some tree species reach substantial diameters. Beech (*Fagus sylvatica*), common oak (*Quercus robur* L.), sessile oak (*Quercus petraea*), maple (*Acer pseudoplatanus* L.) and Norway spruce (*Picea abies*) in the forests of Serbia reach diameters even above 90 cm, narrow-leaved ash (*Fraxinus angustifolia* Vahl.), Hungarian oak (*Quercus frainetto*), fir (*Abies alba* Mill.) and Austrian pine (*Pinus nigra* Arnold) up to 90 cm, and aspen (*Populus tremula*), birch (*Betula pendula*), black locust (*Robinia pseudoacacia*), smooth-leaved elm (*Ulmus minor* Miller), flowering ash (*Fraxinus

Table 39.8 Tree species by number of trees, volume and volume increment (first NFI 2004–2006)

Tree species	Number of trees		Volume		Volume increment	
	1000 trees	%	1000 m^3	%	1000 m^3	%
European beech (*Fagus sylvatica*)	436,582	20.6	146,851	40.5	2782	30.6
Turkey oak (*Quercus cerris*)	234,089	11.1	46,980	13.0	1035	11.4
Sessile oak (*Quercus petraea*)	129,995	6.1	21,543	5.9	554	6.1
Hungarian oak (*Quercus frainetto*)	153,216	7.2	20,986	5.8	519	5.7
Hornbeam (*Carpinus betulus*)	254,122	12.0	15,157	4.2	335	3.7
Black locust (*Robinia pseudoacacia*)	218,845	10.3	11,244	3.1	517	5.7
Common oak (*Quercus robur*)	10,996	0.5	9242	2.5	158	1.7
Euroamer. Poplar (*Populus euroamericana*)	6490	0.3	6138	1.7	338	3.7
Narrow-leaved ash (*Fraxinus angustifolia*)	15,417	0.7	5792	1.6	154	1.7
Large-leaved lime (*Tilia platyphyllos*)	16,763	0.8	3536	1.0	71	0.8
Flowering ash (*Fraxinus ornus*)	103,787	4.9	3506	1.0	102	1.1
Field maple (*Acer campestre*)	47,615	2.3	3181	0.9	73	0.8
Other broadleaves	45,576	2.2	2942	0.8	90	1.0
Aspen (*Populus tremula*)	22,521	1.1	2358	0.7	93	1.0
Willow (*Salix* spp.)	6663	0.3	1912	0.5	43	0.5
Silver lime (*Tilia tomentosa*)	5958	0.3	1779	0.5	32	0.4
Oriental hornbeam (*Carpinus orientalis*)	88,444	4.2	1718	0.5	55	0.6
Hop hornbeam (*Ostrya carpinifolia*)	21,952	1.0	1481	0.4	34	0.4
Maple (*Acer pseudoplatanus*)	10,863	0.5	1433	0.4	39	0.4
Cherry tree (*Prunus avium*)	12,660	0.6	1292	0.4	32	0.4
Smooth-leaved elm (*Ulmus minor*)	18,665	0.9	1098	0.3	43	0.5
Black poplar (*Populus nigra*)	1458	0.1	1017	0.3	42	0.5
Pubescent oak (*Quercus pubescens*)	12,129	0.6	956	0.3	29	0.3
Small-leaved lime (*Tilia cordata*)	7526	0.4	945	0.3	20	0.2
Birch (*Betula pendula*)	11,643	0.6	875	0.2	33	0.4
White ash (*Fraxinus excelsior*)	5983	0.3	767	0.2	21	0.2
Alder (*Alnus glutinosa*)	5080	0.2	764	0.2	23	0.3
White poplar (*Populus alba*)	1988	0.1	607	0.2	25	0.3
Norway maple (*Acer platanoides*)	1694	0.1	418	0.1	10	0.1
Common walnut (*Juglans regia*)	2547	0.1	314	0.1	10	0.1
Turkish hazel (*Corylus colurna*)	2523	0.1	207	0.1	7	0.1

(continued)

Table 39.8 (continued)

Tree species	Number of trees		Volume		Volume increment	
	1000 trees	%	1000 m^3	%	1000 m^3	%
Wych elm (*Ulmus glabra*)	899	0.0	187	0.1	4	0.0
American (white) ash (*Fraxinus americana*)	6482	0.3	158	0.0	4	0.0
Black walnut (*Juglans nigra*)	337	0.0	155	0.0	4	0.0
Wild service tree (*Sorbus torminalis*)	1983	0.1	110	0.0	2	0.0
Balkan maple (*Acer heldreichii*)	817	0.0	95	0.0	3	0.0
Ash-leaved maple (*Acer negundo*)	1090	0.1	92	0.0	3	0.0
Europ. Hackberry (*Celtis australis*)	941	0.0	56	0.0	2	0.0
Europ. white elm (*Ulmus laevis*)	783	0.0	32	0.0	2	0.0
Mountain ash (*Sorbus aucuparia*)	6	0.0	3	0.0	0	0.0
Total broadleaves	1,927,126	91.1	317,930	87.8	7341	80.9
Spruce (*Picea abies*)	57,532	2.7	18,811	5.2	605	6.7
Fir (*Abies alba*)	13,797	0.7	8305	2.3	200	2.2
Austrian pine (*Pinus nigra*)	84,964	4.0	12,659	3.5	715	7.9
Scots pine (*Pinus sylvestris*)	26,178	1.2	3775	1.0	177	1.9
Douglas-fir (*Pseudotsuga menziesii*)	1641	0.1	511	0.1	16	0.2
Weymouth pine (*Pinus strobus*)	2080	0.1	355	0.1	19	0.2
Larch (*Larix decidua*)	996	0.0	108	0.0	5	0.1
Yew (*Taxus baccata*)	13	0.0	2	0.0	0	0.0
Other conifers	309	0.0	31	0.0	2	0.0
Total conifers	187,510	8.9	44,557	12.3	1739	19.1
Total	2,114,636	100.0	362,487	100.0	9080	100.0

Table 39.9 Distribution of volume by diameter classes (first NFI 2004–2006)

Tree species	Volume (million m^3)	Diameter class (cm)					
		<10	11–30	31–50	51–70	71–90	>91
Total broadleaves	318	25	137	93	47	11	5
Total conifers	45	3	21	15	5		
Total	362	28	158	109	52	11	5

ornus L.), hop hornbeam (*Ostrya carpinifolia* Scop) and wild service tree (*Sorbus torminalis* (L.) Crantz) up to 50 cm. These dimensions indicate diversity in the diameter distribution within a tree species.

39.2.2.2 Tree Species and Their Commercial Use

According to the SORS (Statistical Office of the Republic of Serbia) data, the volume of harvested wood and its use for commercial purposes varied in the period 2009–2013 (Table 39.10). The maximum harvested volume equalled 31 % of current volume increment. Fuel wood was dominant use for the harvested volume, followed by technical wood and wood for chemical processing. The waste resulting from harvesting has been treated in recent times as biomass for various uses. There are no reliable data on the share of individual tree species in harvested volume, but it can be claimed with a high level of certainty that such a share corresponds to their share in the total standing volume.

39.3 Assessment of Wood Resources

39.3.1 Forest Available for Wood Supply

39.3.1.1 Assessment of Restrictions

In accordance with the criteria for the assessment of natural values, rarities and cultural and historical monuments (the Law on Forests, the Law on Environmental Protection, the Water Law, the Law on National Parks, etc.), the Institute for Nature Conservation of Serbia has defined the protected areas and established protection regimes as the limiting factor in the use of forest resources. The spatial distribution of these areas and a number of other characteristics are presented in detail in the decision on the declaration of each protected area, which was adopted by the Government of the Republic of Serbia.

39.3.1.2 Estimation

Areas under various protection regimes were also identified within the total area under forests, as a limiting factor to various forms of use (Table 39.11).

If forests under the first regime of protection, in which any exploitation is prohibited, as well as the forests on extreme slopes intended to protect soil from

Table 39.10 Harvested timber volume from 2009 to 2013 (1000 m^3)

Use of harvested timber	2009	2010	2011	2012	2013
Industrial and technical wood	935	968	1019	939	992
Fuel wood	1365	1451	1514	1422	1402
Waste	303	277	300	275	285
Total	2603	2696	2833	2636	2679

Table 39.11 Area of protected forests by protection regime (first NFI 2004–2006)

Protected areas	Degree of protection (1000 ha)			
	I	II	III	Total
Reserves (general and special)	7	32	42	81
National parks	8	44	108	159
Nature parks and landscape	14	18	172	205
Geo-heritage	–	2	–	3
Natural monuments	–	–	–	–
Cultural and historical monuments	–	–	4	4
Total	29	96	327	452

erosion, are excluded, it can be stated that around 95 % of forest area in Serbia is available for wood supply.

39.3.2 *Wood Quality*

39.3.2.1 Stem Quality and Assortments

Individual trees are assessed for stem quality in Serbia's NFI. Assortments are not assessed during field data collection nor are they derived during subsequent data analysis.

39.3.2.2 Assessment and Measurement

The technical quality of timber was assessed on trees with dbh > 25 cm on sample plots, by the following classes:

- High quality—a tree which has a straight stem with slight taper, preferably free of branches, in good health and without technical defects. In broadleaves, the stem must produce a minimum of one veneer log, cylindrical in form and with a diameter of at least 40 cm;
- Medium quality—a tree with straight stem with slight taper, branched, in less good health and with minor technical defects;
- Low quality—a tree with a curved stem with sweep, a heavily branched stem, in poor health and with other technical defects.

The limitations existing in the NFI1 database do not allow for summary statistics to be presented on the quality of wood, although it was assessed during the course of field work.

39.3.3 Assessment of Change

39.3.3.1 Assessment and Measurement

Presently only one NFI cycle has been completed and it was not possible to estimate drain or increment directly using NFI data. As the NFI plots are permanent and the locations of trees are recorded, it will be possible to use the NFI data in the future for estimating both increment and drain.

39.3.3.2 Estimation of Increment

The current volume increment is calculated on the basis of a mathematical model which expresses a link between the percentage of volume increment (p_{iv}), number of trees (N), mean diameter per basal area (d_g) and its appropriate height (h_g), and the share of specific tree species in the mixture (s) (Banković et al. 2000a, b, 2002a, b).

$$p_{iv} = a \cdot N^b \cdot h_g^c \cdot d_g^e \cdot s^f \quad (39.1)$$

The multiplication of the percentage of increment by the volume per ha (v) generates volume increment per ha in an absolute amount (I_v):

$$I_v = V \cdot \frac{p_{iv}}{100} \quad (39.2)$$

Recapitulations of increment at various territorial levels were generated in the same way as for volume. Once the second NFI is implemented, it will be possible to calculate volume increment on the basis of the volume of two consecutive inventories and the volume of the trees removed in the meantime.

39.3.3.3 Estimation of Drain

As there is currently only one completed NFI cycle, it was not possible to estimate drain using NFI data. In the meantime, the SORS data will be used to estimate drain.

39.3.4 Other Wooded Land and Trees Outside Forests

Measurement of trees in NFI1 was limited only to forests areas. Trees which were on OWL, and on other categories of land as well, were not subject either to measurement or to any assessment.

39.4 Conclusion

The first NFI in the Republic of Serbia was implemented in the period 2004–2006. The sampling methodology was compatible with methodologies of most European countries with a long NFI tradition. Unlike the sampling methodology, the scope, structure and definitions of some data were not, in most cases, compliant with COST Action E43 and FAO criteria. This resulted in a highly reliable database on Serbian forests, which meets national needs, but is somewhat more limited in terms of meeting international reporting obligations. Serbia is already benefiting from NFI1 in a number of ways including a better insight into the spatial distribution of forests, the availability for use and the distance from processing capacities, classification of forests by a single purpose, particularly the protection of soil, water, etc. All of this has led to a higher quality of strategic forest planning in Serbia and its further development. The availability of the database and an opportunity to prepare various overviews of the condition of forests meets the needs of the private sector, NGOs and individuals looking for information on the forest estate. Serbia is benefiting greatly from the cooperation with international associations, such as ENFIN and FAO, particularly in terms of involvement in various NFI projects, and the experience of other member states. The NFI will be institutionally established to ensure stable and permanent sources of funds. Certain methodological corrections are required, thus increasing the scope of information collected and its harmonisation with international criteria. This will facilitate the long-term monitoring of forest ecosystems in Serbia and facilitate reporting to regional and global organisations.

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Chapter 40
Slovakia

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40.1 The Slovakian National Forest Inventory

40.1.1 History and Objectives

In the Slovak Republic there are two primary information sources about forests: (1) stand-wise inventory—forest management plans (FMP) and (2) National Forest Inventory (sample-based inventory in a regular grid) (NFI). FMPs have a long history and have served as the basis for sustainable forest management in Slovakia. They are created periodically, on a 10 year cycle for total forest area registered in the cadastre as forest land. Only 10 % of the total forest area is inventoried per year, hence annual information on forest status does not reflect the status of the total forest area. Using the FMP, information on forest status at national level is provided by a simple summation of data from all the FMP which are valid at the time of reporting. Nevertheless, this inventory only allows to assess forest-management related variables such as growing stock, species proportion, age structure, etc. The spectrum of information and the level of detail required have however, broadened, as the importance of forests for society grows. Nowadays, the information covers not only the traditional forest production characteristics and the potential woodcutting possibilities, but also ecology, forest health status, forest value, and biological diversity.

To address these new information needs, the importance of the NFI project was supported by policy and the first NFI in Slovakia was launched in 2004 (Šmelko

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et al. 2008). It's aim was to create a new integral system, which is able to give objective, up-to-date and comprehensive information about the condition and the development of all components of forest ecosystems at national and regional levels in a specified time point (at best in regular 10 year intervals). Also the NFI can be used as a basis for analyses and strategic decision-making by the managing bodies in forestry and other related sectors. The NFI in Slovakia is the first forest inventory based on statistical principles. It was established on a strictly defined grid over the Slovakia territory with strictly defined statistical principles and therefore it does not fit to any other monitoring systems being performed in Slovakia (e.g. monitoring plots within ICP Forests).

The first NFI revealed that there is higher amount of growing stocks in forests compared to traditional stand-wise inventory by 23 %. The likely causes of this difference have been discussed. From among many possible causes, stocking estimation was identified as the most probable and most important along with the fact that stand-wise inventory gives the results for the main stand (excluding thinnings to be done in the current decennium) while the NFI takes entire stand into account. Stand density estimated either by visual assessment or by comparing current basal area to potential one from yield models. It is common that the maximum stocking density is index 1, which means that the real basal area equal to the basal area from yield models. However, as results showed, there is a high frequency of forest stands with the higher density than that expected by models.

40.1.2 Sampling Methods and Periodicity

NFI data were collected during the two-year period, 2005–2006. The National Forest Centre (NFC) was responsible for data collection and data processing. It was a two-stage inventory primarily based on terrestrial sampling with help of remote sensing techniques. Terrestrial inventory plots were circular with an area of 500 m^2, established on a grid of 4 × 4 km over the whole territory of Slovakia. The total number of the plots in the grid was 3071. As many as 1419 plots were classified as forest applying the national definition for the forest, which is very close to the FAO definition (FAO 2004). The only difference is in the minimal crown coverage 20 % compared to 10 % in the case of FAO definition.

The aerial inventory was performed as a visual interpretation of orthophotographs (Geodis–Eurosense, 2002–2003 with the resolution of 1 m). The sampling units were the circular plots of the size 2500 m^2 distributed in the grid of 2 × 2 km. In total 12,667 plots were assessed in the aerial inventory. These plots were primarily used for the identification of Forest/Non-forest land, as well as a support for the orientation and navigation in the field. A base grid of 4 × 4 km was used for the terrestrial inventory, resulting in one quarter of the aerial inventory plots been assessed. Precise determination of the forest area and forest categories at national and regional levels is also an important output. The combination of terrestrial and aerial inventory reduced the sampling error of the forest area estimate by more than one half.

The NFI was carried out on all land covered by tree species, i.e. forests registered in the cadastre as forest land, as well as on other forested lands which met the national forest definition. Four types of ground inventory plots (A–D) were used:

- A—constant circle with radius r = 12.62 m for collecting data concerning terrain, site, stand and ecological characteristics, and for the inventory of deadwood and stumps on the ground; classification of forest/non forest category was done for this circle
- B—two concentric circles (r = 3 m and 12.62 m) for collecting tree characteristics of trees with diameter $d_{1,3}$ = 7–12 cm and $d_{1,3} \geq 12$ cm
- C—variable circle for young trees with diameter $d_{1,3} < 7$ cm, its flexible radius r = 1.0 m, 1.41 m or 2.0 m was chosen depending on the actual regeneration density
- D—enlarged constant circle with the radius 25 m established for the inventory of forest edges, forest roads and water resources.

Terrestrial inventory plots were in specific cases divided into separate homogenous parts—subplots (difference in forest structure, age, forest/non-forest land, etc.) for which all parameters were recorded separately. Minimum area of a subplot was 10 % of the inventory plot. For example, if the plot was established at the border of two forest stands with different age, species or at the forest edge creating the line between forest and non-forest area, or growing on different sites (e.g. forest site type) the plot was partitioned into two (or more if necessary) parts and all attributes were measured or assessed separately.

40.1.3 Data Collection

At least 100 parameters were recorded in each terrestrial inventory plot: production characteristics (number of trees, volume, assortments, stand structure, silvicultural and quality status of stands, forest regeneration, etc.); health status and forest damage; site and ecological characteristics (soil, forest, function type, degree of naturalness, risks, ecological stability, biodiversity, deadwood biomass, food for animals, forest edges, etc.); other characteristics (length, density and state of forest transport network, frequency and parameters of water sources and streams, etc.). In addition, increment cores, humus samples (three per plot) and soil samples (depth 0–10, 10–20 cm per plot) were taken from each plot identified as forest. All samples were archived and may be used for further analyses.

40.1.4 Data Processing, Reporting and Use of Results

40.1.4.1 Volume Estimation

Two-parameter volume equations were completed and verified for the main and related tree species (for 12 groups of species), which estimated tree volume (v) using tree diameter at breast height (dbh) and tree height (h). To ensure a more general utilisation of the results and the comparison with other EU countries, volume equations were prepared for the following five volume units:

1. timber from ground to the top diameter of 7 cm inside bark (HBK), which represents the official timber volume unit in Slovakia
2. timber from ground to the top diameter of 7 cm outside bark (HSK), which is most common in EU countries
3. timber from ground to the tree top excluding bark (KBK)
4. timber from ground to the tree top including bark (KSK)
5. volume of whole tree including tree top, branches and bark (SSK), which is important for other calculations, e.g. for the estimation of carbon storage in the aboveground biomass, etc.

The tree volume equations applied represent the regression $v = f(dbh,h)$, and were derived for 12 tree species from the data collected in the Czech Republic and Slovakia by various authors (see Petráš and Pajtík 1991). Prior to their use, all equations were verified and analysed in detail. The analysis revealed new findings that these equations approximate this relationship not only in the diameter range above 7 cm, which was so far the subject of the main interest, but also in the range from 0.1 to 7 cm (for KBK, KSK, and SSK). Hence, these equations are also applicable to trees with a dbh < 7 cm, which are inventoried within the scope of the NFI for the first time. In addition, the existing volume equations were also used for the tree species, for which no equations are currently available.

Assortment estimation (s) was completed for every tree with a minimum dbh of 7 cm using mathematical models of the national tree assortment tables (Petráš and Nociar 1991a; Mecko et al. 1993).

40.1.4.2 Deadwood

All standing and lying deadwood was measured in the plots. Each piece of lying deadwood with a diameter at the smaller end equal to or over 7 cm (coarse woody debris) was assessed by measuring the diameter at both ends, the length and the position in the plot (fixed area sampling). Deadwood smaller than 7 cm at the smaller end (small deadwood) was assessed by recording an estimated coverage and mean diameter (fixed area sampling). In addition, two perpendicular line transects (line intersect sampling) were used for inventory of small deadwood and the results were compared to fixed area sampling.

The volume of standing dead trees was determined from the volume equations of living trees (HSK). In order to determine the volume, new regression equations were derived, while the diameter at the top of the cut area *D* and the stump height *H* represent input variables. The volume of the lying deadwood with the top diameter of 7 cm was calculated from the measured diameters d_1 and d_2 (cm) outside bark at both ends and the length of each piece inside the terrestrial inventory plot using the Smalian's equation. The volume of small-sized lying deadwood (having diameter from 1 cm to 7 cm) was estimated by the original method, where the volume of small-sized lying deadwood (m^3) densely arranged in 1 m^2 is calculated from the biometrical model as a function of the middle diameter of small-sized lying deadwood multiplied by the area of the terrestrial inventory plot, estimated coverage of small-sized lying deadwood, and tree species proportion.

40.1.4.3 Tree Growth Area

Each tree was assigned a tree growth area, the sum of which for all trees equalled the total plot area. If the inventory plot included different tree species, age classes, growth stages or other forest categories, the plot was divided into separate parts for which the parameters were assessed separately. The particular tree growth area was determined from the regression models derived from the whole NFI data set separately for the individuals with the height below 1.3 m (in this case tree growth area is a function of their height), and for the trees with the height above 1.3 m (in this case tree growth area is a function of their diameter). For each inventory plot the sum of tree growth area of all recorded trees gave the total plot area. Tree growth area is a critical attribute during data analysis in expanding tree data to national estimates.

40.1.4.4 NFI Results

The NFI results were first published in a report for Ministry of Agriculture after the first cycle was finished. The first public-available publication was prepared in 2008 (Šmelko et al. 2008). However, NFI results have not been used for national or international reporting. Results from FMP were used for such reporting due to the long history and to ensure continuity. In addition, there has not yet been sufficient political pressure to use NFI data instead of FMP ones for reporting purposes at national and regional level. One of the reasons is that the results showed high differences between statistics made from FMP and NFI, especially in relation to growing stock.

The data from NFI have been used for some scientific studies (Bošela et al. 2013) and are now considered in several ongoing research projects (e.g. estimating soil carbon stocks using soil samples collected during NFI). Slovakia has joined the

ENFIN group and participated at several projects aiming at establishing NFI network harmonised over Europe for different purposes.

40.2 Land Use and Forest Resources

40.2.1 Classification of Land and Forests

40.2.1.1 General Land Classification

The national land use classification system recognises built-up land, agricultural land, forest land and other land according to cadastre. In total, there is more than 2 million ha of forest following the national definition (Table 40.1). Forests outside of the cadastre forest areas are referred to as "white areas". These areas are classified as agriculture in the national cadastre, but are not managed for agriculture. The total area of this category was officially 50–60,000 ha, but according to NFI it accounts for ca. 273,000 ha or 14 % of the forest area.

In the Slovak NFI, an area is considered as forest area when: (i) is covered by tree species with 5 m of potential height; (ii) crown coverage is more than 20 %; its width is at least 20 m; and (iii) is spanning more than 0.5 ha. The national forest definition indicates that it almost meets the FAO definition except for the crown coverage, as the FAO definition applies a 10 % threshold for crown cover.

Table 40.1 Area by national and FRA (FAO 2004) classifications

Category	Subcategory	Area (1000 ha)	FRA
Forests	Forests on forest lands (forests in cadastre)	1901 ± 20[a]	Forest
	Forests on non-forest lands (agricultural lands)	273 ± 10[a]	Forest
Agricultural land	Arable land	1360[b]	Other land
	Grassland	527[b]	Other land
	Other lands	58[b]	Other land
Build-up land	–	230[c]	Other land
Other land	–	555[d]	Other land
Total	–	4904	

Note [a]Area according to NFI in SR (2005–2006)
[b]Area according to forest management plans (stand-wise inventory) 2012
[c]Area of build-up land was 4.7 % of the total area of SR. *Source* Geodesy, Cartography and Cadastre Authority of Slovak Republic; area of SR according to Statistical Office of SR is 4,903,600 ha
[d]The difference between sum of the individual categories and the total land area of SR

40.2.1.2 Forest Classification by Use

Since 2005, forests available for wood supply (FAWS) have been assessed. To date FAWS has been assessed on 91.5 % of the forest area. The primary functions of the forest area according to FMPs (2012) are:

- Commercial forests (ca. 69 %)
- Special purpose forests (14 %). This includes forests in the protective zones of water sources, spa forests, recreational forests, forests for game management, protected areas, forests for genetic resources preservation, forests for study and research, military forests
- Protective forests (17 %). This includes forests growing on highly unfavourable sites, high-mountains forests under the timber line, forests in the zone of dwarf pine, and other forests were soil protection is considered as prevailing function.

40.2.1.3 Classification by Ownership Categories

Ownership of the forest estate according to forest management plans (2012) is:

- State (ca. 40 %)
- Private (13 %)
- Municipal (10 %)
- Community (26 %)
- Church (3 %)
- Agricultural cooperative (0.2 %)
- Other (8 %).

40.2.1.4 Forest Management and Cutting Systems

Close-to-nature shelter-wood system prevails in Slovakia, while clear-cutting is applied to less than 20 % of the forest area. In particular, protective forests have usually very low harvesting intensity, which is caused by natural circumstances (inaccessible sites, very steep slopes, etc.) and low density of forest road network. The following cutting systems are practiced in the Slovak forest estate:

- Establishment—natural regeneration, planting, or sowing (very low frequency)
- Brush cutting and cleaning (removal of unwanted shrubs or tree species)
- Thinning in young stands aged 50 years or less (no harvesting)
- Thinning in stands of aged over 50 years or more

– Clear cutting (whole mature stand is removed at once)
– Cutting in stands managed by close-to-nature techniques:
  - Preparation cutting (allow seeds to germinate)
  - Cutting to increase a light-use efficiency by seedling or advanced regeneration
  - Final cutting (removal of the rest of trees)
– Selection thinning and cutting (special management of selection forests—uneven-aged, especially those forests consisting of spruce and fir species).

40.2.1.5 Legal and Other Restrictions for Wood Use

In Slovakia forests are generally available for wood supply, but a small proportion of the forest area is strictly protected and thus not available for normal forest management practices. Forests available for wood supply exclude forests under the highest level of protection (such as natural reserves) and forests which are not accessible for harvesting (mountain pine forests on rocky terrain). In Slovakia, military forests are not accessible without permission. However these are commonly managed so the forests are considered to be available for wood supply and should be included in the FAWS category. As a result, there are approximately 96 % ± 1.1 % of forests available for wood supply in Slovakia (Table 40.2). In addition, there are some special-purpose categories where forests are managed but with a level of restriction (Tables 40.3 and 40.4). For example, forests in the National Parks with the 2nd–3rd degree of protection (the scale starts from 1st degree—minimal protection and ends with 5th degree, which is the highest level of protection usually used for natural reserves with total exclusion of forest management) are available for wood supply, but the management is limited so that no clear-cutting is allowed and close-to-nature management is to be preferred.

Table 40.2 Area of forests available for wood supply (NFI)

Category of forests	Area (1000 ha)	% Area (±error)
FAWS	2002 ± 20	92.2 ± 1.1
Natural reserves	92 ± 12	4.2 ± 0.6
Military forests	79 ± 11	3.6 ± 0.5
Total	2173 ± 22	100

Table 40.3 Area of forests according to prevailing functions in relation to FAWS (NFI)

Category	Prevailing functions	Area (1000 ha)	Area % (± error)
Commercial forests	Wood production[1]	1542 ± 31	70.9 ± 1.4
Special purpose forests	Education and research forests[a] National parks and natural reserves, etc.[b] Protected zones of water resources[b] Enclosed game parks[b] Urban forests[a] Military forests[a]	225 ± 19	11.9 ± 0.9
Protective forests	Unfavourable sites[c] Zone of dwarf pine[c] Prevailing function of soil protection[c] High mountain forests[c]	374 ± 22	17.2 ± 1.0
Total		2173 ± 22	100

Note [a]Forest available for wood supply, but with some level of restriction
[b]Forests include strictly protected areas which are not available for wood supply
[c]Forests in which the management is not restricted, but the production function is not primary, and it is often economically inefficient

Table 40.4 Legal restriction classes (NFI)

Degrees of natural protection	Number of plots	Area		Growing stock		
		1000 ha	%	%	Million m^3	m^3 ha^{-1}
1st Basic protection	881	1334 ± 32	61.3 ± 1.4	57.9 ± 2.0	332.8 ± 11.4	250 ± 6
2nd Landscape areas	321	500 ± 25	23.0 ± 1.2	25.6 ± 1.6	147.1 ± 9.3	294 ± 11
3rd National parks	155	242 ± 18	11.1 ± 0.9	12.0 ± 1.1	68.9 ± 6.5	285 ± 16
4th Nature monuments	4	6 ± 4	0.3 ± 0.2	0.3 ± 0.2	1.9 ± 1.1	297 ± 49
5th Reserves	58	92 ± 12	4.2 ± 0.6	4.2 ± 0.7	24.1 ± 4.0	261 ± 27

Note 1st to 3rd degree—wood supply is generally not restricted; 4th degree—management is limited to use close-to-nature techniques (clear-cuttings are not allowed); 5th degree—no management measures are allowed

40.2.1.6 Further Classification of Forests

Among other, the age structure of the forests is traditionally reported information in forestry, because it is an important indicator for ensuring sustainable forest management. However, estimation of forest age is often complicated and sometimes very difficult due to multi-storied forests which have become more frequent. For this reason, the NFI in Slovakia provided new age categorisation of the forests (Table 40.5). Here, forests with only one a clearly identified vertical layer were classified using the standard system with age estimation only for the main layer. Forests, in which two and more vertical layers were present, were classified into three new categories: (a) uneven-aged with the age of upper layer up to 60 years; (b) uneven-aged with the age of upper layer over 60 years; and (c) forests in which the second vertical layer was natural regeneration—typical one-layered forests with the next generation below.

In Slovakia, NFI results show that broadleaved species dominate the conifer species, with 60 % of the total basal area broadleaved versus 40 % conifer. The main tree species are European beech (*Fagus sylvaica*), spruce (*Picea abies*), oak (*Quercus petraea*), pine (*Pinus sylvestris*), hornbeam (*Carpinus betulus*), fir (*Abies alba*), and others (larch (*Larix decidua*), maple (*Acer* spp.), ash (*Fraxinus excelsior*), elm (*Ulmus* spp.), etc.). The proportion calculated from species area (tree growth area) is slightly different (Table 40.6).

40.2.2 Wood Resources and Their Use

40.2.2.1 Standing Stock, Increment and Drain

Total growing stock in Slovakia, estimated by the NFI, was more than 570 million m^3 (Table 40.7). This amount includes also the growing stock of forests which were found in the total forest area, which includes forest land outside of the cadastre forest area. Growing stock estimated from NFI was found higher by about 23 % compared to the growing stock reported by the FMP.

Increment and felling are not yet available in NFI, since only 1st NFI was performed in 2005–2006. The next round started in 2015 and results are to be

Table 40.5 Forest area (national definition) by age classes (NFI)

Age classes (years)	Area (1000 ha)	Area (%)
Clearing—0	15 ± 5	0.7 ± 0.2
1–20	243 ± 19	11.2 ± 0.9
21–40	264 ± 19	12.1 ± 0.9
41–60	215 ± 18	9.9 ± 0.8
61–80	158 ± 16	7.3 ± 0.7
81–100	148 ± 15	6.8 ± 0.7
101–120	38 ± 8	1.7 ± 0.4
>120	33 ± 8	1.5 ± 0.3
Uneven-aged <60	275 ± 19	12.6 ± 0.9
Uneven-aged ≥60	550 ± 26	25.3 ± 1.2
Two-layer regenerated	236 ± 19	10.8 ± 0.8
Total	2173 ± 22	100

Table 40.6 Forest area (national definition) by dominant tree species

Tree species	Area (1000 ha)	Area (%)	Basal area (%)
Picea abies	457 ± 25	21.0 ± 1.1	26.4 ± 1.7
Abies alba	58 ± 10	2.7 ± 0.5	3.5 ± 0.6
Pinus spp.	117 ± 14	5.4 ± 0.6	6.6 ± 0.9
Other coniferous	50 ± 9	2.3 ± 0.4	1.8 ± 0.4
Fagus sylvatica	596 ± 26	27.4 ± 1.2	30.0 ± 1.6
Quercus spp.	226 ± 18	10.4 ± 0.8	11.8 ± 1.0
Carpinus betulus	174 ± 16	8.0 ± 0.7	5.5 ± 0.6
Hard broadleaved	188 ± 17	8.7 ± 0.8	4.9 ± 0.6
Other broadleaved	304 ± 20	14.0 ± 0.9	9.5 ± 1.0
Total	2173 ± 22	100	100

Table 40.7 Growing stocks of tree species aggregated into species groups

Tree species	Number of plots	Growing stock (million m^3)	Growing Stock (%)
Picea abies	577	161.8 ± 10.2	28.1 ± 1.8
Abies alba	232	22.6 ± 4.1	3.9 ± 0.7
Pinus spp.	222	32.1 ± 4.3	5.6 ± 0.7
Other coniferous	116	8.9 ± 2.1	1.5 ± 0.4
Fagus sylvatica	813	202.6 ± 10.5	35.3 ± 1.8
Quercus spp.	404	64.1 ± 5.7	11.1 ± 1.0
Carpinus betulus	407	20.9 ± 2.3	3.6 ± 0.4
Hard broadleaved	643	25.3 ± 2.9	4.4 ± 0.5
Other broadleaved	780	36.7 ± 3.7	6.4 ± 0.6
Total	1419	574.8 ± 12.4	100

available in 2017–2018. However, this information is available from permanent FMP. In 2012, total annual felling was 78.7 % of the annual total increment, and 2.0 % of the total growing stock.

40.2.2.2 Tree Species and Their Commercial Use

Similar to other central European countries, Norway spruce is the most economically important species in Slovakia followed by Euroepean beech and oak. According to the Green Report on Forest Management in Slovakia total fellings in 2012 amounted to over 8 million m^3 (Ministry of Agriculture and Rural Development 2013). However, as much as 43 % of it was reported as incidental caused by different kinds of disturbance, but mostly windstorm damage. From this amount, coniferous species dominated amounting to approximately 60 %. More than 7 million m^3 of the felling were sold to the timber companies in Slovakia and more than 2 million m^3 were exported (not all timber amounts sold to companies established in Slovakia are processed, and are exported). Less than 500,000 m^3 of roundwood from broadleaved species is processed in Slovakia. There is a lack of veneer and high-quality assortments processed by Slovakian timber companies and they are mostly sub-contractors to foreign companies. There is a high demand for pulpwood from both coniferous and broadleaf in Slovakia. Use of timber for energy has been slowly increasing and reached 900,000 tonnes in 2009, from which woodchips amounted to 210,000 tonnes.

40.3 Assessment of Wood Supply

40.3.1 Forest Available for Wood Supply

Around 40 % of the forests in Slovakia are owned by the State, with the remaining privately owned (usually community forests). The primary use of the privately owned forests is wood production and wood supply. However, areas which are in some degree legally restricted for wood supply (natural reserves, national parks, habitats defined under NATURA 2000, and military forests) are often located in such forests making the owners limited to use the wood for industry purposes. On the other hand, only a few forested areas, mostly natural reserves, can be considered completely unavailable for wood supply in Slovakia. However, for the international reporting, only forests in natural reserves that have the highest level of protection are excluded.

Concerning the assessment of FAWS within NFI, each inventory plot was assigned the forest category according to the prevailing forest function it serves at that time (Table 40.3). In addition, for each inventory plot, the degree of protection was recorded as well (Table 40.4). In addition to field assessment, each plot was assigned to the restriction class using GIS techniques and existing GIS layers for comparison and check. To date NFI data have not been used for international reporting and FAWS have been reported using summation of FMP area.

40.3.2 Assessment of Stem Quality and Assortments

40.3.2.1 Stem Quality and Assortments

Stem quality and assortments are assessed and quantified in the Slovakian NFI (Šmelko et al. 2006, 2008). While stem quality is visually assessed in the field, assortments are generated from models developed for Slovakia in the past.

40.3.2.2 Assessment and Measurement

In the Slovakian NFI wood quality was assessed for two objectives. The first was to evaluate the development of the stem quality (including potential and current status —assessment of the quality classes A, B, C) and to quantify the quality structure of the forests (combination of the wood quality and assortments). The Slovakian grading system used in forestry, combines both quality classes with assortments to assess the end use of the tree bole. Information on the wood quality structure describes the current and the potential standing timber. In the NFI, the quality of each tree was assessed, while in mature stands it was evaluated as the actual status and in the younger stands as a potential regardless of the dimension (dbh, height). In this context, potential means that each tree is expected to achieve the particular quality class when it is mature. Each tree was classified into one of the three classes: A (healthy, straight, untwisted, centric, with no shape deformations), B (slightly twisted, with smaller technical defects, thin or medium-sized branches or knots are allowed), C (with great technical defects, large-sized branches, twisted, crooked). These quality classes in combination with tree dimension (dbh) were then used for partitioning the volume of each tree (volume under bark, but also over bark) into the quality classes and assortment.

Parameters used in the field assessment of stem quality:

- *Tree height*
  It is the length of tree from the ground to the tree top. A two-phase method for tree height estimation is applied. All trees on the plot are visually estimated for their height and 1/3 or a minimum of 10 trees for same tree species are measured for their height. The final height of the estimated trees was derived using mathematical models.
- *Diameter at breast height* (*dbh*)
  Measured for each tree on the plot and recorded only for those trees with dbh over 7 cm. In case dbh is less than 7 cm the count of trees at 1 cm dbh classes are recorded on the small-area plot.
- *Living crown base*
  It is the distance between the tree base (or ground level) up to the lower part of living crown. It was measured/estimated for each tree with dbh over 7 cm.
- *Tree fork*
  The occurrence of tree fork at the height below 1.3 m and above 1.3 m is assessed.
- *Damage to stem*—the assessment is performed on lower 1/3 of tree stem, including tree base (stump) and aboveground roots:

  0. No damage
  1. Mechanical (mostly caused by logging)
  2. Insect (bark beetles, ligniperdous, others)
  3. Fungus (necrosis, sporocarps, rot)
  4. Game (debarking, peeling)

5. Others (frost, bolt, birds, etc.)
6. Stem break (breakage below living crown).

- Moreover, the extent of damage is also recognised:

1. Slight damage (up to 1/8 of the circumference)
2. Moderate damage (from 1/8 up to 1/2 of the circumference)
3. Intensive damage (more than 1/2 of the circumference).

- And according to *age of damage*:

1. New damage (recent): The damage that occurred recently or from the last growing season
2. Old damage: The damage that occurred 2 or more growing seasons ago
3. Repeated damage: The damage has signs that it has occurred repeatedly for several years.

Stem quality classification system

Stem quality is assessed using visual indicators regardless tree dimension (height, dbh). Each tree over 7 cm in dbh was assessed for its quality. Only lower 1/3 of the stem is assessed into the following categories (these categories were used for timber grading of each tree using the model, which is described in the last chapter):

A. High quality logs, almost without knots (only healthy knots under 1 cm in diameter at the base), twisting (spiral growing), and without other technical defects. From the tree of the A quality the assortments of I and II classes can be made (as according to Slovak Technical Norm—STN).
B. Average quality logs, with small technical defects. In the case of hardwood all of healthy or unhealthy knots under 4 cm are allowed. For spruce and fir healthy or unhealthy knots under 4 cm and for Scots pine fewer than 6 cm are allowed. This category includes the roundwood used as saw logs (IIIA class).
C. Low quality logs with large technical defects, with high frequency of branches (densely branched trees), twisting up to 4 %. Healthy knots without limit for the size (diameter) are allowed, unhealthy up to 6 cm in the case of softwood, and up to 8 cm for hardwood. It includes the logs which meet the requirements from the quality C2 (III.B class) or C3 (V class).

Quality and assortment classes

National standards define minimal dimensional characteristics (length and diameter) for each individual grading class. The quality classes and the assortments are defined in the STN 480055 for softwood and 480056 for hardwood. The standards define minimal dimensional characteristics (length and diameter) for each individual grading class. Both softwood and hardwood species are assorted into six main quality classes: A1, B1, C1, C2, C3 a D1.

Roundwood of the highest quality A1 is used as veneer logs for sliced veneer or as a special raw wood for musical instruments. High quality class B1 is used for making peeled veneers, sporting goods or wooden barrels. Average quality roundwood is categorised in class C1. This is used as saw logs (C1.1, C1.2, C1.3), logs used for constructions (C1.4) and logs for aggregate processing (C 1.5). Quality class C2 is used in mining industry as pit wood (C2.1) or thin poles (C2.2). Pulpwood for chemical or mechanical processing and chips for particle boards are made from logs of C3 class. Wood logs not sorted in previous classes belong to quality class D. Firewood assigns into this category.

40.3.2.3 Estimation and Models

Model for grading standing trees into stem quality and assortment classes

Tree height, DBH and the tree quality classes (A, B, C) were used as the input variables into a model, which refines the stem quality classification system and produces assortment information. The mathematical model (developed by Petráš and Nociar, 1991a, b; Mecko et al. 1993; 1994a, b) gives the proportion of overbark volume in each standing tree of assortments in six assortment classes I, II, IIIA, IIIB, V, VI. Only trees with DBH over 12 cm are used.

Empirical material and the model description

Data were obtained from 167 research plots which were established over the main growth regions of Slovakia taking into account tree species. In each plot, minimum of 70–80 trees were assessed. In total 16,020 trees were destructively sampled: 1705 trees of Norway spruce, 1161 of silver fir, 1836 of Scots pine, 3042 of oak sp., 4203 of European beech, 1401 trees of hornbeam, 1359 trees of birch and 1313 larch trees.

The tree-level model of wood quality and assortments was built up using regression modelling of the proportion of quality classes and assortments dependent on tree dendrometric characteristics. From among many possible parameters, the dbh, quality and damage to the tree were used from all main species (mentioned above), except for European beech, for which the tree age and the growth region were found to be important in addition to the previous parameters. The damage to trees and the quality are visually estimated in the field. Each standing tree (log) is categorised into quality classes A, B, C.

Estimations of stem quality and assortments from the NFI

Timber quality and assortment structure of all forests in Slovakia were estimated for the first time. The results showed, as expected, that the average stem quality class was most frequent. However, coniferous species were found to have higher proportion of the highest quality stems, while the proportion of growing stock in the worst quality class was found higher for broadleaves (Fig. 40.1).

Concerning the assortment structure of Slovakian forests (Fig. 40.2), the highest proportion of growing stock of conifers was found for IIIA and IIIB (saw timber, logs used for construction, aggregate processing), but the pulpwood (V) was most frequented for broadleaves. Also the higher proportion of firewood was found for broadleaves. The structure of assortments suggested that coniferous species were of better timber quality.

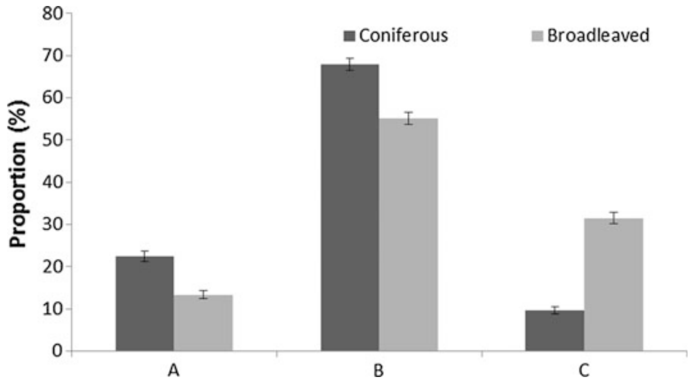

Fig. 40.1 Percentage of growing stock by quality classes assessed directly in the field (Šmelko et al. 2008)

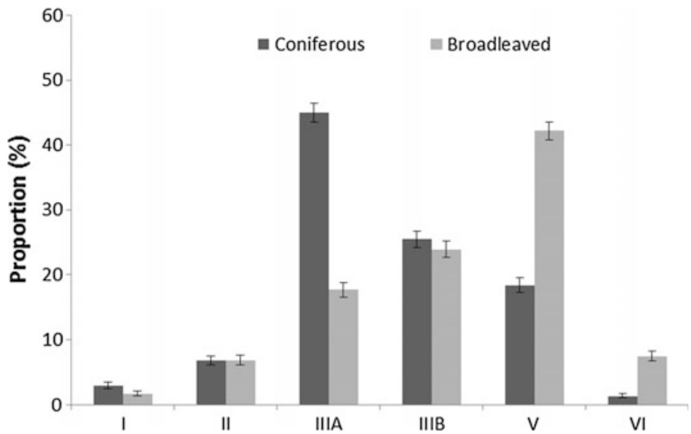

Fig. 40.2 Percentage of growing stock by timber assortments generated by a model using the parameters assessed or measured in the field during the NFI (Šmelko et al. 2008)

40.3.3 Assessment of Change

Since only one cycle of National Forest Inventory has been conducted to date in Slovakia, no information on change estimation is available. The second NFI is being conducted between 2015 and 2016.

40.3.4 Other Wooded Land and Trees Outside Forests

The Slovakian NFI does not assess Other wooded land (OWL), other land with tree cover and trees outside forest. It only distinguishes between forests on forest land (defined as forest land in the cadastre) and forests on non-forest land (defined as e.g. agricultural land in the cadastre). There are no plans to include OWL in the second NFI cycle. However, this may become necessary in the future since there is increasing demand on information about these categories throughout Europe.

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Chapter 41
Spain

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41.1 The Spanish National Forest Inventory

41.1.1 History and Objectives

The necessity to have homogenous and objective forest statistics for decision making at national level provided the impetus for undertaking the first forest inventory on a national scale in Spain (NFI1) between 1965 and 1974. This First National Forest Inventory (NFI), based on aerial photograph interpretation, set the foundations for subsequent NFIs. Although the initial objective was to have a 10 year cycle between NFIs, due to circumstances related to the national infrastructure, the Second National Forest Inventory (NFI2) did not commence until 1986. Since NFI2, there has been a continuous inventory with permanent plots in most of the Spanish regions operating over a cycle of approximately 10 years. NFI2 incorporated certain improvements over NFI1 thanks to the availability of new technology, but efforts were concentrated

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on the measurement of standing woody stock. However, the Third National Forest Inventory (NFI3), which commenced in 1997, included further assessments. Based on recent global concerns in relation to forests, new forest indicators and measurements were required by different reporting obligations such as the Kyoto protocol and international requirements (UNFF, LULUCFF). Furthermore, under the auspices of COST Action E43 in 2010, the need to harmonise forest indicators and definitions worldwide led to the implementation of new field assessments, which were integrated into the NFI3 methodology. The NFI3 field work ended in 2007, and the Fourth National Forest Inventory (NFI4) began in 2008. Field data collection is ongoing and data processing work is progressing simultaneously.

Although the primary objectives of the NFIs have changed over the years, the current aim of the Spanish NFI is to provide information at national and regional level about the state and evolution of forests through the analysis of growing stock, development of forest resources, forest health and forest biodiversity.

41.1.2 Sampling Methods and Periodicity

The NFI covers all forest land in Spain. Nevertheless it should be stated that the national definition of the monitoring area and sampling methods has changed over the different NFIs. In the NFI, all forest areas with a crown cover greater than 10 % were considered, in the NFI2 and NFI3 the minimum crown cover considered was 5 % and in the NFI4 the threshold has changed back to 10 % 2018. However, it is possible to determine the area corresponding to the different crown cover values.

From the second cycle onwards the plots are permanent, enabling growth comparisons and stratification to be undertaken post-sampling. Sample plots are established at the intersections of a 1 × 1 km UTM grid (Alberdi et al. 2010). Since NFI3, land cover classification and forest area estimation are described prior to the NFI using the National Forest Map, (E:1:50,000) (NFM50). Currently, the area of each NFI4 forest strata is estimated using the NFM25 (E:1:25,000), adding the tessera (i.e. basic unit, having a specific land use with homogeneous forest structure and forest type) belonging to each stratum (Table 41.1).

The National Forest Map of Spain (NFM) shows the distribution of Spanish forest types. Its main purpose is to provide the base mapping layer for the NFI. Like the NFI, the project operates on a ten-year cycle, so the latest edition of the map is expected to be developed between 2007 and 2017. The photointerpretation and digitisation is performed on digital orthophotos provided by the National Geographic Institute as part of the National Plan for Aerial Orthophotography (PNOA). The methodology for producing the map comprises three phases: photo-interpretation, field monitoring and quality control. The main stratification factors are: the main species, crown cover, stand age categories and sometimes ownership type. Geographical context such as islands are also considered.

Table 41.1 Spanish National Forest Inventory characterisation

Inventory	Year	Stratification	Sampling method and field plots	Number of plots
NFI 1	1965–1974	Grid over photographs	Optimal allocation of plots; temporary plots	65,000
NFI 2	1986–1995	Grid over maps	Systematic 1-km × 1-km grid; permanent plots	84,203
NFI 3	1997–2007	Grid over digital maps (1:50,000)	Same systematic grid as NFI2; permanent plots	95,327
NFI 4	2008–2018	Grid over digital maps (1:25,000)	Same systematic grid as NFI3; permanent plots	NA

The minimum spatial unit in the NFM25 depends on the land class type: forest land (1 ha); floodplain forest (0.5 ha); agricultural land (2 ha); beaches, dunes and sandy areas (0.5 ha); wetlands (0.5 ha); inland water (1 ha); urban land (1 ha).

41.1.3 Data Collection

Spain's NFI uses permanent field plots that consist of four concentric circular fixed areas with radii of 5, 10, 15 and 25 m. Data collection can be categorised into three main classes: stand description, measured tree data and biodiversity assessment.

Stand description variables describe the forest stand where the field plot is located. It encompasses the following points:

- Site description: Land use/cover levels, erosion, topographic parameters (slope, aspect, altitude), soil type, soil texture, fuel model, etc.
- Growing stock: Tree cover, species dominance (only to the three principal species in the plot), age category, species composition, spatial distribution of trees, stand structure, origin, etc.
- Understory—Shrubs: species cover and average height
- Silvicultural treatments: basic forest management system, cuttings, silvicultural measures, soil scarification, drainage
- Others: accessibility, date, filed work times and team who carried out the survey.

The tree data consists of the following parameters:

- Tally tree data: diameter at breast height (dbh), height, species identification, tree localization (polar coordinates), quality class, taper form and health status (identification, location and degree of affection of the damage)
- Regeneration (ingrowth and saplings)
- Additionally, crown height is being measured in the NFI-4 for a number of purposes such as to assess crown fire crown potential (Fernández-Alonso et al. 2012)

- Dead tree data, only with respect to trees which were alive in the previous inventory.

The biodiversity assessment data are the following:

- Ground cover (bare soil, litter, rocks, etc.)
- Presence of invasive species
- Classification of life forms in ground vegetation cover (structure)
- Complementary stand structure measurements
- Dead wood
- Micro-sites (elements indicating naturalness, such as nests, and others showing human activity, such as the presence of cattle)
- Impact of browsing
- Stand age.

41.1.4 Data Processing, Reporting and Use of Results

NFI data are used nationally and regionally (Autonomous Communities) to formulate forest and environmental policy, for international reporting (Global FRA, FOREST EUROPE, State of Europe's Forests criteria, indicators and reporting related to greenhouse gas monitoring), as well as for basic and applied forest research (Gomez-Aparicio et al. 2011; Marti-Queller et al. 2013; Hernández et al. 2014).

For national and regional reporting, the results as regards the estimation of NFI standing stock can be classified as follows:

1. Estimation (volume, basal area and density) of trees
2. Estimation (volume, basal area and density) of species and forest strata
3. Stratum results.

The volume of single trees is defined as the volume of the bole over bark, above stump (considered 20 cm height) and to a stem top diameter of 7.5 cm. The volume of growing stock of trees includes the stem volumes of all living trees of all species with a dbh ≥ 7.5 cm. The general equations used to calculate volume over and under bark are:

$$V_{ob} = a_1 + b_1 d_i^2 h_i \tag{41.1}$$

$$V_{ub} = a_2 + b_2 V_{ob} + c V_{ob}^2 \tag{41.2}$$

where V_{ob} and V_{ub} are the volume (dm^3) over bark and under bark respectively, and a_1, a_2, b_1, b_2, c the model parameters, d (mm) is the *dbh* and h the total height of the tree. For each tree species and taper form (six categories), an equation is defined.

The volume of large branches (diameter at the thinner end >7.5 cm) is also calculated using specific equations per tree species depending on the *dbh*.

The estimated value per plot and hectare (ha) is calculated by expanding the tree values using a scale factor which varies according to the plot radius (depending on the diameter threshold).

Finally, stratum values are estimated by determining the area and number of plots of each stratum.

Change assessments are obtained with permanent plots through comparisons of two consecutive inventories.

It is important to note that forest area and its classification is provided by the Spanish National Forest Map.

Other estimates provided by the Spanish NFI include: number of stems, regeneration, tree damage (cause, importance and where), shrub species, shrub cover and height (from which biomass can be derived) and dead wood. They can all be classified by forest type, altitude or forest ownership.

41.2 Land Use and Forest Resources

41.2.1 Classification of Land and Forests

41.2.1.1 General Land Classification

In Spain, the land use classification is generated for each of the 17 Autonomous Communities and can be divided into Forest land, Agricultural land, Settlement land (including Urban land) and Inland water (Table 41.2).

In Spain we also apply the FAO-definitions for land use/cover for the elaboration of the NFM. In the national land use classification system, forest land known as "*monte*" includes other wooded land, grasslands, wetlands, dunes and sandy areas. Forest land also includes protected areas where forestry operations are strictly forbidden.

41.2.1.2 Forest Classification by Use

Based on different international definitions from FAO, FOREST EUROPE, EUROSTAT and CBD among others, the Spanish land area is classified into the following uses (Table 41.3):

- Forest: land covered by dominant tree species with Fcc ≥10 %.
- Other wooded land (OWL): land covered by shrubs and herbaceous vegetation. Tree species can be present but always with Fcc <10 %.

In Spain, forest land is not classified according to the forest management system employed or by the productive or protective functions of the forest. However, since

Table 41.2 National land use classes and forest area

Class name		Definition	Area (1000 ha)	Corresponding FRA classes
Forest land	Forest	Trees crown cover over 20 % Dehesas (agrosilvo pastoral systems) are included	16,528	Forest
	Open forest	Trees crown cover over 10 % Dehesas (agrosilvo pastoral systems) are included	1,907	Forest
	Very open forest	Trees crown covers between 5-10 % or shrubs Dehesas (agrosilvo pastoral systems) are included	4,922	Other wooded land
	Forest land. Grasslands, wetlands, dunes and sandy areas	Grasslands, wetlands, dunes and sandy areas	3,814	Other land
Non forest	Agricultural land		21,276	Other land
	Inland water		384,173	
	Settlement land (Urban land)		1,786	Other land, other land with tree cover
Total			50,617	

Comparison with (FAO 2010) classification

Table 41.3 Classes within forest land and areas (IEPNB 2012)

Use	Area (1000 ha)	Area (%)
Forest	18,373	36.30
Other wooded land	9,339	18.45
Total Forest and OWL	27,711	54.75

1992, Spain has compiled annual statistics on productive and protective reforestation by region as well as on afforestation under the Common Agricultural Policy (CAP), which reveal a marked decreasing trend. As regards protective areas, 40.46 % (11,211,569 ha) of the total forest land is protected by the NATURA 2000 Network or other national protective mechanisms.

41.2.1.3 Classification by Ownership Categories

Forests in Spain are classified into public or private:

– The public forest can belong to the State, to the Autonomous Communities, to the Local authorities or to other public entities (government-owned institutions or corporations or other public bodies). This public forest can be patrimonial or of public domain. Public domain forest includes: (i) forests belonging to the Catalogue of Public Utility Forests; (ii) communal forests belonging to local authorities, but utilised by the local people; (iii) forests not included in the previous two classes, but which have been earmarked for public use or service.
– Private forests are those owned by individuals, societies, collectives and other private entities. Collective ownership can be classified into "*Montes Vecinales en Mano Común*" (forests that belong to local associations, the rights to which are unalienable, imprescriptible, indefeasible and indivisible) and "*Montes de Socios*" (properties belonging to different natural or legal persons, in many cases several hundred, which have a percentage of ownership of the corresponding forest).

According to this classification, 29 % of forest land is public forest, 70 % is private forest and 1 % is unclassified or unknown (Table 41.4).

41.2.1.4 Forest Management and Cutting Systems

In Spain, four eco-regions are present: Alpine, Atlantic, Mediterranean and Macaronesic. This fact implies great species diversity with very different stand structure. Due to this diversity it is not possible to define a 'main management system', as the system varies depending on the different variables (species, area, defined objective of the stand, etc.). For instance, there are uneven-aged stands of conifers in the Pyrenees where a selection system is used; *Quercus ilex* stands managed as a coppice system; and in productive forests of *Pinus radiata* in the Atlantic area, an intensive even-aged system is applied. It is important to note that agro-sylvo-pastoral systems of the Mediterranean Dehesas, where stands of mainly *Quercus ilex* and *Quercus suber* constitute an important part of the forested land.

In Spain, no information exists at national level on the type of forest management or silviculture applied in each forest stand, although some regions provide

Table 41.4 Forest area according to the national forest definition by ownership (Magrama 2012)

Ownership category	Forest area (1000 ha)	Area (%)
Public	5,336	29
Private	12,836	70
Unknown	2	1

such information. However the following related information is recorded in every NFI plot:

- Type of regeneration felling (those carried out in mature forest systems with the main objective being to obtain wood) according to the following classes: not observed; clear cutting; clear cutting by clumps; strip cuttings; selective cutting; other or unknown.
- Forest cover improvement treatments (in which the main objective is to improve the tree population that remains after the treatment) according to the following classes: not observed; cleaning (grass-cutting, brush-cutting, brush-out, etc.); cleaning; thinning; pruning; others.
- Ground improvement treatments according to the following classes: not observed; planting with manual auger; dibble-in; ripping; terraced; not identified; others.

There are no statistics at national level for these silvicultural treatments but estimates can be made.

41.2.1.5 Legal and Other Restrictions for Wood Use

Forests in Spain are managed under the framework of the current “Montes Law” (2003). This law specifies certain restrictions associated with forest characteristics, systems employed, wood quality and exploitation areas, among others. The main limitations affecting wood supply are the following:

1. Legal restrictions.

Protected areas: Forest operations are restricted or forbidden in areas protected for biodiversity purposes. These include National Parks, nature parks, reserves, and others. A land protection classification is available in the GIS database.

Protected species: In Spain, the responsibility for the identification and protection of individual species is at provincial level.

2. Topography restrictions.

Altitude: In Spain, a number of studies reveal that above 1700 m, most of the forest which is capable of reaching such altitudes in the Spanish Peninsula and in Balearic Island is not harvested.

Slope. This restriction is associated with the limits of harvesting technology. In Spain, the maximum slope threshold for harvesting is 45–50 %, although in the Atlantic area it can reach 75–80 %.

3. No legal environmental or biodiversity conservation restrictions. The forest has a protective function.

The main restriction is due to erosion. No logging should be carried out beyond the upper limit of 50 tons per hectare per year.

41.2.1.6 Further Classification of Forests

Further classification of forests in national statistics is mainly done through the national classification of development class, crown cover and forest types. A national classification of 60 forest types is used both for NFI and NFM. In Table 41.5, the most representative forest types (with a percentage greater than 1 % of the total forest area) are shown.

Spanish forest land is not classified (to date) into productive or not productive forests or by age classes. However, from the NFI, forest land can be classified according to tree development stages. The development stages defined in Spain are: young growth, thicket, polewood (10 cm < dbh ≤ 20 cm) and high forest (dbh > 20 cm) (Table 41.6). However, stand age is recorded in the NFI-4 and in future it will be possible to characterise each plot by its stand age.

Table 41.5 National forest area (national definition) classified by main forest types

Spanish forest type	Forest area (1000 ha)
Oak Forest of *Quercus ilex*	2,814
Dehesas	2,435
Aleppo pine Forest (*Pinus halepensis*)	2,080
Scots pine Forest (*Pinus sylvestris*)	1,034
Mixed autochthonous broadleaves and coniferous forest of the Mediterranean biogeographical region	1,021
Oak Forest of *Quercus pyrenaica*	841
Maritime pine Forest in the Mediterranean region (*Pinus pinaster* subsp. *hamiltonii*)	823
Mixed broadleaves Forest in the Mediterranean biogeographical region	7,934
Austrian pine Forest (*Pinus nigra*)	701
Eucalyptus grove	637
Mixed autochtonous coniferous forest of the Mediterranean biogeographical region	620
Stone pine Forest (*Pinus pinea*)	402
European beech forest (*Fagus sylvatica*)	397
Mixed Forest in the atlantic biogeographic region	338
Oak Forest of *Quercus faginea*	320
Oak Forest of *Quercus suber*	2,712
Radiata pine Forest (*Pinus radiata*)	262
Oak Forest of *Quercus robur* and/or *Quercus petraea*	251
Maritime pine forest in the Atlantic region (*Pinus pinaster* subsp. *atlantica*)	241
Flood plain forest	225
Savin association of *Juniperus thurifera*	197
Mixed productive species stands	191

Spanish Forest Map (1997–2006), 1:50,000

Table 41.6 Percentage of forest areas according to development class classification

Development stage	Forest area (1000 ha)	Area (%)
Young growth	400.22	2.15
Thicket	2,320.33	12.49
Polewood	5,954.93	32.05
High forest	9,903.99	53.31

41.2.2 Wood Resources and Their Use

41.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock volume and increment are based on the information collected in the different NFI plots. In Spain, the volume of standing stock and increment of survivor trees between NFI cycles is calculated for trees that have a dbh ≥ 7.5 cm at the second assessment stage.

Information regarding cut, removed and dead trees is calculated in a similar way. It is possible to calculate mortality in trees that were alive in the first inventory but which had died by the second cycle. Cuttings are estimated by each of the 17 Spanish Autonomous Communities and reflected in the national forest statistics.

The main productive tree species in Spain are: Scots pine (*Pinus sylvestris*, 16.4 % of total volume), Maritime pine (*Pinus pinaster* in the Meditteranenan forest 10.4 % and *Pinus pinaster* in the Atlantic communities 5.9 %), Aleppo pine (*Pinus halepensis*, 8.6 % of total volume), Austrian pine (*Pinus nigra*, 8.3 % of the total volume); Oak forest of *Quercus ilex* (7.9 % of the total volume), European beech forest (*Fagus sylvatica*, 7.1 % of the total volume); Oak forest of *Quercus pyrenaica/Quercus pubescens/Quercus humilis* (5.4 % of the total volume) and eucalyptus forest (*Eucalyptus globulus*, 5.3 % of the total volume). Each of the remaining species present accounts for less than 5 % of the total volume.

In Table 41.7 the growing stock, increment and cutting statistics for the main productive tree species are shown.

41.2.2.2 Tree Species and Their Commercial Use

The average contribution of the forestry sector was 1.0 % of total Spanish gross value added (1.76 % including the furniture industry) in the 2000/2008 period (Magrama 2012): 43 % furniture and other manufacturing industries, 24 % paper industry, 22 % timber and cork and 11 % silviculture and timber exploitation. Furthermore, 35 % of the economic value associated with Spanish forests comes from non-wood products and services such as cork, hunting, honey, pine nuts and chestnuts, resin, mushrooms and extensive livestock farming. Other factors such as the presence of game and/or environmental benefits are also very important.

Table 41.7 Productive species—volume, increment, tree branch volume and drain

Species	Growing stock (1000 m^3)	Increment (1000 m^3/year)	Tree branches (≥7.5 cm) volume (1000 m^3)	Drain (1000 m^3/year), average 2006–2010
Abies alba	6,547	172	243	24
Acacia spp.	107	10	8	2
Alnus glutinosa	3,978	166	302	9
Betula alba	6,709	279	535	40
Betula spp.	1,770	76	192	7
Castanea sativa	29,120	960	4,642	77
Chamaecyparis lawsoniana	951	88	48	1
Eucalyptus spp.	86,580	8,037	5,512	4,761
Fagus sylvatica	74,786	1,738	6,302	96
Fraxinus angustifolia	300	9	73	1
Fraxinus excelsior	1,372	59	144	2
Fraxinus spp.	619	16	155	3
Larix spp.	2,332	119	106	11
Myrica faya	802	28	90	1
Olea europaea	1,777	46	413	1
Pinus canariensis	9,980	232	657	3
Pinus halepensis	76,551	2,975	6,436	238
Pinus nigra	71,152	3,079	4,095	364
Pinus pinaster	150,364	8,269	7,060	3,171
Pinus pinea	23,541	1,099	2,051	81
Pinus radiata	50,580	4,647	2,430	1,553
Pinus sylvestris	142,625	5,864	8,500	647
Populus nigra	3,190	188	187	2
Populus x canadensis	7,256	517	373	46
Pseudotsuga menziesii	1,298	172	68	9
Quercus faginea	13,769	412	2,580	12
Quercus ilex	687,920	1,563	28,109	33
Quercus petraea	12,969	316	1,252	7
Quercus pyrenaica	43,841	1,574	5,525	31
Quercus robur	35,530	1,185	3,149	115

(continued)

Table 41.7 (continued)

Species	Growing stock (1000 m^3)	Increment (1000 m^3/ year)	Tree branches (≥7.5 cm) volume (1000 m^3)	Drain (1000 m^3/ year), average 2006–2010
Quercus rubra	1,190	67	93	9
Quercus suber	17,367	319	9,140	9
Robinia pseudacacia	394	28	42	4
Salix spp.	326	39	39	5

Conifers are the most frequently managed species in Spain. Today, *Pinus pinaster* is the most productive species with over 500,000 m^3 of stock, followed by *Pinus sylvestris* and *Pinus pinea* which account for 300,000 m^3. Over one-third (34 %) of this stock is used for sawnwood production and 28 % in chipboard production. As regards broadleaves, including species such as *Eucalyptus* spp., *Quercus petraea/robur* and *Fagus sylvatica,* over 400,000 m^3 per year can be produced in northern Spain. Most of the wood from these species (44 %) is used in the pulp and paper industries, particularly in the case of *Eucalyptus* spp. plantations while 32 %, mainly from *Populus* spp. are used for energy purposes. To a lesser extent the harvested wood is used as firewood (mainly resprouting broadleaf species such as the *Quercus* genera) or roundwood.

It is worth noting that although there are plantations which are managed for timber production (mainly in the Spanish Atlantic area, where 7 % of the total forest land in the country provides 76 % of the wood products), the majority of Spanish forests produce secondary (though economically important) products such as cork from cork oak, pine nuts from Stone pine, resin from maritime pine or truffles from *Quercus* stands.

41.3 Assessment of Wood Resources

41.3.1 Forest Available for Wood Supply

41.3.1.1 Assessment of Restrictions

The recently adopted national definition of Forest available for wood supply (FAWS), applied in SoEF 2015, is as follows: "forest land where any legal, environmental or economic (site related) restriction has a significant impact on the supply of wood". It comprises all the forest area apart from Protected Areas (National parks and reserves), protected plant species (where dominant), areas sensitive to erosion, areas at high elevation and steeply sloped areas. The main differences to The Global Forest Resources Assessment 2000 (UNECE/FAO 2001) definition are that economic restrictions are only site related (Table 41.8).

Table 41.8 Main restrictions affecting the wood supply in Spain

Category	Relevance	Comment
Legal restriction. Protected area	Highly relevant	Forest operations not allowed or restricted
Legal restriction. Protected species	Relevant	Forest operations not allowed or restricted
Topography restrictions. Altitude	Relevant	Forest operations non-profitable
Topography restrictions. Slope	Highly relevant	Forest operations non-profitable
Biodiversity and conservations restrictions. Protective functions. Erosion	Highly relevant	Forest operations not allowed or restricted

The sources of information for obtaining FAWS are:

- National Forest Map (for the data from 2000; 2005; 2010). The Forest Map is the basis for the Third National Forest Inventory. Scale 1:50,000
- Third National Forest Inventory (for the data from 2000; 2005; 2010)
- Protected areas Map (CNTRYES, European data base)
- Digital Terrain Model from the Spanish National Geographic Institute (IGN)
- National inventory of soil erosion (INES).

The Spanish Forest Map provides the main source of information for estimating the state of FAWS areas and any changes in them. Using a Geographic information System, the different sources of information are assigned to the NFI plots and the FAWS are estimated. There is no specific field assessment for evaluating FAWS.

41.3.1.2 Estimation

An estimate of the area of FAWS in Spain was first provided within the reporting on the "State of Europe's Forests" (SoEF) 2011 (Sustainable Forest Management Indicators, indicator 1.1a) required by UNECE/FAO. The previous FAWS definition was: "forest land where any legal restriction (protected areas) has a significant impact on the supply of wood". Between 1990 and 2010, the total forest area increased by 4,354,920 ha and the FAWS area increased by 2,430,270 ha. FAWS accounted for 82.1 % of the forest area in 2010, decreasing from 90.4 % in 1990.

The current definition of FAWS was adopted as a consequence of a COST Action Usewood study (Alberdi et al. 2013), which includes all forests except the Protected Areas. Taking into consideration the aforementioned restrictions, the new FAWS area (Table 41.9) is estimated to be 3,676,551 ha or 79.9 % of the total forest area.

Table 41.9 Forest area and forest available for wood supply area in Spain

	Peninsula and Baleares Island	Canary Island	Total
Forest area (ha)	18,135,656	132,150	18,267,806
FAWS area (ha)	14,570,939	20,316	14,591,255
FAWS area (%)	80.34	15.37	79.87
NO FAWS area (ha)	3,564,717	111,834	3,676,551
NO FAWS area (%)	19.66	84.63	20.13

41.3.2 Wood Quality

41.3.2.1 Stem Quality and Assortments

There is no stem quality or assortment classification used in Spain's NFI.

41.3.2.2 Assessment and Measurement

In Spain, "tree quality" is assessed in the NFI field work, which incorporates information on stem quality. It takes into account qualitative characteristics related to the health status of the tree, the tree conformation, the possibility of a tree providing quality goods, tree age and the ecosystem status. The tree quality classification ranges from one to six and are defined as:

– Quality 1. Healthy, vigorous, optimally shaped tree, with no signs of age, able to provide many valuable products, not dominated and with excellent future prospects;
– Quality 2. Healthy, vigorous, not dominated, no signs of aging, slight conformation defect but able to provide many valuable products;
– Quality 3. Tree not totally healthy and vigorous; first signs of aging or dominated, many form defects but able to provide some valuable products;
– Quality 4. Tree weak or with bad health status or over-mature tree with many form defects, only able to provide products of secondary value;
– Quality 5. Tree weak or with a bad health status or over-mature tree with very poor conformation and of limited value;
– Quality 6. Standing dead tree but still able to provide some good-usable wood.

It should also be noted that under the biodiversity assessment in the NFI3 and NFI4, dead wood is monitored to determine whether a tree is standing or fallen. Additionally, the state of decay is classified into one of five decay classes proposed by Hunter (1990) and Guby and Dobbertin (1996), although two additional classes are defined: hollow dead wood and recently cut. Other tree quality related variables assessed for each individual tree are taper and health status.

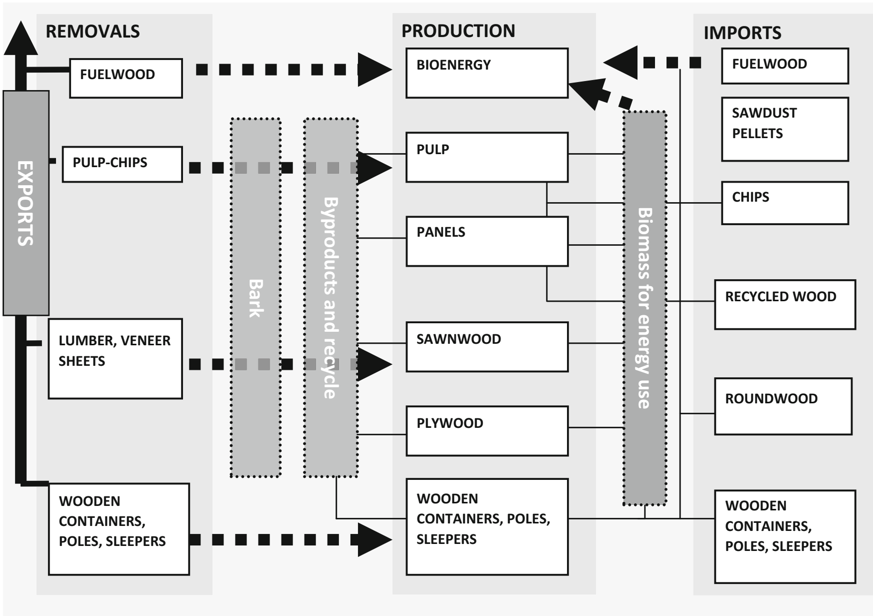

Fig. 41.1 Timber assortments flowchart

41.3.2.3 Estimation and Models

There are no national level models associated with information on quality from the NFI, although in order to estimate the volume of growing stock according to timber assortments (timber, pulp, waste), flowcharts have been generated (Fig. 41.1) with final product information. These values are estimated for national statistics.

As occurs in other countries, the price of timber is much higher than the price of pulpwood. Therefore, it is always more profitable to use the stem for timber if the quality is high enough. Forest bioenergy has also become increasingly important in recent years. Biomass is collected after thinning treatments in young forests and from the stumps and cutting residue of regeneration cuttings. The removal of cutting residues and stumps is recommended to reduce the risk of forest fire. *Quercus* coppices are also used for biomass energy.

41.3.3 Assessment of Change

41.3.3.1 Assessments and Measurements

The increment is assessed in permanent plots. The variables related to increment are diameter at breast height, total height and remeasured taper at each inventory.

The diameter is measured using a tree calliper, total height using a vertex hypsometer and taper is estimated visually according to six taper classes.

41.3.3.2 Estimation of Increment

All measured trees are classified into one of the following categories: survivor, removed, ingrowth, ongrowth or nongrowth. Tree volumes are calculated according to their diameter, height, taper and species; summarised and expanded to per-hectare values by multiplying by an expansion factor depending on the tree diameter. The following includes a comprehensive description of the volume increment components:

All trees remeasured in two consecutive inventories are considered *survivor trees*. For these trees, the volume is calculated at the beginning of the inventory cycle and at the end of it, according to the diameter, height, taper and species. These values are expanded to per-hectare values by multiplying by the respective expansion factor, which depends on the tree diameter at each stage. Finally, all volumes are summarised at each stage, giving V_S1 and V_S2, both in m^3/ha. The volumes are therefore as follows:

V_S1—volume of survivor trees at the beginning of the inventory cycle, weighted by initial inclusion probability;
V_S2—volume of survivor trees at the end of the inventory cycle, weighted by final inclusion probability.

All trees that are measured at the beginning of the inventory cycle but not at the end are considered 'removed trees'. Final volume is estimated through increment volume equations, assuming that the tree was removed in the middle of inventory cycle:

V_R1—volume of remove trees at the beginning of the inventory cycle, weighted by initial inclusion probability
V_R2—volume of removed trees in the middle of the inventory cycle, weighted by initial inclusion probability

Trees that are not measured at the beginning of the inventory but are measured at the end could be:

- ingrowth trees: trees that were not measured at the beginning of the inventory cycle because they had not yet reached the minimum diameter (7.5 cm), but were measured at the end of the inventory cycle in the plot with the smallest radius (5 m).

V_I—volume of ingrowth trees at the end of the inventory cycle, weighted by final inclusion probability.

– ongrowth trees: trees that were not measured at the beginning of the inventory cycle because they had not yet reached the minimum diameter (7.5 cm), but were measured at the end of the inventory cycle in a plot of radius larger than 5 m.

V_O—volume of ongrowth trees at the end of inventory cycle, weighted by final inclusion probability.

– nongrowth trees: trees that were not measured at the beginning of the inventory cycle due to the selection criteria, even though they had reached the minimum diameter (7.5 cm), but they *were* measured at the end of the inventory cycle.

V_N—volume of nongrowth trees at the end of inventory cycle, weighted by final inclusion probability.

According to the categories described above, the volume increment of survivor trees, removed trees and ingrowth trees is calculated as follows:

$$\text{Increment of survivor trees: IV\_S} = \text{V\_S2} - \text{V\_S1} + \text{V\_N} \tag{41.3}$$

$$\text{Increment of removed trees: IV\_R} = \text{V\_R2} - \text{V\_R1} \tag{41.4}$$

$$\text{Increment of ingrowth trees: IV\_I} = \text{V\_I} + \text{V\_O} \tag{41.5}$$

Finally, total increment and net increment are estimated in the Spanish National Forest Inventory according to the following expressions:

$$\begin{aligned} \text{Total Increment: IV\_S} + \text{IV\_R} + \text{IV\_I} &= (\text{V\_S2} - \text{V\_S1} + \text{V\_N}) + (\text{V\_R2} - \text{V\_R1}) \\ &\quad + (\text{V\_I} + \text{V\_O}) \\ \text{Net Increment: IV\_S} + \text{IV\_I} - \text{V\_R1} &= (\text{V\_S2} - \text{V\_S1} + \text{V\_N}) \\ &\quad + (\text{V\_I} + \text{V\_O}) - \text{V\_R1} \end{aligned}$$

The possibility of improving this methodology is currently being studied, taking into consideration the methodology published by Hébert et al. (2005).

41.3.3.3 Estimation of Drain

The estimation of cut, removed and dead trees is performed as described in the previous section. It is possible to calculate the mortality of trees that were alive in the first inventory but had died by the second cycle.

Cuttings are estimated using official removal statistics collected by the Ministry of Agriculture, Food and Environment.

41.3.4 Other Wooded Land and Trees Outside Forests

41.3.4.1 Assessment and Measurement

In the Spanish NFI, the definitions of the different land classes have changed over the four cycles. In the NFI2 and NFI3, the inventoried forest land was that which had a crown cover of more than 5 %. Therefore, all the measurements considered in the NFI were also taken for forest land with a crown cover of between 5 % and 10 %.

In the interests of efficiency and to facilitate international requirements, the monitored forest land in the NFI4 had a crown cover over 10 %. As areas with a canopy cover of <10 % are no longer assessed, there are no estimations of Other Wooded Land.

Nevertheless, it is important to mention that the Spanish National Forest Map does record shrubland and that a number of attributes are recorded such as main species and coverages.

Trees outside the forests are not considered in the Spanish NFI although they are included in the mosaics defined in the Spanish National Forest Map.

In the NFI4, neither the volume nor biomass of shrubs is estimated. However, biomass equations have recently been developed (Montero et al. 2013) which allow the biomass of the main species to be estimated from the information recorded. The carbon stored in shrubs is also excluded from greenhouse gas related reporting.

41.3.4.2 Estimation

It is important to highlight the importance of the area occupied by OWL in Spain (289,681 ha). It is included in the forestry area and provides certain economic benefits, mainly linked to the presence of game. When economic conditions improve, an inventory (as a part of the NFI) is planned which will include the area with trees as well as the area without trees of the 'other wooded land'.

Trees outside the forest are not measured and this is not currently under consideration for inclusion in future inventories.

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Chapter 42
Sweden

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42.1 The Swedish National Forest Inventory

42.1.1 History and Objectives

In Sweden, the National Forest Inventory started in 1923 (Thorell and Östlin 1931). The NFI was established to address concerns on the over-utilisation of wood resources. Nowadays a continuous inventory is performed annually (Fridman et al. 2014). The aim of NFI is to monitor development of forest resources, state of forests, forest health and biodiversity. NFI data and results are used for official reporting nationally, as well as international reporting obligations such as FRA, FOREST EUROPE, the climate convention and the Kyoto protocol, and also for the species and habitat directive (NATURA 2000). Nationwide projections, normally for 100 years, of sustainable cutting levels are estimated using the Heureka RegWise system (Lämås and Eriksson 2003), where NFI data constitute the starting point and provide the necessary tree, site and land-use data for performing the forecasts.

Several research projects have been using data from the Swedish NFI, mainly with focus on biodiversity e.g. Fridman (2000), Fridman and Walheim (2000), Gamfeldt et al. (2013), Vilà et al. (2013). However data is also used for remote sensing applications, e.g. Nilsson et al. (2003) and Reese et al. (2003). There are also examples of methodological papers such as Wulff and Wiersma (2004) and Milberg et al. (2008). A thorough description of the Swedish NFI today, including the development since the first NFI in 1923 can be found in Fridman et al. (2014).

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The Swedish NFI is organised within the Swedish University of Agricultural Sciences (SLU) and a part of the Swedish Official Statistics system. Statistics derived from NFI data are made freely available to society. The NFI web-site is the primary platform for this, however an annual summary document SKOGSDATA (Forest data) is published and made available online also.

42.1.2 Sampling Methods and Periodicity

Since 1953 the inventory has been conducted annually, covering the whole area of Sweden. In 1983 permanent clusters were established, and since then the NFI is based on both a temporal and a permanent systematic sample stratified into five geographical regions. The distance between clusters, shape of the clusters, number of field plots in a cluster, and distance between plots within a cluster vary between temporal and permanent clusters and regions due to the spatial autocorrelation analysed from earlier NFIs. Permanent clusters are re-inventoried with five-year intervals. Further information on sampling methods used in Sweden's NFI are available in Fridman et al. (2014).

42.1.3 Data Collection

The NFI data consist of two main categories: stand and site description and measured tree data. Stand and site description variables provide information about the forest stand where the field plot is located. If a field plot is divided into several stands, or land-use classes, all stands and land-use classes are described. Trees are assessed on four concentric sample plots, measuring 10, 7, 3.5 and 1 m in radius.

Stand and site data in broad categories consist of:

- Administrative data: geographic position, owner group, restrictions for forestry, etc.
- Land use and land cover: in this case, different classification systems are used to fulfil both national and international reporting needs; previous land use also is assessed, etc.
- Site description: site productivity class, soil type, soil texture, soil moisture, etc.;
- Growing stock: stand structure, species composition, crown cover, development class, age, mean height, damage, previous forest operations, etc.

Tree data consists of:

- Sample tree data: dbh and species
- Sub-sample tree data: height (h), crown height (ch), bark thickness (bt), age, diameter increment (only on temporary sub-sample trees) etc.
- Dead tree data; dbh or diameter at thickest end, species, height/length, and decay class, etc.

Digital versions of all NFI field manuals since 1923 can be downloaded from the NFI web-site.

42.1.4 Data Processing

The estimation consists of the following main steps:

1. Calculation of volume and increment for sub-sample trees
2. Estimation of volume and increment for sample trees
3. Volume expansion factors calculated for each sample tree
4. Area expansion factors calculated for each sample plot/part of sample plot
5. Estimation by stratum-wise summation of area/volume expansion factors.

Sub-sample tree volumes are calculated with general volume functions from (Näslund and Hagberg 1951, 1953). The variables dbh, crown height, bark thickness, and height are used as explanatory variables. Volume is then estimated for each sample tree using secondary form height functions, including plot and tree variance functions to mimic natural variability among trees (Appendix A in Fridman et al. 2014).

Area expansion factors are calculated by dividing the "true" stratum area by the area of sample plots within the stratum. The stratum areas are delivered by the National Land Survey of Sweden. The area estimate for an arbitrary stratum is simply the sum of the area expansion factors from sample plots with characteristics of interest, i.e. forest land. Since the Swedish NFI uses two types of clusters, estimates for each cluster are calculated and weighted with weights that are chosen to minimise the variance of the composite estimator. Total volume estimates are calculated in the same way as area estimates; however, volume expansion factors for each tree are used. Details are presented in appendices A and B to Fridman et al. (2014).

Using a combination of NFI field data and different kinds of remote sensing data, e.g. airborne laser data and/or optical satellite data, wall-to-wall estimates, e.g. of volume per ha, ton biomass per hectare, tree species composition, age and height, are made for productive forestland. Some of these products are free to download from the SLU website (Swedish University of Agricultural Sciences 2016).

42.2 Land Use and Forest Resources

42.2.1 Classification of Land and Forests

42.2.1.1 General Land Classification

Every plot, or part of plot, is assigned to both international classes (FAO definition) and national land use classes (Tables 42.1 and 42.2). The national classes are

Table 42.1 National land area by land-use class according to FAO definition (2008–2012)

Land-use class	Area (1000 ha)	Area (%)
Forest land	28,094	68.9
Other wooded land	2392	5.9
Bare unprod. land	4941	12.1
Other land	5370	1.3
Total land area	40,797	100.0

productive forest, pasture land, arable land, mires, rock surface, sub-alpine woodland, high mountains, urban land, and other land (Table 42.2). Productive forest land is defined as land with potential production capacity of at least 1 $m^3ha^{-1}yr^{-1}$ and not used for other purposes. In Table 42.3 the relationships between the national classes and the FAO Forest Resource Assessment definitions (FAO 2010) can be studied.

Table 42.2 National land area by land use class according to national definition (2008–2012)

Land use class	Area (1000 ha)	Area (%)
Prod. forest land	23,099	56.6
Pasture-land	509	1.2
Arable land	2917	7.2
Mires	5034	12.3
Rock surface	976	2.4
Sub-alpine woodland	973	2.4
Alpine areas	5345	13.1
Urban land	1210	0.3
Other land	733	1.8
Total land area	40,797	100

Table 42.3 National land use/land cover classes and areas, comparison with FAO (2010) definition

Class name	Definition	Area (1000 ha)	Corresponding FRA class
Productive forest land	Productivity ≥1 m^3ha^{-1} $year^{-1}$	23,099	Forest FAWS if protected areas are excluded
Mires, rock surface, sub-alpine woodland	Land use in combination with productivity <1 m^3ha^{-1} $year^{-1}$	6983	Partly forest, partly OWL, partly OL TOF if OL
High mountains	Defined by latitude, longitude and altitude	5345	Partly forest, partly OWL, partly OL TOF if OL
Pasture-, Arable-, other- and Urban land	Defined by land use	5369	OL TOF

42.2.1.2 Forest Classifications by Use

In the Swedish national land use classification system, forest land includes both productive and unproductive forest land (Tables 42.2 and 42.3). In the Swedish Forestry act, commercial forestry is only allowed in productive forest land outside legally protected areas (Table 42.3). Using GIS data of protected areas all NFI estimates with national or international definitions, including both area and volume estimates, can be separated into these categories.

42.2.1.3 Classification by Ownership Categories

Using the National land survey GIS data, all plots are assigned to one of the three ownership categories; Non-industrial private forest owners, Private companies and Others (State, Municipalities, Parishes, etc.). Over half (52 %) of the productive forest land outside reserves is owned by NIPF (non-industrial private forest owners), 23 % by private companies, and 25 % by other ownership categories.

42.2.1.4 Forest Management and Cutting Systems

The majority of forests in Sweden are managed in an even-aged management system with silviculture, pre-commercial thinning, thinning and final felling. A typical Swedish management system could be described as:

- Soil scarification after final felling
- Establishment of new stand with sawing, planting or natural regeneration
- Early pre-commercial thinning
- One to three thinnings
- Final felling after 60–120 years depending on geographical location and main tree species.

Over half (55 %) of removals are from final felling and 30 % from thinning. Increased demand for forest bioenergy, during recent years, includes the harvesting also of branches and tops for biofuel.

42.2.1.5 Legal and Other Restrictions for Wood Use

In the Swedish Forestry act, commercial forestry is only allowed in productive forest land outside legally protected areas. The decision on when to thin is completely up to the forest owner. However, for final felling there are limitations on stand age, i.e. it is not allowed to final fell stands that are too young. Before final felling the forest owners also have to inform the Forest Agency that a final felling will be performed, and also describe how regeneration and considerations for biodiversity will be secured, e.g. leaving retention trees, living or dead. After final felling the Forestry Act also regulates the reforestation operation and specifies criteria that need to be fulfilled.

The major parts of company owned forests in Sweden, and a large part of the privately owned, are certified by Forest Stewardship Council (FSC) and/or Programme for the Endorsement of Forest Certification (PEFC). In these certified areas the forest management of course has to be adapted to the certification criteria.

42.2.1.6 Further Classification of Forests

Further classification of forests in national statistics is usually made by site productivity class, age class, maturity class and forest type. Maturity classes are un-stocked area, thicket stage, thinning stage and final felling stage while forest type is defined by tree species composition.

42.2.2 Wood Resources and Their Use

42.2.2.1 Standing Stock, Increment and Drain

Estimates of growing stock, increment and drain are based on sample tree and sub-sample tree measurements on the sample plots. Using a complex set of functions, primarily published by Näslund and Hagberg (1951, 1953), stem volume is calculated for each sample tree. Stem volume includes all stem parts above the stump i.e. the bole with bark and stem top and includes all trees with dbh ≥ 1 mm measured over bark. The Swedish NFI also produces estimates of the above ground biomass for tree components (stem wood, stem bark, branches and needles) of living trees. Biomass is estimated by applying biomass functions by Marklund (1988) to the sample trees of the Swedish NFI. The biomass is expressed in terms of dry weight. The national definitions of standing stock, increment and drain are detailed in Table 42.4.

Table 42.4 Definitions for standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with dbh ≥ 1.0 mm over bark, including the bole (wood and bark), and stem top, and excluding the above-ground part of the stump
Increment	Volume increment of surviving and ingrown trees with dbh ≥ 1.0 mm. Increment on felled trees included
Drain	Volume of felled trees with dbh ≥ 50 mm over bark and volume of naturally dead trees with dbh ≥ 100 mm

According to Tables 42.5 and 42.6, the growing stock in Sweden continues to increase since the annual increment is larger than the annual felling and the annual natural drain by more than 20 million m^3 annually.

42.2.2.2 Tree Species and Their Commercial Use

The main commercial species are Scots pine (*Pinus sylvestris*, 39 %), spruce (*Picea abies,* 42 %) and birch species (*Betula penduda, Betula pubescens*, 12 %) (Table 42.7). These species are mainly used as sawn timber (pine and spruce) and pulpwood. Recently, the amounts of lodgepole pine (*Pinus contorta*, 1 %) harvested for pulpwood has increased.

The area of productive forest land by dominant tree species is shown in Table 42.7. Here the dominating tree species, using a threshold of ≥65 %, defines the forest type. The threshold is defined by proportion of stems per hectare for

Table 42.5 Growing stock (million m^3) in Sweden distributed on land-use classes (2008–2012)

Land-use class	Scots pine (*Pinus sylvestris*)	Norway spruce (*Picea abies*)	Broadleaves	All
All land	1336	1357	624	3317
TOF	5	3	23	31
OWL	6	2	2	9
Forest of which	1325	1353	599	3277
Prod. Forest of which	1240	1302	563	3106
FAWS	1195	1233	538	2966

Table 42.6 The volume of standing stock, annual increment, and annual drain on productive forest land by tree species (2008–2012)

Tree species	Growing stock (1000 m^3)	Increment (1000 m^3/year)	Drain (1000 m^3/year)
Picea abies (Norway spruce)	1,301,990	50,906	51,445
Pinus sylvestris (Scots Pine)	1,204,393	39,254	27,120
Betula spp. (Birch)	375,170	15,724	8416
Other broadleaves	81,509	3452	1831
Populus tremuloides (Aspen)	51,680	1931	1339
Quercus spp. (Oak)	36,931	916	432
Pinus contorta (Lodgepole pine)	35,593	2970	1290
Fagus sylvatica (European beech)	18,088	499	136
All	3,105,355	115,654	92,009

stands lower than 7 m stand height, and by proportion of basal area in higher stands. This definition is only applicable for productive forest land. Table 42.7 excludes productive forest land within National parks and Nature reserves that are protected from forestry activities.

The distribution of age classes (Table 42.8), i.e. the mean stand age calculated as mean age weighted by basal area on a sample plot with diameter 20 m, shows a dominance of forests in the age classes of 20–60 years. This is mainly an effect of the changes to the management system in the 1950s that are still used today.

42.3 Assessment of Wood Resources

42.3.1 Forest Available for Wood Supply

Every plot, or part of a plot, in the Swedish NFI is assigned to both a national and an international (FAO classes) land-use classification (Table 42.1). Forest available

Table 42.7 Productive forest land by dominant tree species (2008–2012)

Species	Productive area (1000 ha)	Area (%)
Scots pine	8673	38.8
Norway spruce	6025	26.9
Lodgepole pine	477	2.1
Mixed Conifer	3224	14.4
Conifer/Broadleaves	1689	7.5
Other Broadleaves	1335	6
Valuable Broadleaves	212	0.9
Unstocked	744	3.3
Total	22,379	100

Table 42.8 Productive forest land by age classes (2008–2012)

Age–class	Productive area (1000 ha)	Area (%)
0–	911	4.1
3–	1877	8.4
11–	2103	9.4
21–	2434	10.9
31–	2388	10.7
41–	3891	17.4
61–	2334	10.4
81–	1964	8.8
101–	1588	7.1
121–	1321	0.9
141–	1568	3.3
Total	22,379	100

for wood supply (FAWS) is then defined as productive forestland outside protected areas. Whether the Swedish NFI can estimate this area or not depends on the availability of GIS data for protected areas. The Swedish National Environmental Protection Agency provides GIS data of all legally protected areas, and the major forest companies provide additional voluntarily protected areas. However privately owned voluntary protected areas are not mapped, at least not in a way that makes them accessible for the NFI.

The availability for wood supply in Sweden is mainly limited by the following factors:

1. Legally protected areas:
   (a) National parks (forestry not allowed at all)
   (b) Nature reserves and NATURA 2000 areas (forestry not allowed at all, limitations, or no limitations depending on management plans for the reserve)
   (c) Nature conservation areas (forestry not allowed at all, limitations, or no limitations depending on management plans for the area)
   (d) In the Swedish Forestry act, commercial forestry is not allowed on unproductive forest land, i.e. potential site productivity less than 1 m^3/year and hectare.
2. Other protected areas:
   (a) Areas set aside due to certification programs, i.e. FSC, PEFC
   (b) Privately protected areas
   (c) Recreation areas, mainly forest areas close to urban areas.
3. Protective functions:
   Protection of water resources causes limitations to forestry operations near settlements. Protective forests for soil (erosion/avalanches) are mainly occurring in southern Sweden on sand-dunes.
4. Other restrictions
   In the alpine parts of Sweden there are some restriction on forestry, i.e. the forest owners have to apply to the Swedish Forest Agency for permission for final felling and the maximum area is 20 ha. In the reindeer herding areas in north-western Sweden, forest owners also have to communicate with the Sami villages when planning forestry actions. There are also restrictions on forestry for sites with cultural heritage objects, e.g. ancient grave fields, settlements, etc.

Restrictions on forest operations are not directly assessed on the NFI plots, however parameters describing accessibility, such as distance to road, ground surface structure, slope, soil moisture, neighbouring land use classes, and neighbouring forest stands, are registered. These registrations can, together with different kinds of GIS data, e.g. reindeer herding areas, urban areas, water protection areas, etc., can be used for the classification of plots and furthermore estimation of forest areas of different availability of forest supply.

To estimate the area, growing stock, annual growth, etc., for FAWS, the standard estimators of the Swedish NFI are used for plots defined as FAWS.

There are two major problems with using NFI data for estimates of FAWS:

- One specific category of legally protected areas, key habitats, is very small in size, and furthermore, not very common. This leads to low precision in the estimates.
- Mapping of privately owned voluntarily protected areas is not done, or the maps are not accessible to public authorities.

42.3.2 Wood Quality

Wood quality on sample- or sub-sample trees is not assessed in the Swedish NFI. However, a number of indicators for quality are measured on all sub-sample trees, e.g. species, dbh, height, crown length and damages. On pine and spruce we also register diameter of thickest branch (up to two meters height), presence and size of long-bend and/or abrupt bend. On temporary plots tree cores from sub-sample trees can also be analysed for age, ring-width, and rot. All these variables can be used for classification into arbitrary quality classes, including the systems used by the Swedish Timber Classification Association.

No estimates for timber assortments by wood quality are made directly using NFI data. However, in the long-term forecasts using the Heureka RegWise system (Lämås and Eriksson 2003), projections for distributions of assortments are made for timber and pulp wood.

The question of assessment of wood quality in the NFI for living trees has been ongoing since the first Swedish NFI in 1923. A number of different methods have been used, often trying to mirror the quality systems used by the saw mill industry. Thus far no system has been fully successful, mainly due to the simple fact that quality on timber at a saw mill is dominated by indicators not visible on standing trees. During recent years the Swedish NFI has focused on measurable indicators described above, but their usage has so far been limited.

42.3.3 Assessment of Change

42.3.3.1 Assessment and Measurement

The estimation of increment and drain from the Swedish NFI is based on the field measurements on permanent plots at two consecutive points in time combined with field measurements on temporary sample plots. This combination makes it possible to have true measurements of change over a period (normally 5 years) for both increment and drain, as well as detailed measurements of tree cores from temporary sample trees for allocation of growth to specific years within the period.

42.3.3.2 Estimation of Increment

To model the five year volume increment for all sample trees, the following general procedure is used:

1. Volume of permanent and temporary sample trees;
   (i) The volume functions of the Swedish NFI are derived from the sub-sample trees on which diameter, height, crown-length and bark-thickness are measured. For the sub-sample trees published volume functions are used for estimates of single tree volumes. Functions for assigning volumes to all sample trees are derived in-house and includes procedures to mimic the actual variability in the tree population.
2. Permanent sample trees:
   (i) $$\text{Increment} = \text{Volume}_t - \text{Volume}_{t-5}. \tag{42.1}$$
3. Temporary sample trees, permanent sample trees not measured earlier:
   (i) Tree cores from temporary sub sample trees are measured and volume increment for these trees are calculated using specially developed increment functions;
   (ii) Volume increment on temporary sample trees and permanent sample trees not measured earlier are calculated by secondary increment functions based on the result from I;
   (iii) For every sample tree the increment expansion factor is calculated as the 5 year volume increment ha^{-1} multiplied the probability of inclusion^{-1}.

The national estimate for a 5 year volume increment is performed by summation and weighting of the increment expansion factors for sample trees from both temporary and permanent sample plots, divided by the number of years of data used.

42.3.3.3 Estimation of Fellings

1. Permanent sample trees:
   (i) For all trees felled since the last inventory, the year of felling is assessed and dbh at the time of felling is modelled, i.e. the felled volume of the tree can also be modelled;

(ii) For every felled permanent sample tree the felled volume expansion factor is calculated as the felled volume ha^{-1} multiplied the probability of $inclusion^{-1}$.

2. Stumps on temporary plots and additional stump plots:

   (i) Diameter on stumps felled during the last felling season, i.e. between the start of growing season the calendar year before the inventory and the start of growing season for the calendar year of inventory, is registered. Dbh on the stumps is modelled, i.e. the felled volume of the tree can also be modelled;
   (ii) For every measured stump the felled volume expansion factor is calculated as the felled volume ha^{-1} multiplied the probability of $inclusion^{-1}$.

3. The national estimate for annual felling is performed by summing the felled volume of expansion factors for all sample trees divided by the number of years of data used. Finally the NFI annual estimate for felling is calibrated with the official estimate of annual felling from the Forest Agency.

42.3.3.4 Other Estimation of Changes

Natural losses

1. Permanent and temporary sample trees:

   (i) For all trees that are assessed to have died during last season, dbh is measured, i.e. the volume of the dead tree can be modelled;
   (ii) For all trees that are assessed to have died during last season the volume expansion factor is calculated as the volume ha^{-1} multiplied by the probability of $inclusion^{-1}$.

2. The national estimate for annual losses is performed by summing the volume of expansion factors for all trees that died during last season divided by the number of years of data used.

Change in land use

1. Permanent sample plots

   (i) For all permanent sample plots the point of time of land use change is assessed and registered if a land use change since last inventory is detected. In the system for data capture, information on land cover/land use class at the previous time of inventory is recorded. If the field crew register another class then the system requires that point of time of change is assessed and registered;
   (ii) For all sample plots the area expansion factor is calculated as the plot area multiplied by the probability of $inclusion^{-1}$.

2. The national estimate for changes in land use for the latest 5-year period is performed by summation of the area expansion factors for the change matrix, i.e. land use 5 years before inventory multiplied by the land use for the year of inventory.

All NFI estimators are unbiased and the most effective estimates available will be used. Estimates of change are performed using the permanent sample plots alone. A problem here is that the difference between the two estimates of state, i.e. a change estimate, may not coincide with the "true" change estimate using the permanent sample. In reporting forest state and changes to FRA, estimates using NFI data is used, except felling, since the Swedish Forest Agency (SFA) is responsible for national statistics on felling data. This is obviously also a dilemma with two estimates for felling, of which one is not official. When needed the NFI estimates are calibrated using the SFA estimates and distributions, e.g. felling separated on tree species, land use classes, diameter etc., can be used directly.

42.3.4 Other Wooded Land and Trees Outside Forests

The Swedish NFI covers all land use classes meaning that the same measurement methods are used for all land use classes. The only land-use classes excluded totally from tree measurements are Alpine areas and Urban land. Originally, the reasons for not measuring trees in Alpine areas were due to restricted accessibility, and thus high costs. However, from 2003 the assessment of Alpine areas is the responsibility of another Swedish monitoring programme (National Inventory of Landscapes in Sweden), although no estimates on volume or biomass have been carried out yet. The reason for excluding Urban land is due to concerns on entering private gardens, etc.

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Chapter 43
Switzerland

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43.1 The Swiss National Forest Inventory

43.1.1 History and Objectives

Forestry in Switzerland has, since the eighteenth century, been characterised by an intensive use of forests and wood resources. At the same time, it has become more widely accepted that the over-exploitation and clear-cutting of forests in the alpine and mountainous parts of the country during the first half of the nineteenth century led to debris flows and floods that caused extensive damage in the lower parts of the country.

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Shortly after the foundation of the modern federal state in 1848, a series of important forestry-related decisions were taken nationally. In 1855 a school of forestry (department) was established as part of the new Polytech, which is today the Swiss Federal Institute of Technology (ETH). In 1874 a forestry inspectorate was established within the federal administration, which today is the Federal Office for the Environment (FOEN). Finally, in 1876 a Forest Act prescribing the national forest law was enacted. Its primary aim was hazard prevention, which is why clear-cutting regimes were banned, and the reforestation and restoration of forests was promoted. This resulted in an increase of forest cover from around 19 % in 1850 to nearly 32 % in the year 2000.

Information about forests remained sparse, limited to public forests and estimates at national level were unreliable due to the different systems been applied at canton level, the member states of the Swiss Confederation. In the late 1950s, Alfred Kurt, then a professor at the ETH in Zürich, initiated the process (Kurt 1957) which led, 25 years later, to the first national forest inventory (Mahrer and Vollenweider 1983). According to him, a national forest inventory (NFI) should provide information to (a) establish a national forest policy promoting the international competitiveness of Switzerland's forestry, (b) further develop the social, protective and recreational services of forests, emphasising the public interests in forests, and (c) include forests in regional and national land use planning (Kurt 1967). The original vision of a national inventory was, therefore, that of a thematically broad survey covering the various products and services of forests.

In the 1960s, it became clear that there was an urgent need for reliable data about forest conditions in Switzerland in order to improve and implement silvicultural planning. The first small NFI was carried out by the *Schweizerischen Anstalt für das forstliche Versuchswesen* (EAFV), today's Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). The study was based on the interpretation of aerial photos and responses to questionnaires from the cantonal forest administrations (Ott 1972).

During the further preparation for a national forest inventory, the original intention to conduct a thematically broad survey was modified to focus more on assessing the productive functions of forests. This change may have been influenced by the 1973 oil crisis and methodological difficulties in assessing and validating further forest goods and services. The political rationale given mentions the need for information on the immediate and potential availability of wood resources, expected harvesting costs and investment required for forest roads and other infrastructure (BAR 1981).

While monitoring social and protective functions was still part of the aim in 1981, only in 1991 did the new Federal Act on Forest make it mandatory to consider all forest functions in sustainable forest management and for the national authorities to inform the public periodically about the state of forests. By then the NFI was already established and recognised as the basic means to fulfil the national forest monitoring obligations.

The terrestrial data for the first national forest inventory (NFI1 1983/1985) were collected in 1983–1985 on permanent sample plots. The inventory was repeated ten years later (NFI2 1993/1995). The main finding from these surveys was that an increase in the yield of timber would be possible (SAEFL 1999). During the third inventory (NFI3 2004/2006), the NFI plot level scenario model MASSIMO (Kaufmann 2001, 2011; Fischer et al. 2015) was used to analyse the role and capacity of Swiss forests in mitigating greenhouse gas effects and fulfilling the increasing demand for wood (Taverna et al. 2007; Hofer et al. 2011).

The Swiss NFI is currently in its fourth cycle (NFI4 2009/2017). The terrestrial data collection on the sample of permanent plots has been changed from a periodic into a continuous system, with nine independent annual grids each of which cover the entire country. The inventory is carried out by WSL in collaboration with FOEN on a four-year contract basis. The current mandate includes the main inventory module and specific modules addressing: (a) greenhouse gas reporting and (b) scenario modelling, as well as detailed analyses of: (c) the protective functions of forests and (d) the biodiversity functions of forests. In addition, (e) international reporting and cooperation are required. The Swiss NFI also supports several cantons in the planning and implementation of regional inventories.

43.1.2 Sampling Methods and Periodicity

The terrestrial data of NFI1 1983/1985 were collected on some 11,000 plots where the centre located in forest land. The sample plots were located on a systematic 1 km by 1 km grid covering the entire country. This sample size was chosen to reach a precision of the total growing stock and forest area estimates of approximately 1 % (relative standard error) in each of the five main regions of Switzerland. These regions—the *Plateau* region, the *Jura* region, the *Pre-Alps* region, the *Alps* region and the *Southern Alps* region—differ greatly with respect to natural and topographic conditions, as well as in the forest management activities and goals.

All sample plots and trees were marked for re-measurement in NFI1, but due to budget constraints the number of plots was reduced to the half in NFI2 1993/1995. To reach the aimed precision, a dense 500 m by 500 m grid of systematically distributed plots for stereo-photo interpretation was introduced and the auxiliary variables gained from photo interpretation were combined with the field data using an estimation procedure known as two-phase (double) sampling for post-stratification (Köhl 1994; Mandallaz 2008).

Two main design changes were introduced in NFI3 2004/2006. The terrestrial data collection has been extended to the *Gebüschwald* ("shrub forest" land), a low productivity forest formation mainly in high mountain areas, which roughly falls under the FAO other wooded land (OWL) category. Furthermore, the aerial photo interpretation has been extended to include tree resources outside forest and OWL.

The newest NFI cycle started in 2009. In the interest of having a balanced budget and up-to-date information annually, it was decided to stretch NFI4 2009/2017 terrestrial data collection over 9 years. For this, nine independent sub-grids were defined on the original grid, so that each year's sub-sample of re-measured plots is fully representative for the entire country and any sub-region of the territory. So far, the results NFI4a 2009/2011 and NFI4b 2009/2013 were compiled and published (www.lfi.ch). The aerial photo interpretation was reduced again to the grid on which the terrestrial data collection takes place, thus to detect new forest plots and measure tree resources outside forest and OWL.

Standing and lying stems are measured on two nested (concentric) circular plots. The smaller plot has a size of 200 m^2, the larger a size of 500 m^2. On the smaller plot, trees and shrubs with a diameter at breast height (dbh) between 12 cm and less than 36 cm are measured, whereas all trees with a dbh of more than 36 cm are measured on the larger plot (Keller 2011). A sub-sample of the living and standing tally trees is randomly selected for the measurement of tree height and an upper stem diameter 7 m above ground. These trees are used in the Swiss NFI two-stage estimation procedure for volume (and biomass) aiming at avoiding a potential bias in these estimates (Mandallaz 2008). On average, 11.8 sample (tally) trees and 2.3 sub-sample trees are selected per plot.

Young trees and main shrub species with a minimum height of 10 cm and a dbh of less than 12 cm are assessed on a separate set of four nested circular plots with radii between of 0.9 to 4 m. The centre of this set of nested plots is displaced from the plot centre by 10 m.

For the assessment of lying dead wood, a line intersect sampling technique is used (Gregoire and Valentine 2007) which consists of three transect lines of 10 m in length. The transects start 1 m from the plot centre in three directions (0°, 120°, 240°). The diameter threshold of lying dead wood is 7 cm at the point of intersection.

If the plot centre is less than 25 m from a forest edge, various structural and biodiversity oriented attributes of the stocking at the forest edge are measured.

A quadratic interpretation area of 50 m by 50 m is used for the (visual) assessment of several site and stand attributes. During photo interpretation, 25 systematically distributed lattice points within the interpretation area are assessed for land cover and vegetation height measurements (Ginzler et al. 2005).

Finally, the Swiss NFI also carries out interviews with the forest service and provides a complete survey of the forest road network.

43.1.3 Data Collection

43.1.3.1 Overview

The Swiss NFI includes data from aerial photo interpretation (Ginzler et al. 2005), field survey, oral interviews with the forest service and an assessment of the forest roads network on topographic maps (Keller 2011, 2013a, b). Data are collected in a step by step process (Lanz et al. 2010). In addition, information from various external sources are used, such as digital maps of administrative regions, soil characteristics or forest reserves. Further sources are specific models, e.g. for single tree volume and biomass, the extent of the potential vegetation or the prediction of site quality (Brassel and Lischke 2001).

43.1.3.2 Photo Interpretation

The photo interpretation mainly aims at reducing costs by excluding clearly non-forest plots from the field survey, and by providing ground control points for the installation of new forest plots. The main variables assessed in manual photo interpretation are land cover (11 classes) and vegetation height for 25 systematically distributed lattice points within the interpretation area (Ginzler et al. 2005).

NFI data from the manual photo interpretation have been used for: the assessment of tree resources outside forest (Ginzler et al. 2011), analysis of landscape patterns and diversity (Mathys et al. 2006) and small area estimation (Steinmann et al. 2013).

The auxiliary data for two phase regression estimation will be available in the future in the form of (a) a 3D point cloud retrieved from airborne digital image strips (Ginzler and Hobi 2015) for the entire territory of Switzerland by the Federal Office of Topography (swisstopo 2015) and (b) a mainly photo interpretation based land use classification on a 100 m by 100 m grid provided by the Federal Statistical Office (BFS 1992).

43.1.3.3 Field Survey

A forest engineer and a forester form one field team. The season for field data collection lasts from April to October. About 820 plots are visited in the field per year, of which some 750 are forest or OWL plots. Field work includes training, the re-assessment of some 8 % of plots by a second team (blind checks) and interviews with the forest service every fifth year. All variables assessed in the field are described in the field manual (Keller 2011, 2013a, b).

Site data: altitude, slope, exposition, surface relief, signs of erosion and landslides, geomorphological objects, waterbodies, traces of rockfall, avalanches and fire, obstacles and constraints to logging, soil damages caused by logging or recreational use, intensity of pasturing, pH and type of topsoil, azonal site type.

Stand data: management type, stand size (in size classes), vertical structure, crown cover total and according to three height layers, share of tree species in upper layer, crown closure, type of gap, development stage, stand age of dominant stand (estimated in even-aged stands), coverage of ground vegetation (shrubs, berry bushes, forest regeneration), type of regeneration, species and damages on regeneration, extent and type of stand damage, occurrence of root plates, stumps and heaps of branches, stand stability.

All tree data: species, diameter at breast height (dbh), status (dead or living, standing or lying), tree age (estimation, if possible supported by year ring counts on stumps), estimated crown length and form, layer, forked tree, coppice, reserved standard, type and place of visible tree damage, height or length of broken stem.

Dead tree additional data: bark cover, degree of decomposition, moss cover, lichen cover, fungi species, woodpecker cavity, regeneration and shrubs on tree.

Sub-sample tree data: tree height, height of crown base and upper stem diameter 7 m above ground.

Young tree and shrub data: species, height class, dbh, type of regeneration (natural vegetal, generative, plantation), damage (e.g. browsing), type of protection against game damage, length of annual shoot, degree of stand shade, proportion of hardly grow over area, type of competing vegetation, type of upper soil.

Lying deadwood: coniferous/broadleaved, diameter, degree of decomposition, lying stump yes/no, part of a heap of branches yes/no, longer 1 m yes/no.

Forest edge data: type of forest edge, structure, shape, density, type of last treatment, barrier, environments, woody species composition, width of shelter belt, shrub belt and herbaceous fringe.

43.1.3.4 Forest Service Enquiry and Forest Road Survey

The cantonal forest service are periodically asked in written form for an updated digital map of forest districts and the status of regional forest planning (forest development plans).

The local forest service (forester) is interviewed by the field team to get a series of information for each sample plot on forest or OWL, and for the entire network of forest roads.

Management and planning: ownership, forest functions, date of management plan, existence of a regional forest plan, size of management unit, certification label, strategy on opening-up forest land.

Forest use and history: year and type of silvicultural treatments since last inventory, proportion of salvage cuts, urgency and type of next treatment, terms for next treatment, intensity and type of recreational use, type of forest and stand origin, year of afforestation, year of last pasturing.

Harvesting: harvesting in-house or with contractors, type of harvest, short or long timber, skidding phases and distances, means of transport, pre-haulage distance.

Forest roads: control and complement of the digital map of forest roads, road surfaces, width and carrying capacity.

43.1.4 Data Processing, Reporting and Use of Results

43.1.4.1 Data Processing

Field teams are equipped with a tablet computer and bespoke software that was developed at WSL for data registration. Plausibility tests based on current input and previous measurements are implemented. The mobile phone network is used to transfer data to the field computer and the field data to the raw database at WSL. All variables needed to produce the result tables are processed into a separate database of derived variables. The derivation may be a copy from the raw data base, but is often the result of a complex combination (model) of various raw data and external data sources. All scripts are stored in a structured way allowing recalculations from the original raw data at any time. The current NFI database is running under Oracle, most of the scripts for the derivation of the variables are written in SQL while some complex derivations are written in SAS.

The production of result tables is governed through a web interface software written in PHP. The user has the possibility to select the inventories, target variables, domains of interest and various technical parameters. The result tables are produced in real time with the estimation procedures implemented in SAS. In the background, the steering parameters for the production of a specific table are stored in the database and can be reused.

43.1.4.2 Reporting and Use of Results

The Swiss NFI provides an important basis for decision making in Swiss forestry policy. WSL is responsible for planning, data collection, data analysis and scientific interpretation of the results; the Federal Office for the Environment (FOEN) is responsible for the political evaluation of the results.

WSL publishes the main results in the form of carefully edited books with illustrations and tables every 9 to 10 years (EAFV/FBL 1988; Brassel and Brändli 1999; Brändli 2010). The content is organised according to the Pan-European (MCPFE) indicators and a scientific interpretation of the results is given. In addition, thousands of output tables and maps can be downloaded from the Internet in four languages (www.lfi.ch, Abegg et al. 2014). Currently, these tables are updated every 4 to 5 years.

The NFI supplies about 50 % of the data for the national reporting on sustainable forest management, e.g. the Forest Report 2005 (SAEFL, WSL 2005) and the Forest Report 2015 (Rigling and Schaffer 2015). The conclusions from such reports were the basis for the development of the Action Programme 2004–2015 within the Swiss National Forest Programme (SAEFL 2004) and the Forest Policy 2020 (FOEN 2013).

The Swiss NFI also provides information for international reporting, such as the Global Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations, the FOREST EUROPE reports on State of Forests and Sustainable Forest Management in Europe, to Switzerland's Greenhouse Gas Inventory submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

NFI raw data and NFI data analyses are often demanded by national and cantonal administrations, by other monitoring programs, e.g. the Biodiversity Monitoring Switzerland BDM (BDM Coordination Office 2014) or the forest health

Sanasilva Inventory (Michel and Seidling 2014), research and education institutions, by the wood and energy industry, by engineering companies, non-governmental organisations and the media.

43.2 Land Use and Forest Resources

43.2.1 Classification of Land and Forests

43.2.1.1 General Land Classification

There are three different statistics which provide the forest area estimates for Switzerland: the *Swiss Forestry Statistics* (BAFU 2014), an annual complete survey of all forest enterprises and private forest owners, the periodically renewed, mainly aerial photo interpretation based Land Use Statistics (BFS 1992), and the NFI. The NFI and the Land Use Statistics use the same forest definition, whereas the Swiss Forestry Statistics uses a more land register based concept of forest land. The NFI is considered to provide the most accurate estimates of forest and OWL, but has no information about further classification of non-forest land.

The NFI *Forest* definition is dependent on three variables: the width of the forest stand, the crown cover and the top (dominant) height of trees (and shrubs). The width is a replacement for the size in international definitions and provides a mean for the exclusion of small extensions and openings of the forest area. The crown coverage has to be at least 20 %, with the exception of afforestation and temporary unstocked forest land. The stocking must have a top (dominant) height of 3 m. The only exceptions are stockings of dwarf mountain pine (*Pinus mugo prostrata*) and green alder (*Alnus viridis*). These areas are considered *Shrub Forest* and are part of Switzerland's OWL in international reporting. Any stocking fulfilling the above criteria but with a crown cover that is to more than two-thirds attributed to shrubs, is also considered *Shrub Forest*. This includes small riverside woodlands stocked with shrub habitat sallows (*Salix* spp.), lowland coppice stands of common hazel (*Corylus avellana*) and common juniper (*Juniperus communis*).

In national reporting the categories Forest without Shrub Forest, Shrub Forest and Other Land are used. In international reporting, national Shrub Forest is reported as Other Wooded Land, and national Forest without Shrub Forest as Forest. As the minimum crown cover of the international definitions is 10 %, one may assume that Switzerland Forest and OWL areas in current international reporting might be slight underestimates of the forest and OWL area which would result under international definitions.

The partition of Switzerland's territory into land use categories is given in Table 43.1. Because the Swiss NFI does not assess land use categories outside forest and OWL, data from the Swiss Land Use Statistics (FSO 2013) is used for further partition of these land categories presented in Table 43.1.

Table 43.1 Land use categories according to national definitions with area estimates from the Swiss land use statistics 2009 (FSO 2013) and corresponding FAO (2012) categories

Class name		Description	Area (1000 ha)	FRA categories
Stocked areas	Forest without shrub forest	The more precise NFI4 2009/2013 estimate is 1239	1134	Corresponds mostly to FRA category forest
	Shrub forest	The more precise NFI4 2009/2013 estimate is 69	67	Corresponds mostly to FRA category OWL
	Wooded areas	hedgerows, groups of trees on agricultural and unproductive land	92	Other Land with Tree Cover (OLwTC), Other Land (OL)
Agricultural land		cropland, orchards and vineyards, grassland, alpine-agricultural land	1482	OL, partly OLwTC
Settlement		urban areas, housing settlements, buildings, roads, railways, industrial areas, parks	308	OL, partly OLwTC
Other land and water		unproductive land: water, glaciers, unproductive vegetation, areas without vegetation (rocks, boulder)	1046	OL and water
Total area (includes inland water)			4129	

43.2.1.2 Forest Classification According to Use

Forest use can be classified either by forest functions or stocking characteristics. The information on forest functions (Table 43.2) comes basically from the forest service interviews, which designates each sample plot with a primary function (and an additional function, if applicable). The forest perimeter with protective functions against avalanches is delineated and legally binding (Losey and Wehrli 2013).

The information on the stocking characteristics distinguish between coppice forest, high forest by various development stages and by further categories (Table 43.3).

43.2.1.3 Forest Classification According to Ownership

Seven ownership classes are registered by the Swiss NFI (Table 43.4) where the *Public Forest* accounts for almost 70 % of the Swiss forest area.

Table 43.2 Classification of national Forest (roughly international Forest plus OWL) according to primary forest use function in NFI4 2009/2013 (Abegg et al. 2014)

Class name	Description	Area (1000 ha)
Predominant protective	Sub-categories: avalanches, landslide/ mudflow, processes in channels, rockfall	583
Predominant wood production		416
Predominant nature and landscape protection		146
Predominant recreational use		17
Others	Water protection, military/airport ground	67
No specific forest function		79
Total		1308

Table 43.3 Classification of national Forest (roughly international Forest plus OWL) according to forest type in NFI4 2009/2013 (Abegg et al. 2014)

Class name	Description	Area (1000 ha)
Inaccessible forest	Plot not accessible in the terrestrial inventory	43
Shrub forest		69
Permanently unstocked forest area	Forest road, creek	35
Temporarily unstocked forest area	Regeneration, damaged	18
Aisles and embankments		6
Permanently open stands		64
Selvas and plantations		2
Coppice forest		54
Coppice with standards		5
Selection type high forest		90
Non-uniform high forest		164
Young growth/thicket		87
Pole timber		142
Young timber		118
Medium timber		178
Old timber		233
Total		1308

43.2.1.4 Forest Management and Cutting Systems

Planning is an important precondition for sustainable forest management. Most cantons require a forest management plan if the forest exceeds a certain minimum size, e.g. 20 ha. But as 29 % of Swiss forests belong to management units smaller

Table 43.4 Classification of the national Forest (roughly international Forest plus OWL) according to ownership in NFI4 2009/2013 (Abegg et al. 2014)

Class name	Subclass name	Area (1000 ha)
Public forest (national definition)	Confederation	11
	Canton	61
	Municipality	285
	Citizens community	426
	Corporation	105
Private forest (national definition)	Individual ownership	345
	Association	75
Total		1308

than 30 ha (Brändli 2010), management plans only exist for 55 % of the forest area. Public interests (forest functions) are established in regional forest development plans under participation of the public. Such regional forest development plans are currently in effect for two third of Swiss forests (Brändli 2014).

Swiss forests are managed under even-aged and uneven-aged silvicultural systems. The latter comprises 30 % of Switzerland's forest area (Brändli 2014). Coppices cover only 1 % of the forest area. The typical treatment of even-aged forest is: (1) stand establishment with natural regeneration (rarely planting), (2) tending of young growth, thicket and young pole wood, (3) thinnings, (4) preparatory cuts for regeneration initiation, and (5) final harvesting of remaining trees after regeneration has established sufficiently. Clear-cutting systems are forbidden by law in Switzerland.

During the period 2004/2006 to 2009/2013, thinning and tending amounted to 35 % of the total drain, preparatory and final harvesting cuts to 33 %, selective cuts in uneven-aged forests and thinning in mountain forests to 18 %, and sanitary fellings (salvage logging) to 14 % (Abegg et al. 2014).

43.2.1.5 Legal and Other Restrictions on Wood Use

According to article 20 of the Federal Act on Forest, forests in Switzerland have to be managed in a way that ensures fulfilment of functions permanently and without restrictions (sustainability). The cantons have to enact regulations on planning and management taking into account the needs for wood supply, for a close to nature silvicultural treatment of forests and to ensure the protection of the nature.

In general, forest owners need the consent of the regional forest service for harvesting wood. Clear cuts are forbidden (article 22 of the Federal Act on Forest), but cantons may allow exceptions, e.g. if a cut could increase biodiversity. For forests with protective functions against natural hazards, the cantons are obliged to ensure minimal tending (silvicultural treatment) maintaining the stability of forests.

The federal state and cantons grant subsidies for forest restoration, the prevention of damages and for the establishment and maintenance of protective forests, as well as for technical constructions against natural hazards. In other words, there is a clear obligation to manage protective forests mostly located in mountain areas, and deficits are paid by the state. Financial support is also available for forest planning, the establishment of management cooperatives, the creation and management of forest reserves and for the construction of infrastructure in protective forests. A pre-condition for any subsidy is a close to nature silvicultural treatment.

The only areas where harvesting is legally forbidden are the Swiss National Park and forest reserves. At present, 2.7 % of the Switzerland's forest area is under strict reserve and 2.1 % is under habitat management, which means that only special tending for the establishment or grade up of habitats for certain animal and plant species is allowed. The political goal is to raise the proportion of such forest reserves from 4.8 to 10 % of the total forest area by 2030.

The most important aspects regarding the availability of wood resources are hindered access and high hauling costs due to the country's topography. During the period 2004/2006 to 2009/2013, 84 % of the gross increment in growing stock was harvested on good and very good sites, and only 43 % on poorer sites (Abegg et al. 2014). There are also security aspects in recreation forests, or along and above railway lines, roads and buildings which increase the harvesting costs. But in principle, such wood is available for use which is also the case for the few forests on military and airport grounds.

43.2.1.6 Further Classification of Forests

All results of the Swiss NFI are published for the five production zones *Jura*, *Plateau*, *Pre-Alps*, *Alps* and *Southern Alps*. Other administrative and thematic domains of interest for which results are published are the 14 economic regions of Switzerland, 6 biogeographic regions, 6 sub-regions of protective forests, the 26 cantons and the 110 forest districts (forest administration).

The Swiss NFI data analyses system is very powerful allowing various variable combinations for results calculation. Results are often classified by site conditions, such as altitude classes, vegetation zones, slope classes, site quality categories or potential natural forest communities.

Classification by stand attributes includes variables, such as the predominant tree species or the proportion of conifers/broadleaves, among others. Forest management related classifiers are the (predominant) forest function or, the potential harvesting cost (Table 43.5), among others.

Table 43.5 National category Accessible Forest without Shrub Forest according to production zone and potential harvesting cost in NFI3 2004/2006 (Brändli 2010)

Harvesting cost	Surface area of Accessible Forest without Shrub Forest (1000 ha)											
	Jura		Plateau		Pre-Alps		Alps		Southern Alps		Switzerland	
	ha	±	ha	±	ha	±	ha	±	ha	±	ha	±
n/a	7	1	10	1	10	1	18	2	6	1	51	3
less than 50 CHF/m^3	90	3	146	3	50	3	17	2	5	1	308	6
51–75 CHF/m^3	71	3	47	3	61	3	53	3	9	1	241	6
76–100 CHF/m^3	18	2	14	2	45	3	79	3	18	2	173	5
110–125 CHF/m^3	7	1	4	1	30	2	81	3	26	2	148	5
126–150 CHF/m^3	4	1	4	1	13	1	60	3	27	2	108	4
more than 150 CHF/m^3	4	1	6	1	9	1	63	3	61	3	142	4
Total	201	2	230	2	219	3	371	4	152	2	1172	6

The average harvesting cost in Switzerland was 83 Swiss Francs (CHF) per m^3 in 2010 (BAFU 2010)

43.2.2 Wood Resources and Their Use

43.2.2.1 Growing Stock, Increment and Drain

Estimates of growing stock, increment and drain are based on sample tree re-measurements on permanent field plots. The volume of the stem is defined from ground to top, includes bark and stump but excluding branches. The growing stock is the volume of all living trees with at least 12 cm in diameter at breast height (dbh). In total, the growing stock in Switzerland's Accessible Forest without Shrub Forest amounts to 419 million m^3 (Table 43.6). This corresponds to an average of 350 m^3/ha. The stem volume of standing dead trees in Accessible Forest without Shrub Forest for the inventory NFI4 2009/2013 is 10 million m^3 (17 m^3/ha), and the volume of lying dead wood amounts to 31 million m^3 (26 m^3/ha).

Growing stock is lowest in the *Southern Alps* region with an average density of 236 m^3/ha, and comparatively high in the lowlands of the *Plateau* region and in the *Pre-Alps* region with 393 m^3/ha and 448 m^3/ha, respectively. The growing stock densities in the *Jura* region (364 m^3/ha) and the *Alps* region (307 m^3/ha) are close to the national average.

Privately owned forests show a higher stock density on average (413 m^3/ha) than publicly owned forests (318 m^3/ha). This can be attributed to the fact that private forests are located on sites with higher productivity, on average.

Table 43.6 Growing stock on Accessible Forest without Shrub Forest in NFI4 2009/2013, and gross annual increment, annual drain, annual fellings and net annual increment on Accessible Forest without Shrub Forest during the period NFI2 1993/1995 to NFI4 2009/2013 according to main tree species (Abegg et al. 2014)

Tree species	Growing stock		Gross annual increment		Annual drain		Annual fellings		Net annual increment	
	1000 m^3	± %	1000 m^3	± %	1000 m^3	± %	1000 m^3	± %	1000 m^3	± %
Picea abies	183,195	2	4309	3	4793	4	3896	4	3412	4
Abies alba	62,589	4	1683	4	1443	6	1203	7	1443	5
Pinus spp.	11,140	8	164	11	261	12	191	15	94	20
Larix spp.	23,320	6	372	7	191	13	139	17	320	9
Pinus cembra	2440	13	34	19	24	38	19	44	29	22
Other conifers	1856	27	66	26	23	48	20	54	64	27
Fagus sylvatica	75,883	3	1773	3	1452	6	1239	6	1560	4
Acer spp.	12,945	5	296	7	152	11	120	13	263	8
Faxinus spp.	17,063	7	481	7	252	11	203	11	432	8
Quercus spp.	7947	9	172	11	147	14	118	16	143	13
Castanea spp.	5243	13	98	17	75	19	17	36	39	42
Other broadleaves	15,213	7	476	7	326	8	168	14	317	10
Total	418,833	1	9923	2	9139	3	7332	3	8116	2

Conifers account for 68 % of total growing stock, broadleaves for 32 %. Conifers are even more dominant in the *Alps* and *Pre-Alps* regions (NFI4 2009/2013). Of all tree species, Norway spruce (*Picea abies*) accounts with 44 % for the largest percentage of total growing stock. It is followed by European beech (*Fagus sylvatica*, 18 %), silver fir (*Abies alba*, 15 %), larch (*Larix* spp., 6 %), ash (*Fraxinus* spp., 4 %), maple (*Acer* spp., 3 %), pine (*Pinus sylvestris*, *Pinus nigra*, *Pinus strobus*, *Pinus mugo arborea*, 3 %), oak (*Quercus* spp., 2 %), chestnut (*Castanea sativa*, 1 %). The remaining tree species altogether account for about 5 % of growing stock (Table 43.6).

The methods for measurement and estimation of increment and drain are further described in Sect. 43.3 of this document. Here, we will focus on changes between NFI2 1993/1995 and NFI4 2009/2013.

During this period, gross annual increment in Switzerland was 9.9 million m^3 on average, which corresponds to a mean annual increment of 9 m^3/ha Accessible Forest without Shrub Forest. Gross annual increment is highest in the Plateau region with 13.1 m^3/ha and lowest in the Southern Alps region with 5.6 m^3/ha Accessible Forest without Shrub Forest. Norway spruce, silver fir and European beech together account for 78 % of total annual increment (Table 43.6).

The average drain per year was 9.1 million m^3 in Switzerland during the period 1993/1995 to 2009/2013, or 8.3 m^3/ha within the Accessible Forest without Shrub Forest. In the Plateau region annual drain amounts to 15.7 m^3/ha which is around seven times higher than in the Southern Alps region with 2.2 m^3/ha. This difference is not only attributed to the lower growing stock and increment, but is also the result of difficult topographic conditions in the Southern Alps region with reduced accessibility of forests and a sparser forest roads network. Spruce adds 52 % to the total drain, followed by beech and fir with 16 % each (Table 43.6).

For Switzerland, the percentage of natural loss on gross increment varies between 60 % for chestnut and 10 % for ash during the period 1993/1995 to 2009/2013. The natural loss in the economically important spruce was 21 % (Table 43.6).

The fellings amounted to 114 % of the net increment for Norway spruce in the period 1993/1995 to 2009/2013 and 203 % for pine species. For European beech, the percentage is only 79 %. Over all tree species, the percentage is 90 % (Table 43.6).

NFI fellings figures differ from those published in the Swiss Forestry Statistics (BAFU 2014). For the period 1993/1995 to 2009/2013 the NFI estimate is 7.3 million m^3 on average per year, of which 56 % from public forests and 44 % from private forests. The Swiss Forestry Statistics reports only 4.8 million m^3 for the same period with 66 % from public forests and 30 % from private forests (3 % undecided). Different methods are the reason for the different figures. The NFI is a statistical sampling based survey with field measurements and the Swiss Forestry Statistics is an annual complete survey of all forest enterprises and private forest owners with felling statistics assembled from timber sale statistics.

43.2.2.2 Tree Species and Their Commercial Use

Economically, the most important tree species in Switzerland are Norway spruce, European beech and silver fir which are the most processed tree species in the Swiss timber industry (BAFU 2010).

The most common assortment produced with softwood is saw log (73 %) followed by energy wood (19 %) and industrial round wood (8 %). Hardwood is mainly used for energy production (74 %) and as stem wood (12 %) (BAFU 2014). Considering the low usage of hardwood for round wood, the Swiss government encourages and stimulates research and the industry to find new applications and products for hardwood in order to increase its demand and value. Over the last 10 years, the use of trees for energy production by chipping has increased by 16 % each year to around 900,000 m^3 in 2013 (BAFU 2014).

Switzerland exports more roundwood than it imports. But imports of sawnwood and other wood products are higher than exports, which leads to overall higher wood imports than exports.

43.3 Assessment of Wood Resources

43.3.1 Forest Available for Wood Supply

43.3.1.1 Assessment of Restrictions

Forest available for wood supply (FAWS) is an important concept in national reporting and at international level. Following the international definition (MCPFE/UNECE/FAO 2007), FAWS includes forests without predominant legal, economic or other specific environmental management restrictions in the supply of wood resources. In the following, we discuss the Swiss NFI treatment of FAWS along these categories of restrictions.

Legal restrictions
In current national and international reporting only forests within the 1914 established *Swiss National Park* are considered as forest not available for wood supply (FNAWS). The park has a total surface area of 170 km^2, of which 28 % is forest land. Harvesting is forbidden in several forest reserves in Switzerland. A digital map of these areas is currently under preparation. It is planned to report these reserves as FNAWS in forthcoming NFI reporting.

Economic restrictions
Switzerland is one of the few European NFIs which derives harvesting costs at plot level. The current model is a further development of the *HeProMo* model (Erni 2003), which uses input parameters from the terrestrial inventory and from the interview with the forest service (Fischer et al. 2015).

The comparison between *HeProMo* modelled harvesting costs and actual timber prices could be used to define an economic restriction. For instance in 2010, the Swiss forest owner association reported an average timber price of 83 Swiss Francs (CHF)/m^3. If compared with *HeProMo* modelled harvesting costs, wood supply is not economically profitable in 50 % of Switzerland's forest (Table 43.5) and only 70 % of the fellings during the period NFI3 2004/2006 to NFI4 2009/2013 have been harvested without economic loss. The reason for harvesting and silvicultural interventions in these economically non-profitable cases is the maintenance of forest functions, such as protection against natural hazards. Therefore, as wood supply exists against purely economically rules with respect to wood supply, these areas are reported as FAWS in international reporting (and the economic situation is explained in national reports).

Environmental and management restrictions
Forest functions are assessed in the interview survey with the forest service and NFI estimates of the forest area with environmental and management restrictions can be estimated. About 45 % of the total forest area of Switzerland has a predominant protective function. Special silvicultural management practices are needed in these forests. Public subsidies are frequently available for these interventions, including harvesting operations. For this, environmental and management type restrictions seem not applicable and these forests are considered FAWS. Wood supply also exists from forest with a predominant recreational function, a predominant nature and landscape protection function, or some other or not specified predominant function than wood production (Table 43.2). All these forests are, therefore, considered FAWS in international reporting.

43.3.1.2 Estimation

The data relevant for the assessment of FAWS are available at plot level, so statistical based estimates of the FAWS area can be easily produced.

43.3.2 Wood Quality

43.3.2.1 Stem Quality and Assortments

Even though wood and stem quality are important variables for modelling the potential income from harvesting operations, they are not assessed in the current NFI4. During the first inventory NFI1 1983/1985, quality grading was applied to a sub-sample of tally trees. Based on variables such as the branching or the curvature, the quality was assessed for two sections of the lower eight meters of the bole in four grading classes. The quality classes were based on the national regulations for timber trading and the results have been published in the first national NFI report (EAFV/BFL 1988). In subsequent NFI's, the variables have been found not to be reproducible and comparable enough, and as a result have been dropped. Currently, efforts towards the reintegration of stem quality assessment into the Swiss NFI are been undertaken.

43.3.2.2 Estimation and Models

The calculation of dimensional assortments for growing stock and fellings have been undertaken since the first NFI. The assortments are based on taper functions (stem form models, splines) and information collected form the interview survey with the forest service. The latter provides the information on assortments according to local customs and usage of the wood. The assortments follow the current timber trading regulations (Riegger 2010), which define four length classes: L0 (<3.0 m), L1 (≥3.0 m and ≤6.0 m), L2 (≥6.5 m and ≤14.5 m) and L3 (≥15.0 m and ≤22.0 m). These length classes are valid for conifers. Broadleaves are assigned to classes L1, L2 and L3.

The final assortments are diameter based and calculated for each tree. The NFI assortment algorithm optimises the available assortments for each stem, and as a result, a tree can consist of several assortments. The diameter (mid-diameter of the logs) assortment classes are: 0 (<10 cm), 1 (10–19 cm), 2 (20–29 cm), 3 (30–39 cm), 4 (40–49 cm), 5 (50–59 cm) and 6 (>60 cm).

All assortments are focused on potential, not actual use, because the actual use of the wood, the quality grading on the market and the actual assortment cut during harvesting operations are not known.

43.3.3 Assessment of Change

43.3.3.1 Assessment and Measurement

The assessment of change is done on the grid of permanent sample plots with the re-identification of tally trees. The dbh growth of trees is measured on all tally trees surviving in the sample.

Tally trees leaving the sample plot are registered. In NFI2 and NFI3 four cases were distinguished: felling, other use, natural destruction, or unknown cause of disappearance. Since NFI4 the possible causes of disappearance are recorded in more detail. A distinction is made between leaving just the local sample or also the forest (population), and trees just leaving the tally but remaining in forest are tracked over inventories in case of their re-entering into the sample (e.g. at plot boundary). Furthermore, a pre-classification of new tally trees is done in the field with the main categories population ingrowth, sample plot ingrowth (non-growth), tally trees moved into the sample and trees excluded by mistake in a previous inventory. The reason for this extension is to prevent unjustified drain and ingrowth (non-growth) trees at the estimation stage.

All change components, except of net change, are only reported and estimated for the domain of common accessible forest in both inventories, i.e. forest plots accessible in both inventories. In other words, growth and drain on new and deforested areas are excluded.

For the estimation of states and changes in growing stock and biomass a two-stage sampling and estimation procedure is used (Mandallaz 2008).

43.3.3.2 Estimation of Increment

Plot level gross increment is calculated as the sum of ingrowth plus the growth of non-growth plus the growth of survivors plus the growth of drain (over half of the period between two plot re-measurements). Ingrowth is the tally tree's target variable as measured in the second inventory. For the growth of non-growth trees into the larger circle of the concentric plots and for the growth of drain, a single tree basal area growth model is used which is calibrated with NFI tally tree re-measurements from previous and the current inventory.

Net increment is defined as gross increment minus natural loss and minus unexplained loss, where natural loss from growing stock (living trees) includes trees that are still in the local sample as dead trees (standing or lying). Tally trees lost by wind-throw or other natural hazards, and which are evidently recovered for wood use, are not considered natural loss in reporting. But this distinction is often not clear-cut.

43.3.3.3 Estimation of Drain

Three components of drain are reported at national level: fellings, natural loss and unexplained loss from growing stock. Currently, the implementation of the corresponding components for the sub-population of dead trees is under way.

43.3.4 Other Wooded Land and Trees Outside Forests

43.3.4.1 Assessment and Measurement

The aerial photo interpretation on digital stereo-photos is also used to assess wood resources outside forest (Ginzler et al. 2011). Outside forest land, linear stockings of trees, such as hedgerows, and single trees are mapped and width and mean height of stockings and trees are measured (Ginzler et al. 2005). Currently, there are no plans for terrestrial data collection of wood resources outside forest.

Another data source is the high resolution vegetation height model (VHM) which combines the digital terrain model (DTM), calculated from country wide airborne laser scanning data and the digital surface model (DSM), calculated from 3D point clouds using stereo aerial images (Ginzler and Hobi 2015). The Federal Office of Topography acquires the digital image data in a six years circle covering the whole country. The first full national coverage of the VHM was finished in 2014 and one-sixth will be updated every year. The automatically produced VHM is planned to replace the first phase manual photo interpretation data on the 500 m × 500 m grid in the two phase estimation procedures of the Swiss NFI in the near future (Steinmann et al. 2013; Massey et al. 2014).

43.3.4.2 Estimation

Based on the manual photo interpretation data on forest and non-forest plots during NFI3, the total amount of tree resources outside forest land has been estimated to be 6.1 % of growing stock in forests (Ginzler et al. 2011)

The possibilities in estimating wood resources outside forest and on Other Land with Tree Cover using the VHM have just started. To date these resources are not considered a domain of primary interest for the NFI.

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Chapter 44
Turkey

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44.1 Forest Inventory in Turkey

44.1.1 History and Objectives

Turkey has not established a statistical National Forest Inventory (NFI) to date. Yet it has a respectably long history of forest inventory (FI) and planning which can be reasonably deemed to date back to the second half of the ninetieth century. Today, FI in Turkey is essentially implemented with a view to establish the current status of forests required for preparation of forest management plans for separate planning units.

As reported by Eraslan (1985) and Eler (2008) who extensively investigated the historical development of FI works in Turkey, the first forest management plan (FMP) was completed in 1918 for a land area of 7147 ha. Later, the Turkish government decided to establish a modern forest management system which led to the enactment of the Forest Law (No: 3116) in 1937. In line with the purpose of this law, the First-Cycle Forest Management Plans were completed between 1944 and 1946. Based upon the data gathered through these first-cycle forest management

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plans (FMPs), the total forest area of Turkey was estimated at 10.5 million ha which is approximately half of the current forest area of Turkey. This vast difference between the two estimates has its origin in the under representation of forest land due to the statistical method used at that time and the availability of aerial photography for only parts of the country. In 1955 a sampling-based forest inventory, that would be based on aerial photographs was planned. However due to the absence of aerial photographs for the entire forest land of the country, the project was not progressed.

In 1963, a new era of planned development began in Turkey. The government work programme for the years 1963 to 1972 included provisions for the establishment of a NFI and preparation of a new FMP cycle. According to this work programme, one tenth of the country would be surveyed annually, which consisted of the interpretation of aerial photographs at a scale of 1:20,000 and a ground assessment of forest conditions by a large number of planning teams. The programme was successfully concluded in 1972 as foreseen. The most remarkable result was, that the country's total forest area was then estimated to be 20.2 million ha, a high contrast to the 10.5 million ha estimated just 26 years before. Evidently, as mentioned before, the forest land did not double within the two and a half decades. Rather the forest inventory of the first-cycle FMPs severely underestimate the extent of the forest land due to methodological shortcomings and insufficient coverage of the country's forest land with aerial photography, which were mostly overcome in the succeeding cycle producing a far more accurate estimate.

In the 1970s, a new system of planning was explored that could be conveniently adapted to the diverse geographic conditions of the country, the different forest structures and to the changing demands and provisions of non-timber forest goods and services. Prototypes of such plans were proposed between the years 1973 and 1991 (Asan and Yesil 1996). Eventually, the "Ecosystem-based Functional Planning" system was developed and officially adopted by the relevant government agency through a regulation in 2008. According to this regulation, the assessment of forest functions were emphasised, and a specific survey adapted to the different forest functions and forest types was prescribed. With this regulation, the scope of the FI in Turkey has been extended to provide more precise information about non-timber goods and services of forest.

FI and FMP work is coordinated and controlled by the Department of Forest Management and Planning under the General Directorate of Forests (GDF). Since 2012 a relatively new National Forest Inventory division was established that is working on the development of a statistical NFI.

The administration and management of state owned forests, which is the case for more than 99 % of the forest land, are organised strictly hierarchy. There are 27 Regional Forest Directorates controlling 218 State Forest Enterprises which comprise a total of 1340 Forest Chiefdoms, which are the basic forest management planning (FMP) units and hence the forest inventory units in Turkey.

44.1.2 Sampling Methods and Periodicity

Hierarchically dependent spatial structures recognised in the forest management plans in Turkey are shown in Table 44.1 (Zengin et al. 2013).

FI work for the purpose of FMP has been traditionally carried out by planning teams employed in the GDF Department of Forest Management and Planning. Yet these works are being increasingly given out to contracting private firms as well. Typically, a planning team, whether government-employed or private, consists of a head forest engineer and several forest engineers. In a normal course of the work program, the team first collects all available printed and electronic data during early spring (e.g. official maps, aerial photos, previous plan documents etc). Then the team prepares the programme of field work which routinely takes place in the summer time. After the ground survey which consists of measurements and professional assessments and lasts 3–4 months, the team returns to the office where the collected data are linked to the respective spatial information of the forest planning units. The elaboration of a FMP is normally completed within one year, after which the team officially starts to work on the FMP of the next planning unit, i.e., Forest Chiefdom. The FMP for a forest planning unit and the associated FI cover a horizon of 10 or 20 years, depending on the length of the rotation cycle of the stocking. A 10 year period is normally stipulated for short rotation plantations, such as of Turkish red pine (*Pinus brutia*), and a 20 year period for a longer rotation plantation, such as of Scot's pine (*Pinus sylvestris*).

Sampling methods and procedures are detailed in the FMP Regulation. According to this regulation, FI must be based on field measurement, aerial photographs and/or satellite images. Both, remote sensing data, and field assessments and measurements constitute the input variables for the estimation algorithms applied by the Turkish FI.

The first step of FI is to draft a preliminary map of forest stands by means of the most-up-to-date aerial photography and/or satellite images, and the previous maps of the plan. Stand types are determined by the criteria of tree species and tree species mixture, stand development class and crown closure. The 5 stand development classes and the 4 categories of crown closure employed for this purpose are presented in Table 44.2.

As a rule, forest sampling in the field is conducted using of a systematic sampling method. Forest sampling is required to finalise the mapping of the stand types. The above mentioned preliminary map of forest stands is utilised as the basis for sampling in the field. Size and spacing of plots are determined by the type of forest management, the crown cover, and the forest function (Table 44.3). It should be noted that sampling plots are not permanent, i.e. the sampling design and plots of consecutive inventories on the same land change over time.

Table 44.1 Elements of spatial arrangement in forest management planning in Turkey

Spatial element	Description	Typical area (ha) range	Criteria	Function
Planning unit	Forest land, with definite ownership, boundaries and management objectives, managed according to a particular management plan	5000–40,000	–Ownership –Socio-economic situation and management intensity –Administration and organisation	–Forest Chiefdom, the basic administrative unit in state forests –Entirety of forest track if owned by non-state entities
Working circle	Forest area, within a planning unit, allocated merely to producing certain goods and services to achieve a specific management objective	100–1000	–Tree species –Stand structure –Management type –Rotation period –Management objectives –Site productivity	–Level of defining the actual and optimal forest structures –Level of calculating the allowable cut
Compartment	A permanent land unit, delimited by natural or man-made lines, homogenous as much as possible with respect to site conditions, stand structure and applied silvicultural technique, hence serving as a reference to keep track of measurements, records, administration and inspection	15–100	–Terrain features –Forest functions –Site conditions –Measures against storm and wildfire hazards –Tree species –Stand structure –Roads and transport possibilities –Management intensity	–Basic level of site-specific data and information –Level of daily and seasonal forestry operations –Basis for unit-cost calculations
Subcompartment or stand	Parts of a compartment definitely homogenous in terms of site conditions, stand structure and applied silvicultural technique	1–10	–Tree species and mixture –Development class –Crown cover –Distribution of trees to diameter intervals	–Smallest homogenous piece of forest for calculating volume and yield elements –Smallest homogenous piece of forest subject to uniform silvicultural technique

Table 44.2 Stand development classes and crown closure categories

Stand development classes			Stand crown closure categories		
Description	dbh (cm)	Symbol	Description	Closure (%)	Symbol
Establishment and density stage	<8	a	Stocked with gaps and glades	1–10	B
Pole and post stage	8–19.9	b	Loosely stocked	11–40	1
Thin tree stage	20–35.9	c	Moderately stocked	41–70	2
Middle tree stage	36–51.9	d	Fully stocked	71–100	3
Thick tree stage	≥52	e			

Table 44.3 Size and spacing of sampling plots in the Turkish FMP

Management type/system	Crown cover (%)	Forest function	Spacing of sampling plots (m × m)	Sample plot size (m^2)
Even-aged	41–100	Timber	300 × 300	400–600
	41–100	Non-timber	600 × 600	400–600
	11–40	Timber and/or non-timber	600 × 600	800
	≤10	Non-timber	Not sampled	Not sampled
Uneven-aged	–	Timber	150 × 300	600
		Non-timber	600 × 600	600
Coppice	1 to 3 plots in grown-up parcels			100
Industrial plantation	At least 5 plots in grown-up parcels			400

44.1.3 Data Collection

FI data is collected as part of the FMP process for each of the 1340 Forest Chiefdoms. Table 44.4 shows measured and assessed attributes on a typical sampling plot of the forest inventory for the purpose of FMP.

Conceptually, FI in Turkey comprises the collection and assessment of information on all that exist in the forest, including plants, animals and minerals, as well as on goods and services that the forest provides, socio-economic conditions, and forest pests and diseases. More specifically, FI in Turkey consists of the following eight inventory components:

- Land inventory
- Site inventory
- Biodiversity inventory
- Timber stock and increment inventory

Table 44.4 Measurements and assessment performed on a typical sampling plot

Purpose	Attribute or object	Description
Timber stock and increment	Tree species	Identification of species of all tally trees with dbh > 8 cm
	Diameter at breast height	Measurement of all tally trees with dbh > 8 cm
	Height	Measurement of average height of 3 trees
	Number of annual rings	Counting the number of annual rings on the last 1-cm sections of increment cores of 1–3 trees per plot
	Ring width	Measurement of width of the last 10 years annual rings
Site productivity	Age and top height	Measurement via cores of height and age of at least 3 of the dominant trees in pure and even-aged forests
	Diameter and height	Measurement of diameter and height of 1–3 trees with a dbh > 38 cm and free from shelter effect in uneven-aged forests
Trees to be removed silvicultural operations	Trees to stay or be removed, and snags	Determination of trees to stay or to be cut with consideration of the stand's sunlight need, competition among individual trees, forest openings, soil protection against erosion, etc. Snags are determined separately
Timber (wood) quality	Stem quality	Assessment of stem quality into 4 categories based on stem shape and condition, and branches
Secondary assets	Vegetal, animal and mineral assets	Observation of secondary assets of plants, animals and minerals, or their parts, on or in between sampling plots (resin, laurel, acorn etc.)
Forest health	Biotic and abiotic hazards	Observation and examination of browsing and grazing, forest clearance, wind- and storm-fallen trees, and traces of harms attributable to frost, pests, fungi, etc.

- Non-wood forest products inventory
- Non-timber forest service inventory
- Socio-economic situation inventory
- Forest health inventory.

44.1.4 Data Processing, Reporting and Use of Results

All data and information collected on sampling plots are used to estimate the total standing stock and increment of the planning unit, as well as the distribution of stock and increment by tree species, diameter classes, wood quality and silvicultural status of trees. Plot data are standardised to per hectare values of the number of trees, the timber volume, the increment and the allowable cut. Subsequently, the plot level per hectare values are averaged to find the per hectare estimate by stand types. Totals are the result of the multiplication between the average per hectare estimate per stand type and the respective known surface areas of the stand types. Finally, the summation over all stand types gives the grand total over the entire forest planning unit. This bottom-up summation approach can be further continued to get estimates for higher hierarchical level, i.e. the State Forest Enterprises, the Regional Forest Directorates and finally the entire country (Asan 2000; GDF 2011).

The data and results of the Turkish FI serve as a basis for decision-making in forest-related policies at regional, national and international levels, and also for the evaluation of the consequences of decisions made. Also, such data and results are reflected in a number of international reporting processes in which Turkey has engaged mainly including the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO), the submissions on Land Use, Land-Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and the indicators for sustainable forest management for FOREST EUROPE.

44.1.5 Development of a Statistical National Forest Inventory (NFI)

Interests in administering forest inventory at national scale date back to the late 1930s, and first attempts to introduce a NFI system in Turkey emerged in the 1970s. To date, however, a formal Turkish NFI has not been established. Eraslan, an eminent Turkish professor of forest management planning, argued in 1978, for instance, that a separate NFI might not be necessary in countries like Turkey in which almost the entire forest land is state-owned (Eraslan 1978). And by the same argument, he expressed his opinion that the forest inventories conducted for the purpose and as part of forest management planning provide the necessary information for the Turkish forest sector. In fact, what he suggested then is the situation today. This means that country-wide data and information about forests and forest conditions in Turkey are essentially estimated and reported by summing the forest planning unit level inventory data. That is, the data are collected at different times by different teams and using temporary sampling plots (Özkan et al. 2011). Nevertheless, interest in NFI has not withered away in Turkey. Certain developments and activities from 2000 towards the establishment of an NFI are worth mentioning here:

- An international Symposium on Turkish National Forest Inventory was organised in September 2002.
- A project titled “Establishing the basis for the Turkish National Forest Inventory: Phase I” was launched in November 2010, contracted by the Dutch Agency for International Business and Cooperation to Forest Ecosystems Consult b.v. and Alterra b.v. This project was intended to form the basis of a longer forest inventory project. In the first phase the focus was on the development of methods and the testing of these methods in a smaller area. Unfortunately, this project was not effectual as intended since it could not be passed on to the next phase(s).
- The Division of National Forest Inventory has been established within the GDF Department of Forest Management and Planning. This division is charged with the tasks of coordinating NFI related works and of international forest reporting.
- A pilot project was recently initiated aiming at the comparison of traditional FI data with data to be obtained by the NFI methodology using permanent plots. The spatial scope of this pilot project is the territory of a Regional Forest Directorate.

44.2 Land Use and Forest Resources

44.2.1 Classification of Land and Forests

44.2.1.1 General Land Classification

Turkey is a relatively vast country. As a matter of fact, it stands to have a land area larger than any other country in Europe, except the European part of Russia. Owing not only to its size but to its transcontinental Eurasian location right between Western Asia and Europe, a myriad of land cover and land use types are commonly observed in Turkey. Despite this diversity, Turkey’s land area can be broadly classified, with bridging to FRA land classes, for the purpose of this report as shown in Table 44.5.

The main issue in such a classification relates to the definition of forest and the statistical consequences thereof. By national definitions more than 27 % of the country is forest. Nonetheless this ratio is to drop to somewhere between 14 and 15 % according to FAO forest definition.

In Turkey, ‘forest’ can be a land cover, a land use, or an administrative unit (Lund 2014). The essential reason for the substantial discrepancy between the FAO statistics and the Turkish national statistics as to forest land area appears to be the criterion of land cover: A land tract of certain extent with less than 10 % crown cover of trees is not defined as “forest” but other wooded land (OWL) by FAO criteria, whereas the very same land tract is nationally defined as “degraded forest” that is legally considered to be within the Turkish forest regime. Meanwhile, the

Table 44.5 Classification of land area and inland water bodies in Turkey, 2012 (FAO 2015)

National		Corresponding FRA categories (1000 ha)			
Classes	Area	Forest	OWL	Other land	Inland water bodies
(a). Normal (productive) forest	11,559	11,559	–	–	–
(b). Degraded forest	10,119	–	10,119	–	–
(c). Other land	55,118	–	–	55,118	–
Total land area (a +b + c)	76,796	–	–	–	–
(d). Inland water bodies	1393	–	–	–	1393
Total country area (a + b + c + d)	78,189	–	–	–	–

national definition for "normal (productive) forest" appears to be very close to the FAO "forest" definition. Therefore, the national category "normal (productive) forest" is used to report for FAO category "forest" while the nationally-defined "degraded forest" is reported for the FAO defined category OWL".

Approximately 70 % of the "other land" category comprises agricultural and range lands and human settlements. Particularly, 2,751,000 ha of the area of "other land" are "other land with tree cover (OLwTC)" composed mainly of fruit and olive groves. Unfortunately and surprisingly enough, statistics on the poplar growing lands is lacking perhaps because poplar trees on private poplar growing fields are not seen either an agricultural nor a forest product. Furthermore, along with the state-owned and private forest lands, individuals and other private entities own woodlands that fall outside the national definition of 'forest'. Although such 'non-forest private woodlands' (NFPWs) are recognised to account collectively for a small proportion of the total forest area, there has been no inventory of their area. In fact, a formal interaction between the forestry administration and NFPW ownerships takes place only when an application is filed by the owner to obtain permission for tree harvesting from the regional forestry administration. However, these woodlands are still important because they are scattered throughout the country, and are of value to a substantial number of households and individuals (Ok and Kayacan 2005).

44.2.1.2 Forest Classifications by Use

Until recently, forests in Turkey were conveniently classified based on their suitability for timber production. Accordingly, a forest area was regarded as a "production forest" when it was technically and economically feasible to continuously produce roundwood therein, whereas forests where such feasibility was absent were classified as "protection forests". However, adoption in 2008 of the regulation "Ecosystem-based Functional Planning of Forest Management" has been a fairly influential step in this as well as many other respects of Turkish forestry, even though the formal application manual was not issued until 2014 (GDF 2014a).

In keeping with the new approach to State forest resources and their management, forest areas are now classified by the predominant functions assigned to them in FMPs. The three main categories are (1) economic function, (2) ecological function, and (3) social and cultural function. As stated in the manual, when assigning functions to forest areas, a number of criteria and indicators should be employed (Table 44.6).

Forests in Turkey can be conveniently classified by the three main functions representing the forest uses as in detailed in Table 44.7. Note that the figures in each cell of the table may represent forest areas solely and predominantly designated to the corresponding function. As it can be observed in Table 44.7, economic function has prevailed in Turkish forestry. Notably, economic function does dominantly comprise timber production as opposed to non-wood forest products. Nevertheless there appears to be little doubt that ecological and socio-cultural uses of forest lands has escalated tremendously within the past decade in Turkey.

44.2.1.3 Classification by Ownership Categories

Turkey is unique in Europe with respect to its dominance of state owned forest land. Nearly all (99.92 %) of country's total forest area is owned by the state. The rest is under the ownership of either non-state public entities or private entities (Table 44.8). Private entities hold more forest and are larger in number than

Table 44.6 Description of the main forest functions used in FMP

Economic	Ecological	Socio-cultural
–Production of timber (roundwood) production –Production of non-wood forest products	–Nature protection –Erosion prevention –Climate protection	–Water –Public health –Aesthetics –Ecotourism and recreation –National defence –Scientific studies

Table 44.7 Forest area distribution by main forest functions[a] (GDF 2014b)

Main forest functions	2002			2012		
	Normal	Degraded	Total	Normal	Degraded	Total
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha
Economic	8616	7596	16,212	7942	5680	13,622
Ecological	1788	2883	4671	2912	4001	6912
Socio-cultural	88	85	173	705	439	1144
Total	10,493	10,564	21,056	11,559	10,119	21,678

[a]Totals may not add up due to rounding

Table 44.8 Pattern of forest ownership according to the national forest definition, by number and area (2012)

Owner	State-owned	Non-State public	Private
Descriptive	Owned by the State at national scale	Owned under a legal personality by universities, foundations, municipalities, village communities, and some public institutions	Owned by private natural persons and corporations
Statistics[a]	Total area in this category: 21,661,000 ha (of which 11,542,000 ha is normal or productive forests and 10,119,000 ha degraded forest)	Total of ownerships: 89 Total area in this category: 7820 ha	Total of ownerships: 437 Total area in this category: 9310 ha

[a]*Data source* Personal communication with the relevant department of GDF

non-state public entities. There are only a few business companies in the private ownership category; most private owners are individuals.

44.2.1.4 Forest Management and Cutting Systems

Almost 96 % of the forests in Turkey are managed under an even-aged silviculture system, the rest comprising mostly fir-dominated uneven-aged stands under a selection cutting system. Approximately 13 million ha of the even-aged forests are dominated by conifers (62 %), and 8 million ha by broadleaved tree species (38 %). Nearly two thirds of the uneven-aged forests are conifers dominated (more than 300 thousand ha), the rest is dominated by broadleaves (about 220 thousand ha) (GDF 2014b).

The prevailing forest forms in Turkey are high forests (17.3 million ha or 80 %) and coppices (4.4 million ha or 20 %). Forests in either form are categorised as either normal (productive) if they have a crown cover exceeding 10 %, or degraded (non-productive) in case of a crown cover of less than 10 % (Table 44.9).

In 2011 silvicultural interventions of all kinds were registered on a total area of 586,384 ha (approximately 2.7 % of the total forest area). In about 81.4 % of this area (477,458 ha) forest tending was carried on while the regeneration areas constituted only about 4.7 % (27,397 ha) thereof. Finally, 81,529 ha of coppice lands were treated for conversion to high forest which corresponded to 13.9 % of all areas of silvicultural works in that year. It is worth noting that the technique of natural regeneration was applied on nearly two thirds of the entire regeneration areas (GDF 2011).

Table 44.9 Area distribution of forest forms in Turkey for selected years (FAO 2015)[a]

Forest Form	1973	1999	2002	2005	2010	2012
High forest	10,935	14,418	15,175	15,548	16,662	17,261
of which normal	6177	8238	8733	8979	9783	10,282
of which degraded	4758	6181	6443	6569	6880	6979
Coppice forest	9265	6345	5881	5700	4875	4418
of which normal	2680	1790	1760	1683	1420	1277
of which degraded	6585	4555	4121	4017	3454	3141
Total forest	20,199	20,763	21,056	21,248	21,537	21,678
of which normal	8856	10,028	10,493	10,662	11,203	11,559
of which degraded	11,343	10,736	10,564	10,586	10,334	10,119

[a]Totals may not add up due to rounding

44.2.1.5 Legal and Other Restrictions for Wood Use

In Turkish forestry the first and foremost wood supply restriction legally imposed on forest lands is the status of protected area. Protected areas are designated by the National Parks Law (1983) into four categories: National park, nature parks, nature monument, and nature protection area. Each of these categories has a different scope and features, yet their common feature is the prohibition of timber production and cutting. The primary function is to serve for ecological and/or sociocultural benefits. In addition to the lands in the aforementioned categories, there exist further categories of forests with wood use restrictions or even full prohibition. Examples include gene conservation forests, seed stands and clonal seed orchards. As of the year 2012, protected areas, designated legally or administratively for conservation of biodiversity, total more than 1.1 million ha, most of which is forest land as defined by FAO definitions, compared to about 860 thousand ha of coverage in 2005 (FAO 2015).

Finally, there are a number of silvicultural and other regulations that restrict wood supply from forests to a certain extent. For instance, the maximum size of forest regeneration (or cutting) areas is restricted for plantations. The area must not exceed 25 ha in even-aged forests assigned to fulfil predominantly economic functions, and must be kept below 5 ha if the forest fulfils predominantly ecological functions. Clear-cutting is prohibited in these forests as well.

44.2.1.6 Further Classification of Forests

In addition to the previously described classifications of the forest area further classifications are used in the Turkish national statistics and reporting. The most common variable for additional classification is the dominant tree species (Table 44.10).

Table 44.10 Forest area (1000 ha) by tree species in productive and degraded forest (2012)[a]

Tree species	Total area (1000 ha)	Normal (productive) forest Area (1000 ha)	Degraded forest area (1000 ha)
Turkish red pine (*Pinus brutia*)	5855	3208	2647
Oak (*Quercus* spp.)	5153	2106	3047
Crimaen pine (*Pinus nigra*)	4693	2580	2113
Beech (*Fagus orientalis*)	1962	1621	340
Scots pine (*Pinus sylvestris*)	1480	751	729
Fir (*Abies* spp.)	670	407	263
Juniper (*Juniperus* spp.)	575	91	484
Turkish cedar (*Cedrus libani*)	464	220	243
Oriental spruce (*Picea orientalis*)	334	230	104
Alder (*Alnus* spp.)	141	100	41
Chestnut (*Castenea sativa*)	111	75	36
Stone pine (*Pinus pinea*)	89	61	28
Hornbeam *(Carpinus* spp.)	20	15	4.7
Lime tree (*Tilia* spp.)	11.5	9.6	1.9
Ash tree (*Fraxinus* spp.)	9.4	8.5	0.9
Poplar (*Populus* spp.)	6.5	1.9	4.7
Eucalyptus (*Eucalyptus* spp.)	2.4	2.4	0.1
Other species	102	70	32
Total	21,678	11,559	10,119

[a]Totals may not add up due to rounding; areas less than 10 thousand ha are rounded to one decimal place while the indicated by one decimal place

The two most widespread coniferous tree species in Turkish forests are the Turkish red pine (*Pinus brutia*) and the Crimaen pine (*Pinus nigra*). Further major conifers include Scots pine (*P. sylvestris*), fir species (*Abies* spp.), juniper species (*Juniperus* spp.), the Turkish cedar (*Cedrus libani*) and the oriental spruce (*Picea orientalis*). Oak (*Quercus* spp.), comprising more than 20 taxa, and beech (*Fagus orientalis*) are the most widespread broadleaved tree species.

44.2.2 *Wood Resources and Their Use*

44.2.2.1 Standing Stock, Increment and Drain

Readers are referred to the relevant subsections in Sects. 44.1 and 44.3 for the technical details as to the calculation and estimation of standing stock and increment in Turkish FI. Definitions of standing stock and increment can be seen in Table 44.11.

Note also that the NFI concept of "drain" cannot be said to apply in Turkish forestry where there is no permanent plot-based inventory in planning units. But, even so, timber production (i.e., roundwood harvest statistics) may conveniently serve for illustrating the forest resources in Turkey. Table 44.12 shows the major forest and timber aspects of the Turkish forest resources.

According to national data derived from the renewed forest management plans, Turkey has 21.7 million ha of forest area. Total growing stock is 1494 million m^3 (68.8 m^3 per ha) standing tree volume over bark, annual increment is 42.2 million m^3 (1.9 m^3 per ha). Importantly, wood supplied from forest lands (timber roundwood production) amounts to less than half of the increment measured in the Turkish FI (see Sect. 44.3.3).

44.2.2.2 Tree Species and Their Commercial Use

Coniferous tree species prevail with respect to area covered and wood supplied in Turkey. Not surprisingly, however, the prevalence of conifers becomes reversed in favor of broadleaved species when it comes to fuelwood production.

As used in Turkish official statistics and reporting, roundwood harvested and sold from Turkish forests can be broadly described as either "fuelwood" or "industrial wood". Furthermore, industrial roundwood comprises seven types of roundwood products including (1) sawlog (2) transmission poles (3) mining poles/posts (4) pulpwood (5) fiberwood and chips (6) thin poles, and (7) other industrial wood (e.g. roundwood merely suitable for packaging, logistics, etc). Nevertheless, the market segment for sawlog is relatively distinct from that of the remaining industrial roundwood products, because of the unique quality of sawlogs needed for manufacturing sawn wood (Kayacan et al. 2012a). There is no further product distinction within the fuelwood category. It is important to note that the fuelwood category includes chips and fibre that are not only used for energy

Table 44.11 Definitions for volume of standing stock and increment in Turkish FI

Quantity	Definition
Standing stock	Above-ground volume of living trees with a dbh ≥ 8.0 cm over bark, including the bole (wood and bark) and the stem top, excluding branches and the above-ground part of the stump
Increment	(Mean) Annual volume increment of living trees with dbh ≥ 8.0 cm over bark

Table 44.12 Standing stock, increment and timber production by species category in Turkey, 2013[a] (GDF 2014b)

Descriptive attribute	Category	Total	Coniferous	Broadleaved
Forest area (1000 ha)	Total	21,678	13,231	8447
	Normal	11,559	7572	3986
	Degraded	10,119	5659	4461
Standing stock (1000 m^3)	Total	1,494,455	989,435	505,019
	Normal	1,417,483	942,020	475,462
	Degraded	76,972	47,415	29,557
Annual volume increment (1000 m^3)	Total	42,179	27,291	14,888
	Normal	40,020	26,150	13,870
	Degraded	2159	1141	1018
Timber (roundwood) production (1000 m^3)	Total	17,855	12,596	5260
	Industrial	13,668	10,848	2820
	Fuelwood	4187	1747	2440

[a]Totals may not add up due to rounding

production but also for manufacturing wood panels or other industrial products by the Turkish wood industry (Kayacan et al. 2012b).

The most widely used coniferous tree species for industrial purposes are Turkish red pine, Crimaen pine, Scots pine, fir, spruce and cedar. Meanwhile forests of oak and beech species provide mainly industrial roundwood for the Turkish wood industry. Whether retained as coppice or being converted to high forest, most coppices are dominated by oak species, and to a much lesser extent by beech (*Fagus orientalis*), hornbeam (*Carpinus* spp.) and chestnut (*Castanea sativa*) species, either in pure or mixed stands. Consequently, fuelwood supplied from the Turkish forests mainly is composed of the aforementioned broadleaved species, with oak predominating. Coniferous fuelwood generally results from the secondary production during the silvicultural treatments and industrial roundwood harvesting.

44.3 Assessment of Wood Resources

44.3.1 Forest Available for Wood Supply

44.3.1.1 Assessment of Restrictions

Forests that are protected by law are excluded from timber management; hence no wood supply is foreseen from these lands including national parks, nature protection areas, nature parks, and nature monuments.

With regard to restrictions in managed forests, slope is a critical factor. Additionally, some other factors such as terrain and soil also affect the availability of wood supply from forests. For example, if a forest area is assigned the management function of "nature conservation", little or practically no timber is planned for harvesting. Table 44.13 details the criteria and indicators for a forest area to be designated for "nature conservation" which severely reduces the possibility of wood supply.

A similar restriction on wood supply is imposed to manage forest areas if the function of "erosion prevention" is assigned. Although the criteria and thresholds are similar to those for nature conservation above, wood supply restrictions are incremental in these forests (Table 44.14).

44.3.1.2 Estimation

Forest areas with restrictions to wood supply can be generalised quantitatively through the bottom-up summation approach explained in the first section of this report.

Table 44.13 Criteria and thresholds for assigning the forest function of "nature conservation" in FMP

Criterion threshold		Conservation objective
Terrain slope	>80 %	Nature conservation for all species
Absolute soil depth	<25 cm	Nature conservation for all species
Physiologic soil depth	<50 cm	Nature conservation for all species
Soil stoniness	>50 %	Nature conservation for beech, Crimean pine, Scots pine, oak and spruce
	>80 %	Nature conservation for Turkish red pine and cedar
	>60 %	Nature conservation for the rest of the species
Forest upper zone	Forest areas within 100 to 150 m of the visible forest upper zone	Nature conservation for all species

Table 44.14 Criteria and thresholds for assigning the forest function of "erosion prevention" in FMP

Restriction criteria	Threshold
Slope	<12 %: None; 13–20 %: Mild; 21–58 %: Moderate; ≥59 %: High
Length of slope	<80 m: Mild; 81–210 m: Moderate; ≥211 m: High
Soil texture	Clay: Mild; Loam: Moderate; Sandy: High
Visual	Layer; gutter, gully

44.3.2 *Wood Quality*

44.3.2.1 Assessment and Classification of Stem Quality and Assortments

Stem quality assessments are usually a routine part of forest inventory (FI) for the purpose of forest management planning (FMP) in Turkey. Based on stem quality criteria observed and measured for each tree in the sample plot tally, stem quality assessments can be compiled at plot, stand and regional level.

By the FMP regulation, on a typical sampling plot all trees with a dbh ≥ 8 cm are numbered consecutively starting from 1, and assigned codes of species and quality class. Stem quality of a coniferous trees is assessed and classified on the bottom third of the total stem length (above stump), and on the bottom part of the stem on a length of 4–8 m (above stump) for broadleaved trees. The four classes of stem quality assessment are detailed in Table 44.15.

44.3.3 *Assessment of Change in Wood Resources*

44.3.3.1 Assessments and Measurements

Estimating the increment of standing timber volume is based on the measurements from temporary sample plots selected for the purpose of FMP. Due to the absence of an NFI system the concept of drain is not strictly applicable in the Turkish FI. Wood removed annually from Turkey forests may be reasonably well estimated using the annual timber harvested from the State Forest Enterprises.

44.3.3.2 Estimation of Increment

Increments of trees with a dbh ≥ 8 cm are calculated by means of a species specific single-tree increment tables for the locality, which is generally the forest planning

Table 44.15 Stem quality classes as assessed in Turkish FI

Stem quality class	Stem description
1	Upright, full-bodied, with circular cross-section, with no or few branches (suitable for 1st grade sawlog)
2	Slightly crooked and branched, with non-circular cross-section and/or slightly twisted (suitable for 2nd grade sawlog)
3	Severely crooked or branched or twisted (suitable for 3rd grade sawlog)
4	Misshapen, never suitable for sawlog production (suitable for fuelwood, fibre, chip and other industrial wood). Trees in coppices are classified in the 4th class of stem quality without exception

unit where the plot is located. Increments given in these tables are based on calculations according to Meyer's Interpolation Method (Meyer 1942) as described below:

$$i_v = \frac{\Delta v}{\Delta d} i_d \tag{44.1}$$

i_v Annual increment of volume in a single tree (m^3)
Δv Volume difference between two consecutive diameter intervals (dm^3)
Δd Range of diameter interval
i_d Annual diameter increase in a single tree (cm)

The application of this equation requires firstly that the single-tree volumes at different diameter intervals. Those volumes can be found in dbh based or dbh and height double tree volume tables. These single tree volume tables are readily available specifically for each forest planning unit, i.e. Forest Chiefdom. A new volume table can be constructed through tree stem analysis at different diameter intervals in case there is a newly designated planning unit, or a need for a volume table for a particular locality within a planning unit. Also, an existing volume table may be updated for the whole of an existing planning unit if deemed necessary.

With the aid of increment core bark thickness as well as the width of latest 10 year annual rings are measured and multiplied by 2 in order to find the 10 year periodic diameter increase. The mean annual diameter increase is thence calculated by dividing the 10 year periodic increase.

The bottom-up approach explained earlier in the relevant sections of this report is conceivably valid for estimation of increment as well. The estimation process begins with the sample plot-level figures, continues with conversion to per hectare values and averaging them for a specific stand type, and ends with adding up the figures for all stand types in order to reach to planning unit-level increment figures. One could naturally find the national figures by summation of relevant figures for all planning units.

44.3.3.3 Estimation of Drain

Due to the absence of a statistical NFI system the concept of drain is not strictly applicable in Turkish FI. As a matter of fact, there is practically no basis for estimating the cut and mortality, together being the drain.

In principle, annual timber harvest is prescribed by the annual allowable cuts and can be calculated beforehand during the planning. Traditionally, annual allowable cuts have been deliberately kept well below the volume increment, making room for ecological needs. As a matter of fact, in 2012 the total annual allowable cuts amounted to about 17 million m^3, and this figure is merely about 40 % of the total annual increment 42.2 million m^3 (GDF 2014b).

However, a discrepancy between the actual and prescribed (allowable) cuts is inevitable to some extent due not only to the quantitative features of the allowable cut estimate but also to the pressing socio-economic demands when it comes to actual felling. What is more, natural forest hazards such as wild fires and pest outbreaks and storms at unexpected times and/or unforeseen scales may aggravate discrepancy between the prescribed and actual cuts. For instance, in 2012 a total of approximately 19 million m^3 of timber (fuelwood in stores converted to cubic metre by multiplying by a factor of 0.7) was actually harvested and removed from the forests in Turkey. This is noticeably larger than the allowable cut but still constituting only about 45 % of the annual increment corresponding to the same year (GDF 2014b).

The forest removal figures are represented by the actually harvested volumes of industrial roundwood and fuelwood that are measured with the supervision of the forest chiefs of the State Forest Enterprises normally right after the felling. While volumes of harvested hardwood species include bark, volumes of the harvested softwood species are measured after debarking in the field. After measurement the harvested timber is removed from the forest compartment or sub-compartment by the buyer in the case of stumpage sales or by the government-employed workers if the harvested timber is to be later sold at roadside or from the outdoor depots.

As a final word in here, illegal cutting is fortunately not a grave issue in Turkey any more as it was in 1980s and 1990s although it can still occur to a small degree.

44.3.4 Other Wooded Land and Trees Outside Forests

44.3.4.1 Assessment and Measurement

First of all, as mentioned earlier in this report the FAO definition of Other Wooded Land (OWL) does not apply in Turkey since the FAO defined OWL are classified as "degraded forest" in Turkey. Even so, several categories can be mentioned as part of other wooded land and trees outside forests in connection with FI in Turkey. Of these, agricultural lands with olive and fruit trees are systematically reported whose statistics are shown in Table 44.16. In view of the data two things are apparent: first, fruit groves have been more than double the area of total olive

Table 44.16 Area of fruit and olive tree groves in Turkey for selected years between 1990 and 2012 (FAO 2015)

Year	Fruit tree groves area (1000 ha)	Olive tree groves area (1000 ha)	Total area (1000 ha)
1990	1348	600	1948
2000	1418	600	2018
2005	1598	662	2260
2010	1748	784	2532
2011	1820	798	2618
2012	1937	814	2751

groves. Second, lands in either subcategory can be said to have expanded moderately within the past two decades.

Another category of other wooded land and trees outside forest comprises the so called "non-forest private woodlands (NFPW's)". In Turkey, these are the non-forest private lands with forest trees covering three hectares or less area. Owners of NFPW's are not obliged to register or report as being an owner of NFPW. In other words, ownership of an NFPW is no different legally from the ownership of a bare land in term of cadastre records. Consequently, no statistics are available as to the totality of NFPW's in Turkey. Nevertheless these woodlands are believed to be important because they are scattered throughout the country, and are of value to a substantial number of households and individuals even though the total area is not believed to be extensive (Ok and Kayacan 2005). Notably, an owner of NFPW is required to file a petition to the local forest administration for approval only when they decide to cut some or all of the trees for domestic or commercial purpose. That is the only legal interaction between such ownerships and the forest administration.

Finally, private poplar growing lands are not defined as forest in Turkey, yet they can be considered as other wooded land or trees outside forests. As pointed out earlier, there is no registration obligation of private poplar fields either as an agricultural asset or a forest stand.

44.3.4.2 Estimation

In Turkey, basically no assessments are made on other wooded lands and trees outside forests as regards wood volume and area. The only exception is in relation to certain official agricultural forecasts concerning fruit and olive groves.

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Chapter 45
United States of America

Ronald E. McRoberts and Patrick D. Miles

45.1 The National Forest Inventory of the United States of America

45.1.1 History and Objectives of the National Forest Inventory

The national forest inventory (NFI) of the United States of America (USA) is conducted by the Forest Inventory and Analysis (FIA) programme of the U.S. Forest Service, an agency of the U.S. Department of Agriculture. The FIA programme has been in continuous existence since 1928 and is the only organisation that collects, compiles, archives, analyses, and publishes state, regional, and national forest information on all ownerships of forest land in the USA. The history of the programme is documented in numerous publications including LaBau et al. (2007), Gregoire (1992) and Van Hooser et al. (1992); recent history is documented in McRoberts et al. (2005, 2010) and Bechtold and Patterson (2005).

In 1998, the FIA programme began implementing a strategic forest inventory plan featuring an annual system, state reports every five years, a set of core variables with national definitions and measurement standards, and integration of the ground sampling components of the FIA and the Forest Health Monitoring programmes. This annual inventory programme uses the ends-ways-means strategic planning model to promote and facilitate national consistency (McRoberts et al. 2005). Ends are the criteria that must be satisfied for the programme to be characterised as nationally consistent; ways are the procedures that lead to achieving the

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ends; and means are the resources that are committed to the effort. The programme is defined in terms of six ends:

End 1: A standard set of variables with nationally consistent meanings and measurements.
End 2: Field inventories of all forested lands.
End 3: Consistent estimation.
End 4: Satisfaction of national precision guidelines.
End 5: Consistent reporting and data distribution.
End 6: Credibility with users and stakeholders.

These ends describe the major foci of the programme and provide direction for methodological research. To facilitate achieving the ends, 10 ways have been prescribed:

Way 1: A national set of prescribed core variables with a national field manual that prescribes measurement procedures and protocols for each variable.
Way 2: A national plot configuration.
Way 3: A national sampling design.
Way 4: Estimation using standardised formulae for probability-based (design-based) estimates.
Way 5: A national database of FIA data with core standards and user-friendly public access.
Way 6: A national information management system.
Way 7: A nationally consistent set of tables of estimates of prescribed core variables.
Way 8: Publication of state-wide tables of estimates for prescribed core variables at 5-year intervals.
Way 9: Documentation of the technical aspects of the programme including procedures, protocols, and techniques.
Way 10: Peer review of and public access to the technical documentation.

In summary, the FIA programme is nationally consistent in its crucial components and is implemented through four regional programmes (Fig. 45.1).

45.1.2 Sampling Procedures

The current FIA sampling design is based on a tessellation of the entire country into 2400 ha hexagons (Fig. 45.2). The federally funded portion of the sample consists of one permanent plot in a randomly selected location in each hexagon without regard to land cover, land use, ownership, or other factors. Across the entire country, the hexagons have been systematically assigned to five groups called panels such that no adjacent hexagons are assigned to the same panel (Fig. 45.2). Panels are selected for measurement of their plots on a rotating basis, and measurement of all plots in a panel in a state is completed before measurement of plots

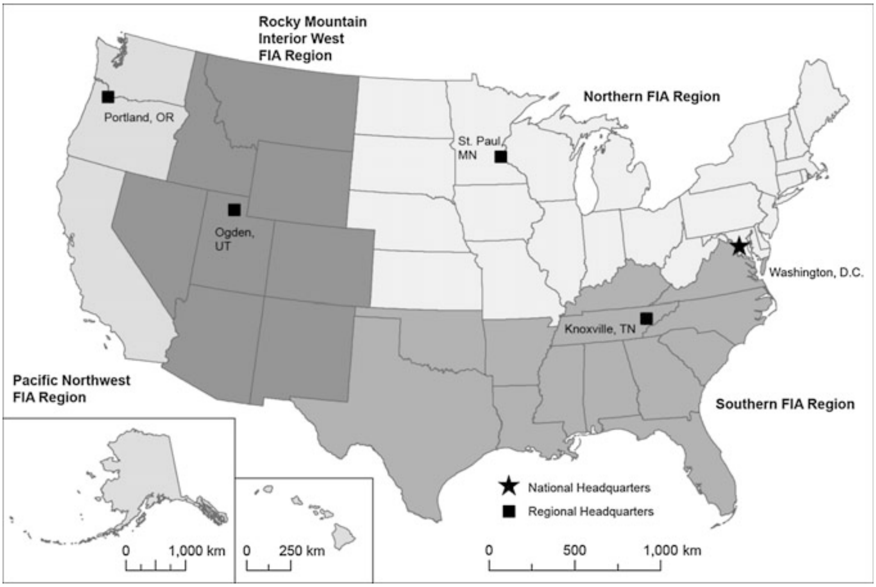

Fig. 45.1 FIA regions and headquarters

in a subsequent panel is initiated. With this approach a complete systematic sample of each state is obtained every year.

All ground plots conform to the national standard plot configuration and consist of four 7.31 m (24 ft) radius circular subplots configured as a central subplot and three peripheral subplots with centres located at a distance of 36.58 m (120 ft) and azimuths of 0, 120, and 240° from the centre of the central subplot. Each subplot includes a 2.08 m (6.8 ft) radius micro-plot on which seedlings and saplings are measured and a regionally optional 18.0 m (58.9 ft) radius annular macro-plot on which additional large trees are measured.

The FIA programme conducts inventories in multiple phases. The primary objective of Phase 1 is to stratify the population area for purposes of reducing the variances of estimates. The objective of Phase 2 is to establish and measure an array of permanent ground plots. Aerial photography is used to observe each plot to assure forest land use before sending a field crew to the plot location. Field crews visit locations of plots with current or previous forest land use or in close proximity to forest land use as determined via photo-interpretation. Plots are installed on all public forest land and on private forest land with permission of the land owner. A set of additional forest health variables including crown condition, vegetation structure, soils, and down woody material is also currently measured on 5–15 % of Phase 2 plots, depending on the variable.

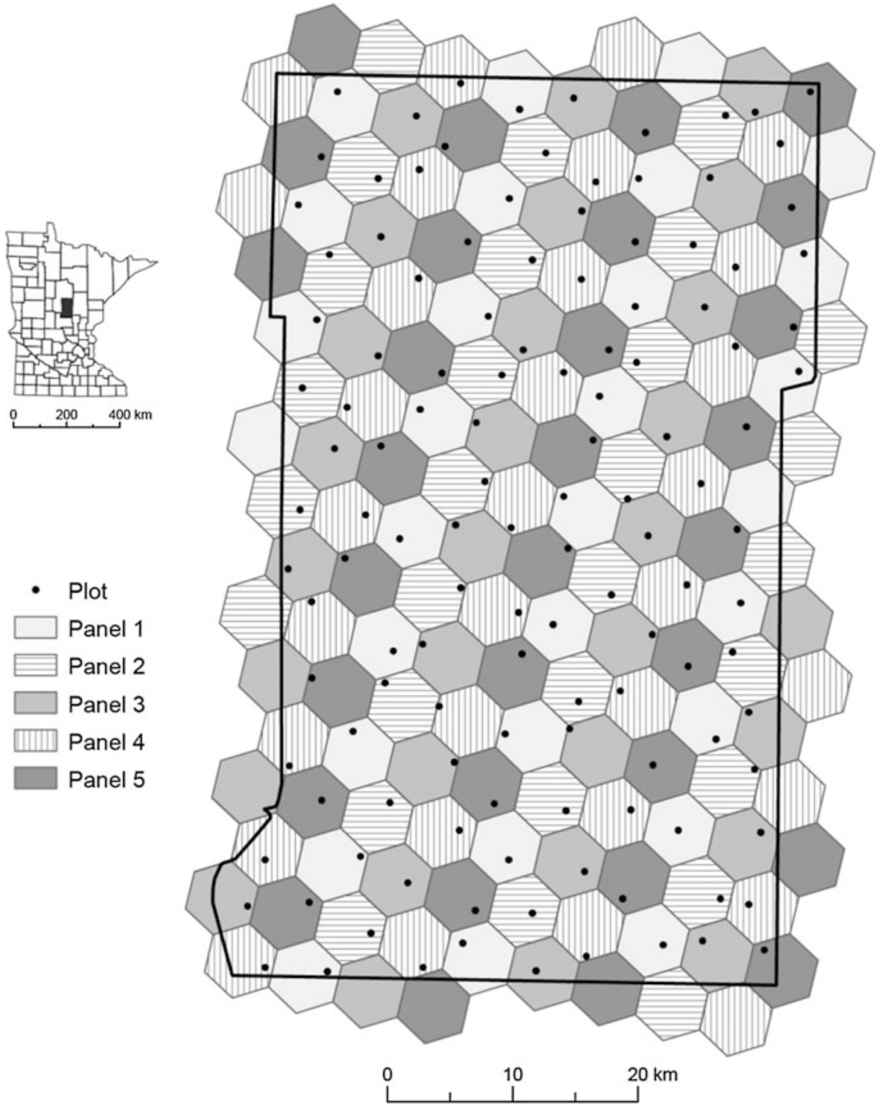

Fig. 45.2 Sampling hexagons with random plot locations for Crow Wing County, Minnesota, USA

45.1.3 Data Collection

Plot-level observations include ownership, land use and land use change, forest type, stand age, disturbance, and regeneration counts. Tree-level observations include species, diameter, height, damage, grade, and cull (decay and rot). FIA field crews identify distinct conditions on plots where conditions are defined as different classes of seven variables: land use, reserve status, owner group, regeneration type, tree density, forest type and tree size class. If multiple conditions are identified on a plot, field crews assign tallied trees to the condition class in which they occur and record information necessary for estimating the portion of the total plot area that is within each condition.

45.1.4 Data Processing, Reporting and Use of Results

Statistical models are used to estimate stem volumes for individual trees with dbh of at least 12.7 cm (5 in.) as volumes of central stems above a 30.48 cm (1 ft) stump and to a minimum top diameter of 10.16 cm (4 in.). The models are constructed regionally and are based on observations and measurements for species, diameter, and height. The effects of the uncertainty in the model predictions on large area volume estimates are regarded as negligible (McRoberts and Westfall 2014). All live volume includes stem volumes for all trees, while growing stock volume excludes volume for the cull portions of trees and all volume for cull trees.

FIA inventories are designed to produce data to estimate components of change which are aggregated to estimate net change. Estimates of growth, mortality, removals, and regeneration are obtained by comparing observations and measurements for the same plots from previous inventory cycles. For all components, change is estimated for elapsed time between successive inventory cycles. Components of change include ingrowth estimated as the volume of trees that first exceed the minimum dbh, reversion estimated as the volume of trees on land that reverts from nonforest to forest land use, mortality estimated as the volume of trees that die from natural causes, cut estimated as the volume of trees cut, and diversion estimated as the volume of trees on land diverted from forest to nonforest land use. Growth is estimated for trees that survive between inventory cycles and between the midpoint of the cycle and either the beginning or the end of the cycle for each category of components of change.

Estimates of parameters related to the term *increment*, as used in Europe to mean the ratio of the difference between inventories in estimates of volume and the interval between inventories, are not commonly reported in the USA. However, similar concepts such as net annual growth of growing stock are commonly used and related parameters are routinely reported (Table 45.3). Similarly, the term *drain* is not routinely used, although the estimated components of change can be used to estimate the equivalent of parameters related to drain.

In general, FIA areal estimation techniques are characterised as probability-based (design-based) and rely heavily on Cochran (1977). FIA estimation procedures have been documented, peer-reviewed and published to achieve four objectives: (1) to ensure a common understanding and practice among the regional FIA programmes, (2) to facilitate development of the national programme including the national information management system, (3) to provide a defensible statistical basis for the sampling and estimation components of the programme, and (4) to promote credibility with clients and stakeholders (Bechtold and Patterson 2005; McRoberts et al. 2005).

The FIA programme uses stratified estimation to obtain estimates of population parameters for most variables. Because all plots are permanent, post-sampling stratification (post-stratification) is used where strata are derived from the predicted classes of satellite imagery (McRoberts et al. 2002, 2006, 2010). FIA plots are assigned to the stratum associated with the satellite image pixel containing the plot centre, and strata weights are calculated as the proportions of pixels assigned to strata. Cochran (1977) provides the basic stratified estimators as,

$$\hat{\mu} = \sum_{h=1}^{L} w_h \bar{y}_h \tag{45.1}$$

and

$$Var(\hat{\mu}) = \sum_{h=1}^{L} w_h^2 \frac{\hat{\sigma}_h^2}{n_h}, \tag{45.2}$$

where h indexes strata, and w_h, $\bar{y}_h$, $\hat{\sigma}_h^2$, and n_h are the within-stratum weight, mean, variance, and sample size, respectively. Strata weights may be adjusted to compensate for random within-strata sample sizes resulting from post-stratification rather than stratified sampling. The positive results of stratification are that variances may be reduced by factors as great as 5.0 for area estimates and 3.0 for volume estimates with no additional sampling or associated costs.

Per unit area estimates by condition class (e.g. volume by forest type) are calculated using a ratio estimator of the general form,

$$\bar{y} = \frac{\sum_{i=1}^{n_h} y_i}{\sum_{i=1}^{n_h} a_i}, \tag{45.3}$$

where y_i is the plot-level observation or measurement of the variable of interest on the *i*th plot and a_i is the area of the condition on the same plot (Särndal et al. 1992).

Estimates of uncertainty are expected to satisfy precision (PREC) for estimate of a parameter, $\hat{\mu}$, expressed as,

$$PREC = \sqrt{\frac{\hat{\mathrm{Var}}(\hat{\mu})}{\hat{\mu} \cdot \mathrm{S}}}, \tag{45.4}$$

where,

$$S = \begin{cases} 40,469\,\text{ha}\,(10^6\,\text{acres})\,\text{for area} \\ 28,316,980\,\text{m}^3\,(10^9\,\text{ft}^3)\,\text{for volume} \end{cases}, \tag{45.5}$$

with precision guidelines of

$$\text{PREC} = \begin{cases} 0.03 & \text{for area estimates} \\ 0.05 & \text{for volume estimates in the eastern USA} \\ 0.10 & \text{for volume estimates in the western USA} \end{cases}.$$

Inventory data and estimates are made available annually for each state, and on a 5 year cycle each state receives a comprehensive analytical report that includes an assessment of the current status and trends of forest resources and ecosystem condition, analysis and discussion of probable factors influencing the status and trends, and 50 year predictions of likely trends in key resource attributes. The FIA programme also reports national assessments on a 5 year cycle.

45.2 Land Use and Forest Resources

45.2.1 Classification of Land and Forests

The land use classes, Other Wooded Land (OWL) and Trees outside Forest (TOF), are not used in the USA and are not assessed separately from other lands with tree cover. The class closest to OWL and TOF is Woodland which is defined as land with trees whose cover is in the range 5–10 %. Most woodland is in the arid, Southwestern region of the USA and consists of juniper, mesquite, scrub oaks, and some woody vines, all with short stature of less than 5 m. Inclusion of this class has been the subject of much debate in the last century. The primary reasons for its current assessment include ecosystem fragility and susceptibility to fire.

Forest area in the USA totals more than 300 million ha (Table 45.1) and has generally been increasing since the 1920s, despite a near tripling of the human population. Currently, more than 30 % of the country is characterised as forest land with 58 % of it in various categories of private ownership (Table 45.2; Fig. 45.3). Unlike in many European countries, private forest land owners in the USA have considerable freedom to convert their land from forest to non-forest uses and vice versa in response to varying commodity prices and other factors. This feature of private land ownership at least partially explains substantially varying forest areas over time.

Although the term Forest Available for Wood Supply (FAWS) is also not commonly used in the USA, the concept is prevalent (Table 45.1). For example, the definition of the land use category Timberland includes the specification that the land must not be withdrawn from timber utilisation. Conversely, the land use

Table 45.1 Land use categories

Category	Definition	Estimate (1000 ha)	Standard error (%)
Total land area		914,995	0.01
Forest land	0.4 ha (1 ac), 36.58 m (120 ft) minimum width, 10 % cover or equivalent stocking with trees able to reach 5 m at maturity, forest land use	310,091	0.14
Timberland	Same as forest land plus capable of producing 1.37 m^3/ha (20 ft^3/ac) per year and not withdrawn from timber utilisation	210,908	0.16
Reserved forest land	Forest land where management for the production of wood products is prohibited through statute or administrative designation; examples include national forests, wilderness areas, national parks, and national monuments	29,753	0.91
Woodland	Land with tree cover in the range 5–10 %	2174	1.22

Table 45.2 Categories of forest area by ownership

Category	Forest land (1000 ha)	Timberland (1000 ha)	Reserved forest land (1000 ha)
Public	129,974	65,147	29,621
Private (corporate)	59,680	45,034	6
Private (non-corporate)	120,437	100,727	127

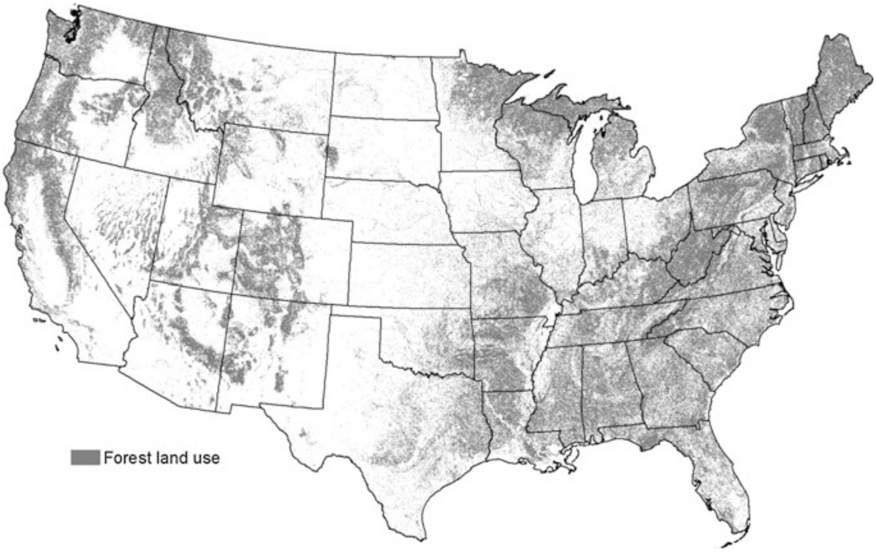

Fig. 45.3 Forest land in the USA. *Data Source* National Land Cover Database, 2011

category Reserved forest land is defined to be land where management for production of wood products is explicitly prohibited. Reserved forest land constitutes 7–10 % of forest land, includes mostly State and Federal parks and wilderness areas, has doubled in area since the early 1950s, and is concentrated in western States.

45.2.2 Wood Resources and Their Use

Wood resources are generally available for use on all private non-reserved forest lands and most public non-reserved forest lands. Local exceptions include buffer zones established for aesthetic purposes and for filtering purposes such as near water sources. Net growing stock volume on timberland, one measure of wood resources, totals nearly 30 billion m^3 (Table 45.3) and has increased by more than 50 % since 1953. Most of the increase has been in the eastern USA (Oswalt et al. 2014). Between 2007 and 2012, the southern region of the country had 63 % of removals (Oswalt et al. 2014), hence the characterisation of this region as the "woodbasket of the country."

Over the past 50 years, growth has generally exceeded removals throughout the USA. Although removal levels have stabilised in recent years, the source of removals has shifted decidedly from public land in the West to private land in the East. In 1996, coniferous removals in the South exceeded growth for the first time since 1952, when data were first reported.

Sawtimber is defined to be live trees of commercial species containing at least a 3.66 m (12 ft) log or two non-contiguous 2.44 m (8 ft) or longer logs that satisfy regional quality specifications. Coniferous species must have dbh of at least 22.9 cm (9 in.), whereas deciduous species must have dbh of at least 27.9 cm (11 in.). Tree grade is based on tree diameter and the presence or absence of knots, cull primarily in the form of decay, and curvature of the bole. Trees with the greatest quality receive a grade of 1, whereas trees with poorest quality receive a grade of 4. Sawtimber volume by grade and coniferous/deciduous classes is typically reported at the State-level. At the national level, all live volume includes stem volume for all trees, whereas growing stock volume excludes volume for the cull portions of trees (Table 45.3).

45.2.3 Additional Assessments of Wood Resources

FIA data are the primary source of large area forest information for use by public land management and planning agencies, forest industry, environmental groups, and non-governmental organisations. In addition, the FIA programme conducts special studies related to utilisation of timber outputs, forest ownership patterns and trends, and non-timber resources such as recreation, hydrology, and wildlife habitat.

Table 45.3 Forest resource definitions and estimates

Category	Definition	Estimate	Standard error (%)
Volume parameters			
Net volume of growing stock on timberland	Live trees with dbh ≥ 12.7 cm of commercial species meeting standards of quality or vigour; excludes volume of rot and poor form; estimated for central stem above 30.48 cm stump to minimum of 10.16 cm top diameter outside bark	29,907,000,000 m^3	0.32
Net annual growth of growing stock timberland	Average annual net change in wood volume of trees with dbh ≥ 12.7 cm excluding losses from cutting (gross growth minus mortality) during the inter-survey period, the total volume of trees entering all of the diameter classes with dbh ≥ 12.7 cm through ingrowth; volume losses from natural causes	747,937,000 m^3	0.57
Net annual removals of growing stock on timberland	Average annual wood volume of trees ≥ 12.7 cm dbh. removed from the inventory by harvesting, cultural operations (such as timber-stand improvement), land clearing, or changes in land use during the intersurvey period, in addition to the volume in logging residues or mortality due to logging damage (harvest removals). This component of change also includes the volumes of growing-stock trees removed due to land use changes (other removals)	363,976,000 m^3	1.32
Volume of sound dead wood on timberland	Net volume in salvageable dead trees on timberland	1,286,884,000 m^3	1.00
Volume per unit area parameters			
Net annual growth of growing stock per unit area on timberland	Net volume of growing stock on timberland divided by area of timberland	3.55 m^3/ha	0.29
Net annual removals of growing stock per unit area on timberland	Net annual removals of growing stock on timberland in cubic meters divided by area of timberland in hectares	1.73 m^3/ha	1.38

45.2.4 Timber Products Output

The Timber Products Output (TPO) component of the FIA programme conducts studies to estimate industrial and non-industrial uses of roundwood in each state. All primary wood-using mills in a state are canvassed using questionnaires designed to determine the locations, sizes, and types of mills; the volume of roundwood received by product species and geographic origin; and the volume, type and disposition of wood residues generated during primary processing. Logging utilisation studies are conducted to relate TPO to inventory volume by visiting a sample of logging operations to characterise the sites logged, trees cut, products taken, and residues left behind.

The term assortment, meaning size classes of logs, often with reference to particular categories of wood products, is not used in the USA. However, the concept is prevalent, and parameters related to classes such as sawlogs, pulpwood, fuelwood, veneer, and poles, posts, and mulch are estimated by the TPO component of the FIA programme (Oswalt et al. 2014). In 2011, timber harvested for industrial products and domestic fuel wood totalled 362 milllion m^3, an approximately 15 % decline since 2006. Since the 1970s, veneer output has been stable, pulpwood has increased, and both pulpwood and fuelwood have varied considerably (Oswalt et al. 2014).

45.2.5 National Woodland Owner Survey

The National Woodland Owner Survey (NWOS) is a survey of forest owners conducted to increase understanding of woodland owners as the crucial link between forests and society (Butler 2008). The NWOS inquires of forest owners regarding their forest land, how they use and manage it, their concerns and issues, and their future intent. Information from the NWOS is used to design and implement services and formulate policies that affect interested parties including government agencies, non-governmental organisations, landowner organisations, private service providers, forest industry companies, and academic researchers.

45.2.6 Urban Forests

The U.S. Forest Service acquires information on urban tree canopy distribution, species composition and health, and urban tree benefits. Information is reported at state, county, and sub-county levels and is used for multiple purposes: (1) to identify trends in urbanisation and the growth and decline of urban forests, (2) to determine priority areas for urban reforestation, (3) to quantify ecosystem services that urban forests provide such as carbon sequestration and storm water management, and (4) to support urban and community forest management and green infrastructure planning. Research efforts combine satellite, local field, and national urban map data to facilitate understanding of the magnitude and composition of the resource, how urbanisation is expanding, and factors that lead to changes in tree species health and distribution in the future (Nowak et al. 2013).

45.3 Auxiliary Uses of FIA Data

FIA data are used by a wide array of other public and private organisations. The data are the primary source of forest information for reporting on the nation's renewable resources to the U.S. Congress every 10 years (Oswalt et al. 2014) and for international carbon reporting (Birdsey and Lewis 2003; O'Neill et al. 2005; Heath et al. 2011; Woodall 2012; US EPA 2014). In response to extensive forest wildfires in the western USA, FIA data were the primary source of information for a biomass assessment for western states (Rummer et al. 2003). FIA data were used for accuracy assessment of a national satellite image-based land cover product constructed by the U.S. Geologic Survey and for describing major vegetation cover types by the U.S. Fish and Wildlife Service. FIA data were also used by the Heinz Center which was best known for its reports on the state of the nation's ecosystems. These reports became seminal references for policy makers and environmental managers (Heinz 2008, 2010). The Forests on the Edge project used data from multiple sources including FIA to identify areas where private forest timber resources might be adversely affected by housing development, fire, insects, pests and diseases (Stein et al. 2005, 2010).

45.4 Summary

The basic features of the national sampling design and plot configuration have remained unchanged since the mid- to late 1990s, and will remain the same for the foreseeable future. Parameters associated with primary variables such as forest area, volume, and volume by species are estimated using stratified estimation where strata are constructed from classified satellite imagery. Although stratified estimation will continue to be used, the kind, date and resolution of the product from which strata are derived may change. Plot data (except for exact plot locations) and estimates of primary parameters are made available annually via the Internet. A complete report for each state is published every five years. The report includes discussions of trends, health and disease issues, and spatial depictions of resources.

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