Erkki Tomppo
Thomas Gschwantner
Mark Lawrence
Ronald E. McRoberts
Editors

National Forest Inventories

Pathways for Common Reporting

Springer

COST

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Preface

Forest inventories throughout the world have evolved gradually over time. The content as well as the concepts and definitions employed are constantly adapted to the users' needs. Advanced inventory systems have been established in many countries within Europe, as well as outside Europe, as a result of development work spanning several decades, in some cases more than 100 years.

With continuously increasing international agreements and commitments, the need for information has also grown drastically, and reporting requests have become more frequent and the content of the reports wider. Some of the agreements made at the international level have direct impacts on national economies and international decisions, e.g., the Kyoto Protocol. Thus it is of utmost importance that the forest information supplied is collected and analysed using sound scientific principles and that the information from different countries is comparable.

European National Forest Inventory (NFI) teams gathered in Vienna in 2003 to discuss the new challenges and the measures needed to get data users to take full advantage of existing NFIs. As a result, the European National Forest Inventory Network (ENFIN), a network of NFIs, was established. The ENFIN members decided to apply for funding for meetings and collaborative activities. COST–European Cooperation in Science and Technology - provided the necessary financial means for the realization of the program. 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 FIA programme of the U.S. Forest Service, Scion from New Zealand and the Joint Research Centre, Institute for Environment and Sustainability, joined COST Action E43 as institutions from non-COST countries. Furthermore, NFI representatives from several other countries participated in the meetings and work of COST Action E43.

COST Action E43 worked closely together with international organisations and institutions, such as the United Nations and the European Commission.

COST Action E43 adopted a mission to develop methods, concepts and definitions to be employed in harmonising the NFIs so that the information from different countries would become fully comparable. The work was carried out in meetings, workshops and scientific missions. Some of the results have been published in scientific journals. The information was collected both from the participants and by using questionnaires directed to a wide group of NFI data providers. The official duration of COST Action E43 was from June 2004 to December 2008 but the publishing work continued into 2009. The participation of the forest inventory experts, directly involved in practical work, stimulated the work and promoted successful outcomes. However, a single volume on the status of forest inventories in different countries was lacking.

The members of COST Action E43 collected a large amount of information from the NFIs of the participating countries, and agreed to compile national forest inventory reports into a single book. In addition to the member countries and institutions, reports were contributed by some of the most significant forestry countries around the world. As a result, this volume also includes NFI reports from Brazil, Canada, China, Japan, Luxembourg, Poland, the Republic of Korea and the Russian Federation, in addition to the 29 reports of the participating countries and institutions; in total 38 reports. The forests of these countries comprise over half of the global forests, 2.4 billion hectares out of 4.0 billion hectares. Furthermore, United Nations and Agricultural Organization, NFMA programme provided a description of the approach used when supporting countries in development in establishing forest inventories. Most of the reports follow the same structure. This includes a brief history, use of the results, information about basic forest resources, data collection and estimation methods, an assessment of how well the country is able to provide forest resource related estimates on the basis of the agreed reference definitions (status of harmonisation), and future prospects.

The information was collected into the present book. The authors and editors hope that forest inventory experts, and other people interested in the forest environment worldwide, find this information useful. Furthermore, one of the principal ideas of this book is to be an essential source of information for those planning a new forest inventory or modify the existing one.

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The demanding typesetting was made in a highly professional way by Ms. Sari Elomaa at Metla. Valuable technical support at the very last phase was provided by M.Sc. Mia Landauer BOKU Vienna. We are deeply indebted to all the individuals whose support has made this book possible. We also express our sincere thanks to Dr. Catherine Cotton, Publishing Editor, and Ms. Ria Kanters at Springer for their guidance and assistance during all the phases of the production of the book.

COST Information

COST – the acronym for European Cooperation in Science and Technology – is the oldest and widest European intergovernmental network for cooperation in research. Established by the Ministerial Conference in November 1971, COST is presently used by the scientific communities of 35 European countries to cooperate in common research projects supported by national funds.

The funds provided by COST – less than 1% of the total value of the projects – support the COST cooperation networks (COST Actions) through which, with EUR 30 million per year, more than 30 000 European scientists are involved in research having a total value which exceeds EUR 2 billion per year. This is the financial worth of the European added value which COST achieves.

A "bottom up approach" (the initiative of launching a COST Action comes from the European scientists themselves), "à la carte participation" (only countries interested in the Action participate), "equality of access" (participation is open also to the scientific communities of countries not belonging to the European Union) and "flexible structure" (easy implementation and light management of the research initiatives) are the main characteristics of COST.

As precursor of advanced multidisciplinary research COST has a very important role for the realisation of the European Research Area (ERA) anticipating and complementing the activities of the Framework Programmes, constituting a "bridge" towards the scientific communities of emerging countries, increasing the mobility of researchers across Europe and fostering the establishment of "Networks of Excellence" in many key scientific domains such as: Biomedicine and Molecular Biosciences; Food and Agriculture; Forests, their Products and Services; Materials, Physical and Nanosciences; Chemistry and Molecular Sciences and Technologies; Earth System Science and Environmental Management; Information and Communication Technologies; Transport and Urban Development; Individuals, Societies, Cultures and Health. It covers basic and more applied research and also addresses issues of pre-normative nature or of societal importance. Web: http://www.cost.esf.org

Contents

Abbreviations

ARD	Afforestation, Reforestation and Deforestation
CBD	Convention on Biological Diversity
COP	Conference of Parties
COST	European Cooperation in Science and Technology
EEA	European Environment Agency
EEC	European Economic Community
EFI	European Forest Institute
EFICS	European Forestry Information and Communication System
ENFIN	European National Forest Inventory Network
EU	European Union
EUROSTAT	Statistical Office of the European Commission
FAO	Food and Agriculture Organization of the United Nations
FIA	Forest Inventory and Analysis Programme
Forest Focus	Forest Condition Monitoring Programme following ICP Forests
FL	Forest Land
FRA	Forest Resources Assessment
GHG	Greenhouse gas
GPG	Good Practice Guidance
Habitats Directive	European Union Directive on the conservation of natural habitats and of wild fauna and flora
ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
INBAR	International Network for Bamboo and Rattan
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KP	Kyoto Protocol
LiDAR	Light Detection and Ranging
LUC	Land Use Change
LULUCF	Land Use, Land-Use Change and Forestry
MCPFE	Ministerial Conference on the Protection of Forests in Europe

METLA	Finnish Forest Research Institute
NEFD	National Exotic Forest Description
NFI	National Forest Inventory
NVS	National Vegetation Survey
OWL	Other Wooded Land
PSP	Permanent Sample Plot
REDD	Reducing Emissions from Deforestation and Degradation
SBSTA	Subsidiary Body for Scientific and Technical Advice
SNS	Nordic Forest Research Co-operation Committee
TBFRA	Temperate and Boreal Forest Resources Assessment
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WG	Working Group

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Chapter 1
Introduction*

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1.1 History of NFIs

The history of forest inventories goes back to the end of the Middle Ages when intensive use of forest resources first led to wood shortages which, in turn, forced users to begin forest planning, particularly near towns and mines (Loetsch and Haller 1973; Gabler and Schadauer 2007). The first information collected for these purposes was from assessments of forest area and crude estimates of growing stock.

As a noun, the word 'inventory' refers to a detailed list of articles according to their properties, and as a verb the word refers to the process of constructing the list. Thus, forest inventory refers to both the tabulated forest information and to the process of measuring and analysing the data on which the tabulated information is based. Further, the tabulated information generally includes estimates for trees, tree properties and forests, often on the basis of areal units (Loetsch and Haller 1973; Loetsch et al. 1973; Davis et al. 2001) and is regarded as reliable and adequate for its intended purposes.

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The first inventories were often local with the aim of assessing the available timber resources for specific purposes and were often conducted by the timber users, for example companies (Loetsch and Haller 1973; Loetsch et al. 1973; Davis et al. 2001). It soon became obvious that such inventories could not easily be used to compile national level forest information for purposes of formulating national forest policy; thus, National Forest Inventories (NFIs) were initiated.

Since that time, forest information has been collected via user-driven NFIs in many countries. NFIs have different histories in different countries, but some type of forest information has been collected in both European and North American countries since the nineteenth century (USDA 2007; von Berg 1858).

However, systematic forest assessments based on statistical sampling methods began only in the twentieth century. The mathematical bases for sampling methods in NFIs had already been developed by the beginning of the nineteenth century by C.F. Gauss and P.S. Laplace (Gabler and Schadauer 2007). The formulas were derived from the theory of probability (Laplace 1814) and the least squares method of C.F. Gauss (Abdule and Wanner 2002).

Sample-based national forest inventories were initiated in the Nordic countries in the late 1910s and early 1920s, but were not introduced in other European countries until after World War II: in the 1960s in the German Democratic Republic and 1987 in the Federal Republic of Germany, in 1958 in France, in the 1960s in Austria and Spain, and in the 1980s in Switzerland. Some European countries have only recently introduced sample-based inventories. At the global level, national inventories are still lacking in many countries, although new inventories are being initiated all the time.

The early national inventories in the Nordic countries included not only information about areas, volume and increment of growing stock and the amount of timber, but also age, size and species structure of forests, silvicultural status of forests, accomplished and needed cutting and silvicultural regimes (Ilvessalo 1927). The purpose was to provide information for forestry authorities, timber users, and planners who developed national forest policies.

In the United States of America (USA), the earliest large-area, sample-based inventories date to passage of federal legislation in 1928. This enabling legislation is likely due, at least in part, to the influence of Professor Yrjö Ilvessalo, head of the Finnish NFI, on Calvin Coolidge, the President of the USA. However, these forest inventories were developed and implemented at statewide and regional levels, and as a result consistent and timely reporting across state boundaries was difficult. In the 1990s, inventories conducted by the Forest Inventory and Analysis programme of the U.S. Forest Service were standardized across the country to include a common sampling design, plot configuration, set of common variables, measurement protocols, estimation formulae, and reporting standards.

Today, sample-based inventories are conducted in most European and North American countries, although the tradition in Eastern Europe has been to gather national data by aggregating data from stand-level inventories originally designed for management planning purposes. However, many Eastern European countries have recently revised their systems in favour of statistical, sample-based NFIs.

1.2 Uses of NFI Data

1.2.1 The Use of NFI for National Forestry and Environment Planning and Policy

The primary purpose of NFIs in the Nordic countries has been to provide accurate information for forest management and forest industry investment planning, although assessing the productivity of forests and possibility of taxing forest income was one of the motivations for starting the Finnish NFI in 1921. Accordingly, future forest development scenarios based on NFI data have been used to propose alternative cutting scenarios which have then formed the basis for forest policy and utilisation. For Central European countries, the main purpose for conducting forest inventories has been to monitor sustainable use of forests. The term sustainability dates back to the eighteenth century (e.g. Onomatologia 1773). In the nineteenth century sustainability included economical and beneficial functions. The Austrian Forest Act of 1852 already included the term sustainability (RGBl. LXXII 250/1852 (1852)). After World War II, the possible overutilisation of forests was a main driving force for starting NFIs in Central Europe.

Timber processing and marketing practices changed dramatically in these countries during the 1980s and 1990s. Previously, long time intervals elapsed between harvesting and the delivery of the timber, panel or paper products to the customer. Harvesting decisions were mainly driven by forest production considerations, derived from long-term yield regulations and management plans, and modified by operational logging schedules. Large timber and end product stocks had to be maintained, and prices fluctuated rapidly as the market changed. New practices have increased the need for timely forest resource information.

Forest health monitoring emerged as an important issue when increased acidic deposition led to local declines of sensitive forest ecosystems during the 1980s. These declines increased public and scientific awareness of all kinds of forest damage and led to the initiation of forest health monitoring programmes. These monitoring programmes were integrated into at least some NFIs and are essential elements of forest inventories.

The role of forests in providing non-wood goods and services such as wildlife habitat, recreational opportunities, and contributions to water quality has received increased attention in recent years, particularly in urbanised societies. Human-induced habitat losses, as well as continuing deforestation in the tropics, have resulted in an accelerating rate of species extinctions. The current estimated extinction rate, which is 100–1,000 times greater than under natural conditions (Hanski 2005; Lawton and May 1994), led to international regimes to prevent unsatisfactory development. The increased international discussions and awareness of the status of biodiversity led to the Convention on Biological Diversity (CBD 2009) of the United Nations Environment Program (UNEP 2009). CBD motivated the initiation of forest biodiversity monitoring programmes in the early and mid-1990s.

For several decades some NFIs had already collected species information, but mostly it pertained to ground vegetation (Kujala 1926a, b, 1964). At the same time, monitoring overall forest sustainability became more common. Processes such as the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (2003) and the Montréal Process (2005) were established with the goal of providing data on forest sustainability criteria and indicators. Forest inventory teams had to develop methods to obtain information about this complex issue with reasonable costs. Surrogates, such as the amount and quality of dead and decaying wood, were introduced to indicate the potential occurrence and abundance of species.

The use of fossil fuels, deforestation in the tropics and farming have increased CO_2 and other greenhouse gases (GHG) in the atmosphere and lead to global warming. Over a decade ago, most countries joined an international treaty – the United Nations Framework Convention on Climate Change (UNFCCC) – to begin considering what could be done to reduce global warming and to cope with the inevitable temperature increases (UNFCCC 2009a). More recently, a number of nations approved an addition to the treaty, the Kyoto Protocol (KP), which has more powerful and legally binding measures. The UNFCCC secretariat supports all institutions involved in the climate change process, particularly the Conference of Parties (COP), the subsidiary bodies and their Bureau (UNFCCC 2009a).

The KP was adopted in Kyoto, Japan, on 11 December 1997, entered into force on 16 February 2005, and has been ratified by 184 Parties of the Convention to date. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh in 2001, and are called the "Marrakesh Accords." "The major distinction between the Protocol and the Convention is that while the Convention encouraged industrialised countries to stabilize GHG emissions, the Protocol commits them to do so" (UNFCCC 2009b).

COP 7, by its decision 11/CP.7 (UNFCCC 2002) invited the IPCC to prepare a report on good practice guidance and uncertainty management relating to the measurement, estimation, assessment of uncertainties, monitoring and reporting of net carbon stock changes and anthropogenic GHG emissions by sources and removals by sinks in the Land-Use, Land-Use Change, Forests (LULUCF) sector. The "Good Practice Guidance for Land use, Land-use Change and Forestry" (IPCC GPG for LULUCF) was adopted by the IPCC Plenary in 2003. The role of this GPG is not to replace the Revised 1996 IPCC Guidelines but rather to provide advice consistent with them. The GPG assists countries in producing inventories for the LULUCF sector that are neither over- nor under-estimated so far as can be judged, and in which uncertainties are reduced as far as practicable. It is also intended to support the development of inventories that are transparent, consistent, complete, comparable and accurate.

The IPCC (2007) estimated emissions from deforestation in the 1990s as 5.8 Gt CO_2 per year. It also noted that reducing and/or preventing deforestation and the release of carbon emissions into the atmosphere is the mitigation option with the largest and most immediate carbon stock impact in the short term per hectare and per year globally.

Parties to the UNFCCC process recognized the contribution of GHG emissions from deforestation in developing countries to climate change and the need to take action to reduce such emissions. After a 2-year process, the COP adopted a decision on "Reducing Emissions from Deforestation and Degradation in developing countries: approaches to stimulate action" (REDD), Decision 2/CP.13 (UNFCCC 2008). The decision provides a mandate for several elements and actions by parties relating to reducing emissions from deforestation and forest degradation in developing countries. Examples of the activities are to support and facilitate capacity-building, technical assistance and transfer of technology relating to methodological and technical and institutional needs of developing countries, and to explore demonstration activities to address drivers of deforestation and enhance forest carbon stocks due to sustainable management of forests. In 2008, the Subsidiary Body for Scientific and Technical Advice (SBSTA) initiated a programme of work on methodological issues. SBSTA reported on the outcomes, including any recommendations on possible methodological approaches, to the COP at its 14th session (December 2008). In 2008 and 2009, policy approaches and positive incentives relating to REDD and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries were considered under the process of the Bali Action Plan (Decision 1/CP.13) (UNFCCC 2008; 2009c).

The role of forests in the global carbon balance has placed forests in a new light and created new expectations for both forestry and forest inventories. While forests are carbon sinks in many industrialised countries, they are a source in many developing countries, particularly in Africa and South America. Forests and the LULUCF sector of the UNFCCC have the potential to become a world-wide carbon sink.

The changing roles of forests and the requirements for national reporting and common international reporting have substantially altered demands for forest information. Because NFIs are the primary source of forest information for all these purposes, the scope of NFIs has broadened accordingly and has resulted in the introduction of a wide variety of new variables requiring assessment.

Despite these new ways of using NFI data, one of the most important roles of NFIs is as the key information source for national forest policies and forestry programs by providing a picture of the status of the forests at sub-national and national level. In countries with significant forest industry, NFIs are a part of what is called the national forest cluster, and, in that sense, are important instruments not only in forestry but also in supplying strategic information for nations' industrial policies.

1.2.2 The Use of NFI Data for International Reporting

The Food and Agriculture Organization (FAO) of the United Nations has been monitoring the world's forests at 5–10 year intervals since 1946. The Global Forest Resources Assessments (FRA) are based on data that countries provide to FAO.

FAO compiles and analyses the information and presents the current status of the world's forest resources and their changes over time. The scope of the assessments has gradually expanded. The first assessments were focused on wood supply in response to fears of a wood shortage after World War II (FAO 2009).

Today, the assessments have a much wider scope, providing a holistic perspective on global forest resources, their management and uses by addressing seven broad topics, also known as the thematic elements of sustainable forest management: (1) extent of forest resources and their contribution to the global carbon cycle, (2) forest health and vitality, (3) forest biological diversity, (4) productive functions of forests, (5) protective functions of forests, (6) socio-economic functions of forests, and (7) legal, policy and institutional framework related to forests.

In the recent reports, special attention has been paid to harmonisation of the variables used for international statistics. Countries have been asked to report data for variables using agreed-upon FRA definitions. If countries used other than national definitions for reporting, they were asked to report progress toward reporting using the FRA definitions (FAO 2005).

The United Nations Economic Commission for Europe (UNECE) (UNECE/FAO 2000) has collected, analysed and published the Temperate and Boreal Forest Resources Assessment (TBFRA) as a regional contribution to the Global FRA (UNECE/FAO 2000). The Global FRA has received crucial assistance and support from the UNECE secretariat in Geneva (MCPFE report 2007 which replaced the earlier TBFRA report) (MCPFE 2007).

Within the framework of the MCPFE, European countries and the European Union (EU) have proposed and agreed upon 35 quantitative indicators that describe sustainable forest management. Many of these indicators originate from NFIs and are reported through FRA and special MCPFE reports. Similar efforts have been conducted under the auspices of the Montréal Process and its 12 member countries: Argentina, Australia, Canada, Chile, China, Japan, Mexico, New Zealand, Republic of Korea, Russian Federation, the USA and Uruguay.

At the European level, the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was launched in 1985 under the Convention on Long-range Transboundary Air Pollution of the UNECE because of the growing public awareness of the possible adverse effects of air pollution on forests (ICP 2009). ICP Forests monitors European forests in cooperation with the EU using two different monitoring intensity levels. The first grid (Level I) is based on approximately 6,000 observation plots on a transnational 16 × 16-km grid throughout Europe. The second more intensive monitoring level (Level II) includes approximately 800 plots in selected forest ecosystems in Europe. The link between the NFI sampling grids and the Level I or Level II grids varies from country to country. In some countries the ICP grids form a subset of the NFI sample; in other countries, the link is restricted to the institutional level; and in some countries the two systems are completely independent. As a result of ongoing activities, the link at the institutional level as well as at the plot level is strengthened in many European countries. At the end of this process, most countries should have only one organization responsible for both the NFI and ICP

Forests and one sample-grid with three intensity levels (NFI, Level I and Level II). At the European level, ICP Forests has been conducted by, or closely linked to, NFIs (ICP 2009). Participants in ICP Forests have agreed to continue and widen its scope within the framework of Forest Focus (2007) and LIFE+, a community scheme for harmonised, broad-based, comprehensive and long-term monitoring of European forest ecosystems with emphasis on protecting forests against atmospheric pollution and fire. The search for synergies between LIFE+ and NFIs is necessary to ensure coordinated and cost effective forest assessments.

1.3 Harmonising Forest Resource Information

FRA 2000, and particularly TBFRA 2000 as a part of FRA 2000, was the first assessment to use a homogeneous set of definitions. The harmonisation effort continued with the Global FRA 2005 (FAO 2005) and included revision of the 1990 and 2000 estimates to conform to the 2005 definitions. Yet, both the FRA 2000 and FRA 2005 reports indicated severe problems in harmonisation for definitions of some variables such as natural forests (no human intervention), forest area available for wood supply, and forest area by protection categories. In addition, even implementation of harmonised definitions of base line variables such as forest area and volume of growing stock when collecting data has been found to be challenging.

To respond to the needs for harmonised European information, representatives of the European NFIs established an informal network called the European National Forest Inventory Network (ENFIN) in Vienna, Austria in 2003. ENFIN applied for common research funding with the aim of investigating techniques leading to comparable European forest resource estimates. The European programme, Cooperation in Science and Technology (COST 2009) provides funding for large consortia such as the combined NFIs of European countries. COST is one of the longest-running European instruments supporting cooperation among scientists and researchers across Europe. COST is a flexible and efficient tool for coordinating nationally funded research activities, bringing scientists together with only minimal strategic guidance and letting them investigate their ideas. COST is based on networks, called Actions, centered around research projects in fields that are of interest to at least five COST countries (COST 2009). Although COST provides funding mostly for meetings, it is one of the few sources of funding for large groups. COST Action E43, Harmonisation of National Forest Inventories in Europe: Techniques for Common Reporting, entered into force in June 2004, was chaired by the Finnish Forest Research Institute (METLA), and lasted until December 2008 (COST Action E43 2009)

The efforts of COST Action E43 were not the first attempts to harmonise information from NFIs. In addition to the FAO FRA efforts to harmonise forest resource reports, the EU Council regulation (EEC) No. 1615/89 extended by Council Regulation (EEC) No. 400/94 established the European Forestry Information and Communication System (EFICS). The objective of EFICS was to collect comparable and objective information on the structure and operation of the forestry sector in the European Community (EFICS 1997). In this context, the Commission entrusted the European Forest Institute (EFI) in 1996 with a planning task whose overall aim was to analyse in detail the statistical methods used by member states for forest resource assessments. The EFICS study produced detailed information on differences among NFIs in EU countries. Although a set of key variables was found to be of interest to all stakeholders, not all variables were sufficiently harmonised among European NFIs. The findings of the EFICS study provided a good baseline for COST Action E43. Further, the study has been followed by development of a prototype European Forest Information System for the EU Joint Research Centre whose aims are resource information management and data presentation (European Commission Joint Research Centre 2009).

A substantial number of European countries participated in project FAIR CT98 4045 'Scale Dependent Monitoring of Non-Timber Forest Resource based on Indicators assessed in Various Scale'. The project identified forest characteristics and indicators that are applicable over different ecological zones. Some research groups for these projects also participated in COST Action E43. Harmonised forest resource information for large areas are presented in the report of the 'Bionord' project, funded by the Nordic Council of Ministers.

Two previous COST Actions addressed the issue of harmonisation and common strategies. COST Action E27 (Protected Forests in Europe – Analysis and Harmonisation) improved the harmonisation level of protection categories and the definition for natural forests (COST Action E27 2009), both of which are important elements of sustainable forestry. Nevertheless, whereas COST Action E27 was closely related to MCPFE, COST Action E43 had a broader scope of NFI data uses and users. COST Action E21 (Contribution of Forests and Forestry to Mitigate Greenhouse Effects) aimed at developing a common carbon accounting strategy. COST Action E21 "requires input data from forest inventories, forest management practices, perspectives of use of forestry products and socio-economics" (COST Action E21 2009). COST Action E43 supported the goals of COST Action E21 by improving the quality of input data from forest inventories. The experiences of COST Action E21 in using different methods for carbon balance estimation were used in COST Action E43 when recommending estimation procedures for NFI based reporting.

The EU CARBO-INVENT project aimed at developing methodologies for carbon inventories of forests that would satisfy requirements at both national and EU levels. The project also addressed scientific problems related to the estimation of carbon stock changes in forest ecosystems.

1.4 Objectives and Overview of COST Action E43

In Europe, two NFI approaches are used: one is based on sampling, and the other is based on aggregating stand-level data collected mostly for management inventories. There is clear evidence that these two approaches tend to give different results (Adermann 2009; Tomppo et al. 2001). In addition, as previously noted, the EFICS study documented differences among European NFIs and inferred a great need for harmonisation. Since the EFICS study, information needs on forests and the scope of forest inventories have broadened considerably. In addition to assessing the sustainability of forestry and possibilities for production of various kinds of goods and services by forests, one of the most important NFI tasks is to produce information on the forest carbon balance for which harmonisation in measurement and estimation procedures is seriously lacking. This example highlights the need for an international forum where European NFIs can discuss and respond to new information needs and further develop scientifically sound estimation procedures and definitions for both traditional and new variables. In addition, there is still the question of selecting methods for measuring and monitoring biodiversity that produce comparable estimates among countries.

Emerging techniques based on earth observation data from airborne, satellite, and automated ground observation sources have potential for improving the cost effectiveness of NFIs. However, these techniques have been adopted with different collection methods and have been modified for specific applications. In addition, evidence exists that these emerging techniques contribute to differences in measurement practices and in forest resource estimates rather than to enhancing harmonisation (Woodcock and Strahler 1987). For example, different spatial resolutions of remotely sensed data that are not accommodated in estimation techniques contribute to the lack of harmonisation. In addition, failure to use commonly accepted definitions in data analyses by units conducting remote sensing-aided inventories is also a contributing factor. An important point is that forest definitions should be independent of measurement devices such as remote sensing instruments and sensors.

The motivations for COST Action E43 are threefold: (1) a new and broader scope of forest information is frequently required, (2) new measurement and assessment technologies are emerging, and (3) most inventory activities are conducted by national institutes that operate independently of institutes in other countries. Further, despite the efforts of international organisations such as FAO to promote harmonised definitions, these organisations do not have the resources to produce results at the level of detail necessary to construct operational harmonised definitions and procedures.

1.4.1 Structure and Detailed Objectives of COST Action E43

These new information needs and expectations increase the pressure to modify NFIs in such a way that the inventory results become more comparable among countries.

The main objective of COST Action E43 has been to improve and harmonise existing European NFIs. The secondary objectives are twofold: to support countries in the development of new sample-based inventories that satisfy national, European and global requirements for timely, 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.

To achieve its objectives, COST Action E43 took the following steps:

- Established and maintained a forum for sharing experiences and new ideas, ensuring continuous improvement of NFIs
- Worked actively with harmonisation issues to provide a core set of harmonised forest resource estimates at regular intervals
- Cooperated in projects for scientific development within the field of data acquisition for sustainable multi-functional forestry
- Promoted active and open dialogue with stake holders and openness to new forest data requirements for emerging policy needs
- Assessed methods for reporting and producing comparable European forest resource information
- Identified research needs for joint projects within the EU Framework Programmes and regional (e.g., SNS – Nordic Forest Research Co-operation Committee) and national funding

The ultimate goal was to enhance forest information services at the national level as a means of optimising inventory benefits, enhancing the advantages of local knowledge, and satisfying local and international requirements. The goal was also to improve knowledge transfer among NFIs and European and global level processes and policies that require forestry information, recalling that there are more than 500,000 field plots measured by European NFIs of which about 100,000 are measured annually.

COST Action E43 established three working groups:

- Working Group 1 (WG1): Harmonised definitions and measuring practices
- Working Group 2 (WG2): Harmonised estimation procedures for carbon pools and carbon pool changes
- Working Group 3 (WG3): Harmonised indicators and estimation procedures for assessing components of forest biodiversity using NFI data

1.4.1.1 WG1

The primary task of WG1 was to critically review existing definitions and to recommend new definitions and measuring practices for use in NFIs. This task was crucial for NFI methods and involved issues such as inventory designs (e.g., sample-based versus stand-level inventories), inventory frequencies, data collection methods and analyses. WG1 goals were established and the following tasks were addressed:

1. Analysing current national and international forest inventory definitions and concepts

2. Establishing principles and developing methods for constructing forest inventory definitions (Vidal et al. 2008)
3. Establishing common reference definitions (Gschwantner et al. 2009; Lanz et al. 2009)
4. Developing methods for converting estimates based on national definitions to estimates based on common reference definitions, a task characterised as bridge building

1.4.1.2 WG2

The efforts of WG2 focused on definitions and measurement practices in European NFIs as a basis for reporting GHG emissions and forest removals within the LULUCF sector of the UNFCCC and its KP. New guidelines for this reporting issued by the IPCC (IPCC 2003) were fully considered. A specific motive for this work was that both EU and individual member states are parties to the UNFCCC and the KP. Further, the requirements for harmonised reporting will increase in the near future because of new LULUCF guidelines from IPCC for reporting under the UNFCCC and because complementary reporting on LULUCF activities under KP has been required since 2008. WG2 also adopted tasks that were similar to WG1 tasks 1–4 (Cienciala et al. 2008). Further, WG2 introduced general procedures for constructing bridges (Ståhl et al. 2010).

1.4.1.3 WG3

The primary task of WG3 was to identify possibilities for using NFI data to produce biodiversity assessments that are comparable over vegetation zones. Biodiversity is commonly divided into genetic, species and ecosystem diversity as well as functional diversity. WG3 developed and distributed a questionnaire on 41 relevant biodiversity variables to the NFIs of countries participating in COST Action E43. Based on responses pertaining to the importance of the variables and feasibility of assessing them via NFIs, seven essential features of biodiversity were selected: forest categories, forest age, forest structure, dead wood, regeneration, ground vegetation and naturalness (Winter et al. 2008). A second questionnaire sought information on the degree to which variables related to the essential features were currently harmonised. Based on the responses to the second questionnaire, methods using NFI data were investigated for constructing reference definitions and bridging techniques.

The WGs worked jointly on common tasks such as constructing reference definitions and to some degree solicited assistance and support from other WGs on their own tasks. In addition, all three WGs used similar methods, although modifications were introduced to accommodate specific WG objectives.

1.4.2 Participating Countries and Institutions

The COST Action E43 memorandum of the understanding was signed by 27 COST countries whose representative institutions participated in the Action. Furthermore, the Forest Inventory and Analysis National Programme (FIA) of the USDA Forest Service (USA), the New Zealand Forest Research Institute (Scion) and the Joint Research Centre, Institute for Environment and Sustainability, European Commission, were accepted by the COST Action E43 Management Committee as participating institutions from non-COST countries (Table 1.1). The list of the participating personnel and the institutes are noted on the COST Action E43 website (www.metla.fi/eu/cost/e43/). NFI reports were solicited for this book from participating COST countries, participating non-COST countries (FIA of the USA and Scion of New Zealand), and also non-participating COST countries in Europe, Luxembourg, Poland and the Russian Federation, as well as Brazil, Canada, China, Japan and the Republic of Korea outside of Europe (Table 1.1, Fig. 1.1). In addition to the representatives from the participating institutes of the COST and non-COST countries, representatives from international organisations (FAO, UNECE/FAO, EEA, MCPFE) participated actively in the meetings and work of COST Action E43.

1.4.3 The Approach Taken

The COST Action E43 WGs collected and analysed information on current national and international definitions, measurement practices and methods. Because of the multitude of definitions, a comprehensive review of existing definitions was initially necessary. The review was based on definitions published at the international level and on in-depth analyses of responses to specific questionnaires on national definitions distributed to participating countries. The questionnaires addressed multiple aspects of national definitions including variables and threshold values, application of these definitions, assessment methods, and the flexibility of NFIs to provide results according to different definitions. International definitions were obtained from FAO Global FRA (FAO 2001, 2005), UNECE/FAO TBFRA (UNECE/FAO 2000), the Good Practice Guidance of IPCC (2003) and reports of the CBD (2007). Syntheses considered the achievements of existing international definitions, applicability in different vegetation zones and practical measurement and assessment limitations. Based on the findings, refined and new definitions were proposed to national inventory experts in the WGs and discussed and revised until final agreement. The resulting definitions were characterised as reference definitions.

Processes leading to change in inventory practices, such as acceptance of new definitions, are usually slow. Therefore, methods were developed to convert forest resource estimates corresponding to non-reference definitions to estimates corresponding to the reference definitions. These methods, which may or may not

Table 1.1 COST Action E43 participating countries and countries with participating institutions as well as countries that submitted NFI reports and forest areas (1,000 ha)

Country	Code	Forest area	Country	Code	Forest area	Country	Code	Forest area
Austria[a]	AT	3,960.0[c]	Great Britain[a,b]	GB	2,665.0[c]	Norway[a]	NO	9,311.0[c]
Belgium[a]	BE	544.8[c]	Greece[a]	GR	2,512.0[c]	Republic of Korea	KR	6,265.0[d]
Brazil	BR	477,698.0[d]	Hungary[a]	HU	1,869.3[c]	Poland	PL	9,200.0[e]
Canada[a]	CA	310,134.0[d]	Iceland[a]	IS	38.7[c]	Portugal[a]	PT	3,867.0[e]
China	CN	197,290.0[d]	Ireland[a]	IE	710.0[e]	Romania[a]	RO	6,648.7[e]
Croatia[a]	HR	5,592.0[e]	Italy[a]	IT	8,583.0[c]	Russian Federation	RU	882,975.2[e]
Cyprus[a]	CY	172.8[c]	Japan	JP	24,868.0[e]	Slovak Republic[a]	SK	1,931.6[e]
Czech Republic	CZ	2,752.0[c]	Latvia[a]	LV	3,149.7[e]	Slovenia[a]	SI	1,308.0[e]
Denmark[a]	DK	534.5[c]	Lithuania[a]	LT	2,096.0[c]	Spain[a]	ES	13,905.0[c]
Estonia[a]	EE	2,391.1[c]	Luxembourg	LU	90.1[c]	Sweden[a]	SE	28,366.0[c]
Finland[a]	FI	22,487.0[c]	Netherlands[a]	NL	365.0[e]	Switzerland[a]	CH	1,213.0[c]
France[a]	FR	15,708.0[c]	New Zealand[a]	NZ	8,309.0[d]	USA[a]	US	304,022.0[c]
Germany[a]	DE	11,075.8[c]						
							Total	2,374,608.3

[a]Member of COST Action E43.
[b]The participating country is United Kingdom.
[c]The data comes from country report in this book.
[d]The data comes from Global Forest Resources Assessment (2005).
[e]The data comes from State of Europe's Forest Focus (2007).

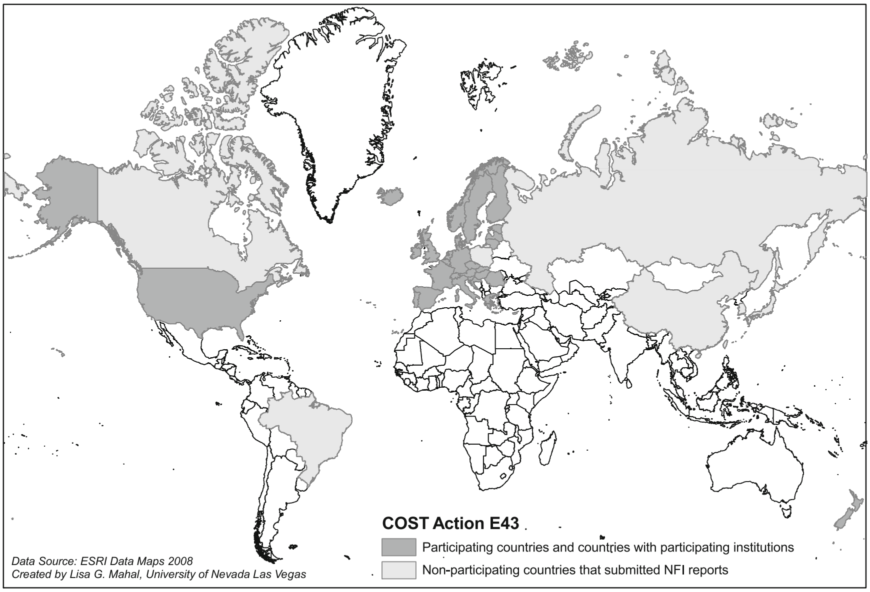

Fig. 1.1 The geographical distribution of COST Action E43 participating countries and countries with participating institutions as well as countries that submitted NFI reports

be statistical in nature, are called bridges in COST Action E43. Ståhl et al. (2010) describe and illustrate categories of bridges.

1.4.4 The Primary Benefits of COST Action E43

The primary benefits of COST Action E43 are numerous:

- Improved quality of European forest resource and forest environment data
- Improved ability of NFIs to satisfy both national requirements for forest information and requirements for harmonised and timely forest information at European and other international levels
- Input to the future Forest Focus activities (Forest Focus 2007)
- A forum for sharing experiences and new ideas which ensures that the momentum for continuous NFI improvement will be maintained
- A clearly visible option for provision of harmonised European forest information using NFI data through active and open dialogue with international stake holders and openness to new requirements on forest data for emerging policy needs
- Maintenance of a dialogue within ENFIN and its projects and continuation of the work after completion of COST Action E43

COST Action E43 supports the UNECE, Forest Focus and MCPFE activities, especially Vienna Resolutions 4 and 5 of the MCPFE where there is a strong reference to improve and harmonise existing forest assessment and monitoring systems. NFIs are the source of information for the pan-European indicators for sustainable forest management. Thus, COST Action E43 harmonisation efforts support the aims of MCPFE. In addition, it provided a feedback and discussion forum for global level forest inventory systems or data users such as FAO FRA process and UNFCCC.

The output of the Action has been communicated by four primary means: peer-reviewed journal articles, scientific reports, presentations and this book. Several peer-reviewed scientific articles have been submitted to and published in journals. Approximately 10–15 more peer-reviewed articles are in preparation (in 2009) for publication in a special issue of the journal, Forest Science. Articles, reports and presentations are noted on the COST Action E43 website (COST Action E43 2009), and a detailed list appears in the COST Action E43 Final Report (COST Action E43 2009).

In addition to constructing reference definitions and developing bridging techniques, COST Action E43 solicited NFI reports from participating countries that include descriptions of inventory practices, sampling designs, and estimation methods and also basic forest resource estimates (NFI Reports section). In addition, reports were solicited from non-participating European countries as listed in Section 1.4.2. These reports constitute the core material of this book.

1.5 COST Action E43 Contributions and the Structure of the Book

The preceding sections provided a brief history of NFIs, the need for harmonisation, the motivation for COST Action E43, and the objectives and structure of the Action. The following chapters and the NFI Reports section outline the contributions of the Action to the overall objective of harmonisation for purposes of common reporting. Chapter 2 summarizes the individual NFI reports that are included in the NFI Reports section with emphasis on the diversity in three primary NFI features: (1) two key definitions, those for forest and growing stock volume, (2) NFI sampling designs including plot configurations and the spatial distribution of plots, and (3) approaches to estimation. The essential conclusion of Chapter 2 is that while NFIs exhibit similarities, they also exhibit considerably diversity in key NFI features. Thus, considerably more effort will be required before the overall objective of harmonised reporting is realised.

Chapter 3 provides an overview, with examples, of harmonisation procedures. The overview emphasises two aspects of harmonisation, construction of reference definitions and construction of bridges that facilitate estimation consistent with reference definitions using data based on national definitions. Examples illustrate the construction of a reference definition for forest area and the construction of the three types of bridges: (1) reductive bridges which apply when the national data is more extensive than is required for the reference definition, (2) expansive bridges which are necessary when the scope of the national data is less than that required for the reference definition, and (3) neutral bridges which may be used when the scope of the national data is adequate for the reference definition. An illustration of at least one bridge is provided for each WG of COST Action E43. Much of the content of Chapter 3 is addressed in greater detail in scientific papers published in peer-reviewed journals (Vidal et al. 2008; Cienciala et al. 2008; Winter et al. 2008; McRoberts et al. 2008, 2009) including a special issue of Forest Science which had not been published by the time this book was submitted.

Chapter 4 summarises successes in constructing reference definitions, methods for constructing and comparing them, and the degree to which agreement has been reached on them. The chapter also summarizes the conceptual framework for constructing bridges for converting estimates obtained using national definitions to comparable estimates based on reference definitions.

The NFI Reports section includes a series of reports from individual countries describing the key features of their NFIs. These reports constitute the core material of this book and certainly represent the most comprehensive summary ever compiled of NFIs. As such, they will certainly remain an important reference for the foreseeable future.

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Chapter 2
Comparisons of National Forest Inventories

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2.1 Introduction

The evolution of national forest inventories (NFIs) has varied enormously among countries, and the process still continues. This evolution is documented in the histories of European NFIs, as well as others in North and South America, Asia, and New Zealand that are included in the NFI Reports section of this book. COST Action E43 has been a catalyst for harmonising European definitions that have resulted from these varied evolutions and has produced a template that can be used for harmonisation in other regions. The purpose of this chapter is to summarize the NFI reports, albeit by illustrating the diversity in NFI features as partial motivation for Chapter 3 which describes harmonisation procedures and touts the successes of the Action. Much of the information in this chapter is presented in the form of tables that report details of NFIs for individual countries. However, because the purpose of the tables and the entire chapter is primarily to illustrate the diversity of NFI features, only selected details for selected countries are reported. The complete details for all countries submitting NFI reports may be found in the NFI Reports section of this book.

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2.2 Diversity in Definitions

The two most basic NFI variables for which estimates are produced relate to forest area and growing stock volume. The substantial diversity among the definitions of these variables highlights the need for harmonisation if comparable international reporting is to be realized.

2.2.1 Forest Area

The 2005 FAO Forest Resources Assessment (FAO 2005) defined forest as

> *Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent. It does not include land that is predominantly under agricultural or urban land use*. (FAO 2004).

This definition is used by many countries as the basis for their national definitions of forest or as a definition towards which their national definitions will migrate. Based on the general acceptance of this definition, COST Action E43 participants agreed to use it as the basis for a reference definition for purposes of harmonisation. However, the COST Action E43 reference definition includes additional details that address issues such as forest boundaries and land use. Current national definitions for forest and the manner in which they deviate from the COST Action E43 reference definition are highlighted in Table 2.1.

All countries assess forest area, and nearly all countries base their definitions of forest on percent crown cover and minimum area (Table 2.1). Note that COST Action E43 decided to use the term crown cover instead of terms such as canopy cover, although FAO (2004) states that crown cover, crown closure and canopy cover have the same meaning. Many authors have reported inconsistency in the use of these terms, and Lanz et al. (2009) reports arguments supporting the use of crown cover. Crown cover thresholds range from 10% to 50% among national definitions used in the countries. The smaller threshold is the most common and conforms to the COST Action E43 reference definition. However, rather than percent crown cover, some countries, such as the USA, use stocking which relates to the degree to which a site is fully occupied with trees (Stage 1969). Nevertheless, stocking can be approximated by percent crown cover. Use of the 10% crown cover threshold in the COST Action E43 reference definition means that countries with greater thresholds will require expansive bridges (Chapters 3 and 4), often the most difficult to construct, to produce harmonised estimates of forest area. Minimum area thresholds range from 0.04 to 0.50 ha of which the latter is the most common and which conforms to the COST Action E43 threshold. In this case, selection of the larger threshold for the reference definition means that countries with smaller thresholds will require only the simpler reductive bridges. Fewer countries include minimum width or minimum in situ height thresholds in their definitions of forest, but when they do, their thresholds often conform to the COST Action E43 thresholds.

Table 2.1 National definitions of forest and estimators for forest area

Country	Forest area				Estimation method
	Crown cover (%)	Minimum area (ha)	Minimum width (m)	Minimum tree height in situ (m)	
Austria	30	0.05	10		Field plots
Belgium (Walloon Region)	***10***	0.1		***5***	Photo dot grid
China	20	0.0667			Field plots
Cyprus	***10***	***0.5***		***5***	Photo interpretation
Czech Republic	20	0.04	10		Map
Denmark	***10***	***0.5***	***20***	***5***	Field plots
Estonia	***30***	***0.1***			Field plots
Finland	***10***	0.5	20	***5***	Field plots
France	***10***	***0.5***		***5***	Photo interpretation
Germany	50	0.1	10		Field plots
Great Britain	20	***0.5***	***20***		Map
Greece	***10***	***0.5***	30	***5***	Photo dot grid
Hungary	50	***0.5***	***20***		Photo interpretation
Iceland	***10***	***0.5***	***20***	***2***	Field plots
Ireland	20	0.1	***20***	***5***	Photo interpretation
Italy	***10***	***0.5***	***20***	***5***	Photo interpretation
Korea	30	1.0			Map
Latvia	20	0.1		7	Photo interpretation
Lithuania	30	0.1	10	5	Field plots
Luxembourg	***10***	0.1		***5***	Photo dot grid
The Netherlands		***0.5***	***20***		Map
New Zealand	30	1.0		***5***	Field plots
Norway	***10***			***5***	Field plots
Romania	***10***		***20***	***5***	Photo dot grid
Slovak Republic	20	0.3		***5***	Field plots
Slovenia		0.25		***5***	Map
Spain	20			***5***	Map
Sweden	***10***	***0.5***		***5***	Field plots
Switzerland	20		25–50	3	Field points
USA	25	0.4	36.58		Field plots

Bold, italicised entries indicate conformity with the COST Action E43 definition.

If forest area sampling and estimators are unbiased, then detrimental effects on harmonised reporting as a result of their diversity are minimal. Nevertheless, diversity in methods still inevitably contributes to differences in estimates. Methods used to assess forest area fall into three categories: (1) assessment of field plots or field sample points, (2) interpretation of plot locations or systematic grids of points using aerial photographs, and (3) assessment of maps. Assessment of field plots is the most common method, is increasing in frequency of use, and likely is the most accurate method. Countries that base forest area estimates on interpretation of aerial photography sometimes conduct assessments at plot centres, sometimes on landscape level assessments, and sometimes on dot grids. Several countries use aerial photography or maps in a first phase to distinguish between plots with and without forest cover, but then base forest area estimates on second-phase assessments of field plots. Numerous countries base forest area estimates on land cover maps and occasionally on forest maps. Presumably, conversion of forest land to other uses in these countries is legally constrained or in practice is extremely minimal; such is not the case in the Americas and in many developing countries. In many of the latter countries, plots are established on non-forest lands as a means of assessing conversion of non-forest land to forest uses. For countries that use maps, the unbiasedness of forest area estimators depends on the accuracy of the maps. Finally, many countries that use maps indirectly use field plots, aerial photography, or a combination of both as reference data for constructing the maps. The important finding is that the diversity of definitions and estimation methods provides important motivation for considering techniques for harmonisation.

Although national definitions vary considerably from the reference definition, most participants thought that for purposes of harmonisation, estimates could be reported based on the reference definition using data collected with national definitions, although possibly augmented with ancillary data. For example, Great Britain will use a sample survey separate from the NFI to assess the area of forest with crown cover in the range of 10–20%. Estimates based on this additional data can be combined with estimates obtained from the NFI to provide an estimate of total national forest area that is harmonised with the COST Action E43 definition.

2.2.2 Growing Stock Volume

National definitions of growing stock volume differ considerably with respect to multiple components (Table 2.2).

All reporting countries base growing stock volume on tree diameters overbark (Table 2.2). However, beyond this criterion, definitions of growing stock volume are quite diverse. For example, in Europe, the height at which diameter is measured (breast height) varies from 1.3 to 1.5 m, the minimum tree diameter at breast height (*dbh*) varies from 0.0 to 12 cm, and the minimum tree top height diameter varies from 0.0 to 7.0 cm. Further, both extreme and mid-range thresholds for *dbh* and top height diameter are used by many countries, suggesting that harmonisation to satisfy a reference definition threshold would require large numbers of both reductive and expansive bridges (Chapters 3 and 4). In addition, countries are approximately evenly split between those that do and those that do not include stump volume in growing stock volume. Only three countries include branches, and only two countries include dead trees and then only trees that have died since the last measurement. In addition to the diversity of tree elements, the difficulty of comparable reporting for growing stock volume is exacerbated by the variety of forest land classes for which volume is included in growing stock volume. For example, most countries estimate volume for productive forest land (FL), but others also

Table 2.2 Components of national growing stock volume definitions

Country	Land[a]	Minimum *dbh* (cm)	Diameter at top height (cm)	Stumps	Branches	Deadwood
Austria	Productive FL	5.0	0.0	No	No	Yes
Belgium (Wallonia)	Productive FL	7.0	7.0			
Estonia	FL, OWL	0.0	0.0	No	No	No
Finland	Productive and poorly productive FL, OWL	0.0	0.0	No	No	Yes
France	Productive and non-productive FL, OWL	7.5	7.0	Yes	No	No
Germany	Productive and non-productive FL	7.0	7.0	Yes	Yes[b]	Yes[d]
Great Britain	Conifer and hardwood plantations	7.0	7.0	No	No	No
Greece	Productive and non-productive FL	5.0	7.0	Yes	No	No
Iceland	Plantation, some natural birch forests	0.0	0.0	No	No	No
Ireland	FL	7.0	7.0[e] 0.0[f]	Yes	No	No
Latvia	FL, plots on non-FL with trees or bushes	2.1	0.0	Yes	No	No
Lithuania	FL	0.0	0	Yes	No	No
Slovak Republic		7.0	7.0		Yes[c]	
Slovenia	FL	10.0	7.0	Yes	Yes[c]	Yes
Spain	Crown cover ≥5%	7.5	7.5	No	No	No
Sweden	FL or all land	0.0	0.0	No	No	No
Switzerland	FL	12.0	0.0	Yes	No	No
USA	FL	12.7	10.1	No	No	No

[a]FL = forest land, OWL = other wooded land.
[b]Main branches of deciduous trees.
[c]Minimum diameter = 7 cm.
[d]Newly dead trees only.
[e]Coniferous.
[f]Deciduous.

estimate it for poorly productive FL and other wooded land (OWL). Although volumes for these land classes are usually estimated separately, the definitions for the classes vary considerably.

Reporting comparable estimates of growing stock volume is particularly difficult. The diversity of the land class definitions, *dbh* and top height thresholds, and inclusion or exclusion of stumps, branches, and trees that have died recently are important factors that contribute to this difficulty. In addition, countries use different models and techniques based on different geometrical shapes for estimating the volume of individual trees. Most countries use models based on *dbh*, height, species and possibly a few other variables to estimate individual tree volumes. However, some countries do not measure the heights of all trees on plots, but rather use estimated heights in the individual tree volume models; other countries do not use height at all in their models. Some countries measure heights and predict volumes for a sub-sample of trees and predict the volumes for the rest of the trees using information from the measured sub-sample. Any lack of fit and uncertainty in the height and/or volume model predictions propagate through to large area growing stock volume estimates.

2.3 Diversity of Sampling Designs

No reference definition has been constructed for sampling design, and as expected sampling design features vary substantially among countries participating in COST Action E43 (Table 2.3). The histories of NFIs show a progressive evolution towards statistical sampling techniques, with the majority of countries now using probability-based sampling designs and at least a proportion of permanent plots. For purposes of efficiency, sampling designs should accommodate variation in forest attributes and land use structure which suggests that the idea of a single design for a large region may not be relevant.

The great variety in NFI sampling features makes simple summarisations difficult. The most common NFI features include systematic sampling components based on two-dimensional grids, although the grid spacing varies considerably. Increasingly, NFIs use permanent sample plots, although some countries, particularly in northern regions, use a combination of permanent and temporary plots. Inventory cycles are typically either 5 or 10 years, but they may be achieved in different ways. Some countries conduct periodic inventories in which a complete inventory is completed in one or a few years and then is repeated 5–10 years later. Increasingly, however, countries are moving toward annual or rolling inventories in which 10–20% of plots are measured each year. Many countries use cluster sampling in which multiple plots are established in close spatial proximity as a means of increasing logistical efficiency. Most countries that use cluster sampling include four plots per cluster, although the number may be considerably larger. Many countries also use concentric circular plots which permit observation of variables on plots of different sizes for different variables. The primary advantage of concentric plots is that small trees can be measured on small plots which decreases costs with little loss in precision of the estimates. Nearly all countries have changed from aggregating data obtained from inventories conducted for stand management purposes to more efficient and scientifically credible inventories using statistical sampling and their corresponding unbiased estimators. A substantial advantage of the latter approaches is estimation of sampling error.

Table 2.3 Features of probability-based sampling designs used by NFIs

Country	Systematic grid spacing for plots or clusters of plots (km × km)	Strata criteria for stratified sampling	Random component in plot location	Number of field plots per cluster	Permanent plots (proportion of all plots)	Last NFI cycle	Current/ future NFI cycle
Austria	3.889 × 3.889	–	–	4	1.00	2000–2002	2007–2009
Belgium (Walloon Region)	1 × 0.5	–	–	1	1.00	1994–2008	2008–2018
Brazil	20 × 20	–	–	4	–	–	2009–
Canada	20 × 20	Terrestrial ecozone	–	1	1.00	2000–2006	2007–
China	–	–	–	1	1.00	2004–2008	–
Cyprus	–	–	–	1	1.00	2001–2005	–
Czech Republic	2 × 2	–	Within 300 m of grid point	1	1.00	2001–2004	–
Denmark	2 × 2	–	–	4	Approximately 0.33	2002–2006	2007–2011
Estonia	5 × 5	–	–	16	0.25–0.50	2004–2008	2009–2013
Finland	3 × 3 to 10 × 10	In North Lapland[a]	No	9–14	Approximately 0.25	2004–2008	2009–2013
France	1.41 × 1.41	–	Within 900 × 900-m cell	2	0.00	2004–2009	–
Germany	2 × 2 to 4 × 4	–	–	4	1.00	2000–2002	2011–2012
Great Britain	–	Forest type	Within polygons	1	–	1995–1999	2009–2013
Iceland	0.5 × 1 to 1.5 × 3	Plantation and birch	–	1	1.00	–	2005–2009
Ireland	2 × 2	–	Within 100 m of grid point	1	1.00	2004–2006	–
Italy	1 × 1	Administrative region and land cover	–	1	0.00[b]	2003–2007	–
Japan	4 × 4	–	–	1	1.00	2004–2008	–
Korea	4 × 4	–	–	4	1.00	1996–2005	2006–2010
Latvia	2 × 2 to 4 × 4	–	–	1	1.00	2004–2008	2009–2013

(*continued*)

Table 2.3 (continued)

Country	Systematic grid spacing for plots or clusters of plots (km × km)	Strata criteria for stratified sampling	Random component in plot location	Number of field plots per cluster	Permanent plots (proportion of all plots)	Last NFI cycle	Current/future NFI cycle
Lithuania	4 × 4	–	–	1	0.75	2003–2007	2008–2012
Luxembourg	1 × 0.5	–	–	1	1.00	1999–2001	2008–2010
Netherlands	1 × 1	–	Within 1 × 1-km grid cell	1	0.5	2001–2005	2010–
New Zealand	4 × 4 and 8 × 8	Forest category	–	1 or 4	1.00	1945–1955	2002–2010
Norway	3 × 3			4	Some	2000–2004	2005–2009
Poland	4 × 4			1	1.00	–2001	–2009
Portugal	2 × 2			1	0.00	2005–2006	
Romania	2 × 2 to 4 × 4			4		2007–2008	
Slovak Republic	4 × 4			1	0.00	2005–2006	
Slovenia	4 × 4			5	1.00	2007	
Spain	1 × 1			1	1.00	1997–2007	2008–2018
Sweden	varying			4–12	Approximately 0.60	1993–2002	2003–2012
Switzerland	1.41 × 1.41			1	1.00	2004–2006	
USA	2,400 ha systematic hexagonal tessellation		Within 2,400 ha hexagon	4	1.00	2004–2008	2009–2013

[a]Percent non-productive forest land, volume, cumulative day-time temperature.
[b]All plots marked for possibility of future measurement.

2.4 Diversity of Sample Plot Configurations

The number, shape and size of sample plots vary enormously among NFIs. Circular plots, often with multiple concentric components, are used by more than 90% of NFIs, although square and rectangular plots are used as are transect and angle count sampling. Some NFIs use a mixture of plot shapes and transects depending upon the variables measured. As is clear from the NFI reports, the diversity of plot sizes and shapes and sampling approaches (e.g., plot versus transect sampling) has increased recently to accommodate the need for more diverse forest information. NFIs whose sole objectives previously related to estimation of timber resources have given way to NFIs that encompass a host of outputs including ground vegetation, deadwood, biodiversity, and soil information in addition to timber information.

The forest area represented by NFI field sample plots varies enormously, from 50 ha for plantations in Iceland to 269,700 ha in Canada (Table 2.4). The table does not take into account plot sizes, only the total number of plots or plot clusters reported by countries. The forest area represented by each field plot is either based on the ratio of total national forest area and the total number of plots reported in the NFI reports or comes directly from the NFI report. Examples are given in Table 2.4 to demonstrate some of the variation within the NFI reports.

In addition, some countries base their inventories partially or completely on plots assessed using aerial photography. For some countries, interpretation of photoplots are the only measurements obtained, particularly for remote or inaccessible regions; for other countries, photoplots are used in double or multi-phase sampling schemes whereby a proportion of photoplots are also assessed in the field. For countries such as the USA where land use is generally not legally prescribed or constrained and where it may change frequently, plots are established on non-forest land for purposes of estimating the area of lands converted from non-forest to forest uses. Because the greatest expense associated with measurement of an NFI plot is travel to and from the plot location, each plot in the USA is first assessed with aerial photography; plots without accessible forest land are not further assessed, whereas plots with accessible forest land are measured in the field.

If NFI sampling schemes are based on probability samples, and the statistical estimators are unbiased, then the diversity of areas represented by plots has no effect, or only limited detrimental effects, upon the ability of NFIs to report comparable estimates. However, the diversity of the sampling schemes may have considerable effects on the precision of reported estimates.

2.5 Diversity of Increment and Drain

For countries that provided details in the NFI reports of the methods they use to estimate increment, drain and error, several patterns emerged. Volume increment is usually defined as the mean increase in tree stem volume over bark from above the

Table 2.4 Number of plots per NFI and the approximate forest area represented by each plot

Country	Number of interpreted "photo-plots"	Number of field sample plots on land	Number of field sample plots on forest land	Approximate forest area represented by each field plot (ha)
Austria		22,236		178
Belgium (Walloon Region)			Approximately 11,000	50
Canada	18,850	1,885	1,150	269,700
China	2,844,4000	415,000		407
Croatia	30,000		Approximately 6,000	
Cyprus			1,970	88
Czech Republic	Approximately 39,000		Approximately 14,000	197
Denmark	42,793		7,610 (on forest and OWL)	87
Estonia		4,500	2,300	1,040
Finland		69,388	51,845	129.3–1996.5
France	275,000	50,000	35,000	449
Germany			54,009	205
Great Britain	100% land coverage		Approximately 15,000	170
Greece	95,220	2,744		916
Iceland			Plantations –663 Birch woodlands – 203	Plantation – 50 Birch – 450
Ireland	17,423	17,423	1,742	400
Italy	301,000 (first phase)	301,000 (first phase)	30,000 (second phase – forest and OWL), 6,865 (third phase – forest)	1,310
Japan			15,700	
Korea			4,000	1,598
Latvia				300
Lithuania			5,600 permanent and 1,900 temporary	300
Luxembourg			Approximately 1,800	50
Netherlands			3,622	99
New Zealand			889 indigenous forest 253 post-1989 plantations	7,005
Norway		16,522		900
Portugal	355,737		6,478	525
Romania			24,000 permanent and 5,000 temporary	
Russia			Approximately 150,000	
Slovak Republic	12,268	1,486	1,161	731
Slovenia		778	778	1,600
Spain			95,327	272,58
Switzerland	165,000		Approximately 7,000	
USA (excluding Alaska)		325,812	91,988	2,400

stump to the stem top of the tree. For countries whose NFIs use permanent plots, volume increment estimates are most frequently based on differences in individual tree volumes between measurements. Most countries also include estimates of ingrowth which refers to the volume of trees that have reached the minimum *dbh* threshold since the last inventory. Some countries, particularly those without permanent plots, use radial increment, measured using an increment borer, as input to a model that is used to predict volume increment or volume at previous time (e.g. 5 years). Finally, yield tables are also used to estimate volume increment. Total drain includes multiple components: harvest removals, harvesting losses, non-commercial removals such as for fuel wood, and natural losses.

A variety of methods are used to estimate the components of drain. Countries that use permanent plots often base estimates of the harvest component on volumes at the previous measurement for removed trees. In addition, some countries update these volumes to the midpoint between inventories using growth models. Other countries use models based on stump measurements to predict the volume of harvested trees. Natural losses are estimated using measurements of newly dead trees or, in some countries, by the opinion of experts. In addition, some countries augment NFI data with information acquired from land owner and mill surveys.

As should be apparent from this brief discussion, estimation methods for increment and drain exhibit tremendous diversity.

2.6 Error Estimation

Error, often characterised as sampling error, is defined as the uncertainty associated with estimates that are based on sample observations or measurements and are typically reported for both area and volume estimates. Errors associated with model predictions, such as for individual tree volumes, are usually omitted. Many countries calculate estimates of error using traditional simple random sampling or stratified variance estimators as described by Cochran (1977). However, when using cluster sampling, caution must be exercised to accommodate the fact that observations of variables on plots that are in close spatial proximity are generally not independent. Further, simple random sampling variance estimators are not valid for cluster sampling when there are large scale trends in observations of variables such as volume per hectare. To overcome these problems, Finland uses ideas proposed by Matérn (1947, 1960). Error estimation methods are extremely diverse, and further analysis is needed to assess the effects of this diversity on the comparability of the error estimates and to determine if further work is needed to harmonise error estimation.

2.7 Use of COST Action E43 Reference Definitions in Country NFIs

The use of COST Action E43 reference definitions varies among countries as expected (Table 2.5). However, the majority of participating European countries either use the reference definitions or can report estimates based on them. In addition, many countries that do not currently use the reference definitions are considering adopting them for their next NFI cycle. This table can be used as a baseline that reveals both the current status of harmonisation and the success of COST Action E43 in promoting greater harmonisation. The country NFI reports provide examples of estimates and assessments conducted by countries regardless of whether estimates can be reported using a reference definition.

Table 2.5 Use of COST Action E43 reference definitions

Country	Using reference definitions of COST Action E43
Austria	Where feasible within NFI framework
Belgium (Walloon Region)	Not yet
Brazil	No
Canada	No
China	Yes, mainly
Estonia	Where feasible within NFI framework
Finland	Yes, mainly
France	No, mainly not
Germany	Partially
Great Britain	Yes, mainly
Iceland	Yes, mainly
Ireland	Not currently, likely for next NFI
Italy	Yes, mainly
Latvia	No
Lithuania	Not yet
Luxembourg	Not yet
Netherlands	Yes, mainly
New Zealand	Influenced design of NFI
Norway	Yes, mainly
Romania	Yes, mainly
Slovenia	Partially
Spain	Yes, mainly
Sweden	Yes, mainly
USA	No, but can report using them

2.8 Discussion

The need for harmonisation is mainly driven by reporting requirements resulting from international commitments such as the Kyoto Protocol (1997), the FAO Forest Resources Assessments (FAO 2005), the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2003), the Montréal Process (2005) and the Convention on Biological Diversity (CBD 2007). The diversity in definitions, sampling designs, plot configurations, and estimation methods among NFIs highlighted in this chapter illustrates the degree to which reporting of comparable estimates is currently difficult. However, the NFI reports reflect a sense that considerable communication has already occurred among countries as their NFIs have evolved. COST Action E43 has provided a focus and a forum for this communication that motivates continued discussions for purposes of closing the harmonisation gap. The COST Action E43 reference definitions are based on the shared expertise of participants and have influenced the direction of their NFIs. Over the life of the Action, numerous NFIs have adopted the reference definitions or have modified their NFIs so they can report using them (Table 2.5). Nevertheless, numerous harmonisation issues remain. Agreement on and harmonisation of further definitions is still required, and the variation in estimation procedures must be addressed. Without a focal point for harmonisation, progress will likely be fragmented and slow. However, the descriptions and examples of harmonisation techniques in Chapter 3 document the considerable harmonisation progress that can be attributed to COST Action E43.

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Chapter 3
National Forest Inventories: Prospects for Harmonised International Reporting

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3.1 Introduction

Despite the important differences in inventory estimates resulting from the use of different national definitions, variables, and variable thresholds, prospects for developing procedures leading to compatible estimates among countries are generally positive. Analyses of national definitions and responses to questionnaires

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distributed by COST Action E43 indicate that definitions tend to be based on the same rather small set of inventory variables. For example, national definitions of forest all focus on minimum area, minimum cover, minimum width, and minimum height, although the thresholds for these variables differ considerably among countries (Vidal et al. 2008). Important differences among these national definitions relate mostly to kinds of lands with tree cover that are considered forest for reporting purposes: for example, managed versus unmanaged forest land, inclusion or exclusion of forested park and leisure lands, inclusion or exclusion of forest lands whose tree cover consists primarily of non-native species, and inclusion or exclusion of permanently non-stocked areas within forest land (Cienciala et al. 2008).

For reporting to the UNFCCC, estimates for carbon pools are to be reported separately for different carbon pools and within pools for lands whose land use category has remained unchanged and for lands whose land use category has changed (IPCC 2003). European countries participating in COST Action E43 report estimates by the same carbon pools as the USA, although estimates for individual carbon pools are obtained by aggregating estimates for different constituent components (McRoberts et al. 2009b). Estimation by unchanged and changed land use categories requires techniques for distinguishing between the two classes. Among COST Action E43 countries, 70% use sampling techniques alone or in combination with other techniques for this purpose, 32% use map analyses alone or in combination with other techniques, and 18% use both sampling techniques and map analyses (Cienciala et al. 2008). For estimating carbon stock changes, two approaches are used: estimation based on differences between successive inventories, characterized as the stock change method, and estimation of biomass increment and removals separately from the inventory, characterized as the default method. Among COST Action E43 countries, the two approaches are used in approximately equal proportions. As an example, estimates for the deadwood component are obtained by 74% of countries using ground measurements whereas 37% of countries use predictive models.

For biodiversity estimation, a broad consensus exists among COST Action E43 countries regarding the variables that are most ecologically relevant and that are most feasible for observation or measurement by forest inventory programs (Winter et al. 2008). However, of the 16 most relevant and feasible variables, only tree species and tree diameter were assessed by all 22 COST Action E43 countries responding to a questionnaire, although each is assessed by at least eight countries. Nevertheless, achieving the goal of compatible biodiversity estimation would require that only a few countries introduce substantial numbers of new inventory variables.

Overall, national definitions and national sets of assessed inventory variables relevant for carbon and biodiversity estimation are generally similar; the primary differences relate mostly to variable thresholds and measurement techniques. Although the consequences of these differences and the methods for compensating for them are not necessarily trivial, the prospects for compatible estimation are generally positive.

3.2 Standardisation or Harmonisation

The effects of differences among national forest inventories (NFI) on production of comparable estimates may be minimised using one of two approaches, standardisation or harmonisation. Köhl et al. (2000) describe standardisation as a top-down approach that follows a common system of nomenclature and focuses on common NFI definitions and methods. Although standardisation of NFIs would produce the most direct route to comparable estimates, other factors must be considered. For example, NFI features such as sampling designs and plot configurations for individual countries have been developed over time to accommodate their unique topographies, climates, forest types, and commercial interests. Further, because information from countries is currently required for many different national, regional, and international agreements, standardisation may not even be possible due to different reporting requirements for different agreements. Thus, standardisation may not be a realistic option. Harmonisation acknowledges that individual countries have developed the unique features of their NFIs for specific purposes and are justified in their desire to maintain them. Harmonisation, therefore, focuses on developing methods for producing comparable estimates despite the lack of standardisation. Köhl et al. (2000) describe harmonisation as a bottom-up approach that begins in divergence and ends in comparability.

COST Action E43 accepted the underlying premise that unique features of individual NFIs were justified and focused its efforts on construction of common definitions and development of procedures for producing harmonised estimates. However, as an outcome of the harmonisation investigations, countries participating in COST Action E43 were strongly encouraged to adopt the common definitions or at least to implement field procedures that would permit reporting according to the common definitions.

3.3 Constructing Reference Definitions

The basic approach to harmonisation consists of two steps: construction of common or reference definitions and construction of bridges that convert estimates based on national definitions to estimates based on the common or reference definitions. Vidal et al. (2008) assert that reference definitions should feature nine prominent attributes:

1. *Acceptability*, meaning adoption at national and international levels
2. *Objectivity*, meaning free of particular interests of individual stakeholders
3. *Clearness*, meaning easily grasped and clearly stated
4. *Sufficiency*, meaning covering all relevant cases
5. *Usefulness*, meaning satisfaction of forestry, industry, and environmental needs and industrial requirements at national and European levels
6. *Sustainability*, meaning long-term validity

7. *Neutrality*, meaning not to be used as a means of assessing the quality of national definitions
8. *Practicality*, meaning the ability to produce estimates based on reference definitions
9. *Independence*, meaning validity is independent of the measurement protocols and instruments

The procedure provided by Vidal et al. (2008) for developing reference definitions begins with an analysis of key definitions, usually national and international definitions, for the target variable of interest. If the key definitions include imprecisely defined terms (e.g., stem and branches as tree components, height and crown cover as tree variables, living/dead status, shrub/tree status) the catalogue of precise terms and definitions provided by Gschwantner et al. (2009) may be used. The analysis of key definitions focuses on decomposing them into their variables and associated thresholds, creating classes for the thresholds, and selecting the variables and their thresholds for the reference definition. A preliminary reference definition is reviewed and revised using an iterative process until final acceptance.

By way of example, the procedure for constructing a reference definition for forest land is illustrated (Vidal et al. 2008). Variables used in the key national definitions of forest land were tabulated along with other relevant information pertaining to the extent of their use (Table 3.1). The most commonly used variables in key definitions as indicated by the proportions of countries that use them and the areas these countries represent include minimum area, minimum tree crown cover, and minimum tree height. Nearly all countries also use a minimum width to avoid characterising narrow linear formations, windrows, shelterbelts, and planted tree groupings as forest land. Thus, the proposed reference definition for forest land is based on four variables: minimum area, minimum tree crown cover, minimum height, and minimum width in cases of linear formations.

A reference definition must not only identify its constituent variables but must also specify thresholds for these variables. Because the selected reference definition variables for forest land are continuous in nature, national thresholds may be ordered, and the cumulative proportion of countries that collect data using thresholds less than or equal to particular values can be tabulated (Table 3.2). For a tree crown cover threshold of 10%, data are currently collected by countries representing 67% of the total area of the 27 European countries participating in COST Action E43 and 73% of their total forest area. Thus, the proposed reference definition for forest land includes a tree crown cover threshold of 10%. Similar analyses were

Table 3.1 Variables used in national definitions of forest land

Variable	Proportion		
	Countries	Area of countries	Forest area of countries
Minimum area	0.96	0.99	0.99
Minimum tree crown cover	0.81	0.69	0.56
Minimum width	0.74	0.66	0.54
Minimum tree height	0.59	0.47	0.42

Twenty-seven European countries participating in COST Action E43.

Table 3.2 Minimum tree crown cover threshold used in national definitions of forest land

Tree crown cover threshold (%)	Cumulative proportion	
	Country area	Forest area
5	0.12	0.12
10	0.41	0.34
20	0.54	0.42
30	0.58	0.48
50	0.69	0.56
Not used	0.31	0.44

Twenty-seven European countries participating in COST Action E43.

used to select a threshold of 0.5 ha for minimum area, 5 m for minimum height, and 20 m for minimum width. Thus, the following reference definition for forest land was constructed by COST Action E43:

> Forest is land spanning more than 0.5 ha with trees higher than 5 metres and with tree crown cover of at least 10%, or able to satisfy these thresholds in situ. For tree rows or shelterbelts, a minimum width of 20 m is required. Forest does not include land that is predominantly agricultural or urban land use.

3.4 Constructing Bridges

Bridges that use data collected under national definitions to produce estimates based on reference definitions can take different forms: e.g., exclusion of a portion of sample data, complex statistical models to predict missing data, and expert opinion. Generally, each party desiring to report estimates based on a reference definition must construct its own bridges. Crucial factors affecting construction of bridges are the variables and corresponding thresholds in the national definitions under which data are acquired. Gabler et al. (2009) report a mathematical approach for distinguishing between national and reference definitions. The nature of data acquired using national definitions is the primary factor that distinguishes among kinds of bridges: *reductive*, *expansive*, and *neutral* bridges. Reductive bridges are appropriate when the national definition is broader in scope than the reference definition. In this case, there is a surplus of national data of which some can be simply excluded. Expansive bridges are appropriate when the scope of the reference definition is broader than that of the national definition. In this case, data is missing for estimation based on the reference definition and must be supplied via prediction, imputation, or other method. For construction of expansive bridges, *auxiliary variables* correlated with the target variable and/or variables are often available to facilitate acquisition or prediction of missing information and data. Auxiliary variables may be of many varieties and may be obtained from a variety of sources other than the NFI. When the scopes of the reference and national definitions are the same, neutral bridges are appropriate. Ståhl et al. (2009a) provide a comprehensive discussion of reductive, expansive, and neutral bridging techniques. In summary, bridges are necessary when national definitions under which data are collected deviate from reference definitions. Four examples illustrate procedures for constructing bridges.

3.4.1 An Expansive Bridge for Forest Area

Forest land area is a target variable for which harmonised estimates are frequently required. The definition of forest used by the Food and Agriculture Organization (FAO) of the United Nations for the 2005 Global Forest Resources Assessment (FRA), which is very similar to the COST Action E43 reference definition, includes lands with tree cover that are not considered forest land according to the definition used by the Swedish NFI (FAO 2004). In particular, the Swedish NFI does not conduct inventories of the mountain birch forests in northern Sweden, both because of their remoteness and because they do not satisfy a productivity criterion. Furthermore, the Swedish definition of forest in use until 2009 includes a criterion that the productivity of the land must be at least 1 m^3/ha per year, although from 2009 forward Sweden will adopt the FAO definition as its national definition as a means of simplifying international collaboration. Therefore, to report consistently with the FAO definition, including the old data, Sweden must construct a bridge between estimates based on the Swedish national definition and estimates based on the FAO reference definition. Further, because the scope of the FAO reference definition is broader than the scope of the Swedish national definition, an expansive bridge is required. Fortunately, the National Inventory of Landscapes in Sweden (NILS) (Ståhl et al. 2009b) assesses all terrestrial land cover types in Sweden including the mountain birch forests and records measurements for the FAO reference definition variables height and crown cover. Thus, by using the NILS plot data, an expansive bridge was constructed by counting plots in the mountain birch region whose measurements satisfied the FAO thresholds of 5 m for height and 10% for tree crown cover. The number of mountain birch plots satisfying the FAO threshold was then multiplied by the constant land area represented by each plot to obtain the area estimate. The estimate of the mountain birch forest area was then simply added to the Swedish NFI estimate of forest area to obtain an estimate based on the FAO reference definition. Thus, in the larger Swedish national context, the NILS height and tree crown cover variables may be considered auxiliary variables, and the procedure using these variables to supply the missing mountain birch forest area constitutes an expansive bridge.

3.4.2 A Neutral Bridge for Forest Type Classification in Italy

A forest type is a category of forest defined by its species composition and/or site factors, as determined by each country using a system suitable to its situation (Montréal Process 1998). A set of 35 pan-European indicators has been endorsed

Table 3.3 Bridge from the Italian forest type to the European forest type system

Italian classification system	European classification system	
	Forest type	Forest category
Larch, Arolla Scots pine and Mountain pine (Mountain pine dominated)	Subalpine larch-arolla pine and dwarf pine forest	Alpine coniferous forest
Spruce Fir	Subalpine and montane spruce and montane mixed spruce-fir forest	
Scots pine and mountain pine (Scots pine dominated) Black pine	Scots pine and Black pine forest	
Horn-beam Other broadleaves forest (Maple, Lime)	Sessile oak-hornbeam forest Ravine and slope forest	Mesophytic deciduous forest
Beech dominated forest (Beech pure)	Subatlantic submontane beech forests	Beech forest
Beech dominated forest (Beech and Fir)	Apennine-Corsican montane beech forest	Montane beech forest
Hygrophilous forest (Alders dominated)	Riparian/fluvial forest	Floodplain forest
Hygrophilous forest (Aspen dominated)	Riparian/fluvial forest	
Hygrophilous forest (Willow dominated)	Riparian forest	Non-riverine alder, birch or aspen forest
Hygrophilous forest (Plane tree)	Mediterranean and Macaronesian riparian forest	
Other broadleaved forest (Italian alder dominated)	Italian Alder forest	
Other broadleaved forest (Birch dominated)	Southern boreal birch forest	

under the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2008) to measure progress towards sustainable forest management in the region. Compliance with this agreement requires reporting for seven indicators (forest area, growing stock volume, age structure/diameter distribution, deadwood, tree species composition, damaging agents, naturalness) by forest type (Barbati et al. 2007). The European forest type system (EEA 2006) is a hierarchical classification consisting of 14 forest categories subdivided into 76 forest types. A neutral bridge can be constructed to harmonise estimates by forest type corresponding to national classification systems to estimates based on the European forest type classification system (Table 3.3).

3.4.3 An Expansive Bridge for Above-Ground Biomass

The most important carbon pools for which forest estimates are to be reported under the Kyoto Protocol of the United Nations Framework Convention on Climate

Change are above- and below-ground living biomass, deadwood, litter, and soil. Estimates of above-ground biomass are often based on models for which diameter at breast height (*dbh*) is the most important predictor variable. The ability to report compatible estimates is hampered by a large variety of minimum *dbh* thresholds, ranging from 0 to 12 cm in Europe, for which NFIs collect data. COST Action E43 has included a minimum *dbh* threshold of 0 cm in its reference definition for above-ground biomass. The Portuguese NFI, however, uses a minimum *dbh* threshold of 5 cm which means that its estimates of above-ground biomass are incompatible with estimates based on the 0-cm threshold. Thus, for purposes of international reporting, Portugal requires an expansive bridge to harmonise estimates based on a 5-cm minimum *dbh* threshold to a 0-cm threshold.

To construct the bridge for eucalyptus forests, additional field data for planted and coppice eucalyptus production forests were acquired from commercial forest companies for 180 field plots. The data included observations for trees with $dbh \geq 0$ cm and were used to construct models of the relationship between biomass for trees with $dbh \geq 0$ cm as the dependent variable and biomass for trees with $dbh \geq 5$ cm as one of several independent variables. The models took the mathematical form,

$$\hat{W}_0 = W_d \exp\left[\hat{\beta}_0 \left(\frac{d_t}{d_q}\right)^{\hat{\beta}_1}\right], \quad (3.1)$$

where d_t is the minimum *dbh* threshold used to collect data, d_q is quadratic mean stand diameter for trees with $dbh \geq d_t$, W_0 is above-ground biomass for trees with $dbh \geq 0$ cm, and W_d is above-ground biomass for trees with $dbh \geq d_t$ (Dunger et al. 2009). The quality of fit of the model to the data was sufficiently good that biomass for trees with $dbh \geq 0$ cm could be confidently predicted for NFI eucalyptus plots for which only trees with $dbh \geq 5$ cm were measured.

3.4.4 A Reductive Bridge for Forest Structural Diversity

Multiple international agreements, including the MCPFE, the Montréal Process (1998), and the Convention on Biological Diversity (CBD 2008), specify criteria and indicators related to forest biodiversity. Within the broad scope of forest biodiversity, forest structural diversity is characterized with respect to three components: species composition, often assessed using the Shannon index (H′) as an indicator; horizontal diversity, often assessed using the standard deviation of diameter at breast height (s_{dbh}) as an indicator; and vertical diversity, often assessed using number of height layers (McRoberts et al. 2008, 2009a; Pommerening 2002; Varga et al. 2005). Forest structural biodiversity may be assessed at three spatial scales (Whittaker 1972): alpha diversity, which refers to ecosystem diversity; beta diversity, which refers to the change in diversity between ecosystems; and gamma diversity, which refers to the overall diversity for different ecosystems within a region.

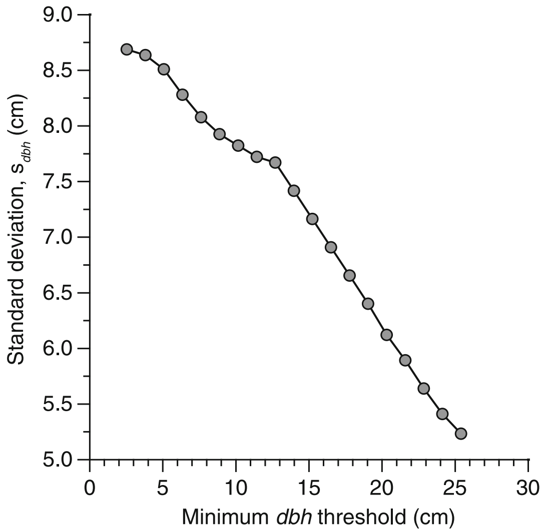

Fig. 3.1 s_{dbh} versus minimum *dbh* threshold

COST Action E43 selected s_{dbh}, the standard deviation of *dbh* for trees observed on NFI plots, as an indicator of forest structural diversity at the alpha scale. Thus, s_{dbh} is a target variable whose estimates are candidates for harmonisation. However, McRoberts et al. (2009, 2010) demonstrated that NFI plot-level estimates of s_{dbh} are sensitive to minimum *dbh* threshold and plot radius (Fig. 3.1). Therefore, harmonisation of estimates of s_{dbh} requires a reference definition for plot measurement that includes these two variables, minimum *dbh* threshold and plot radius, and that specifies thresholds for them. However, selection of variable thresholds is constrained by the expectation that expansive bridges will be too imprecise for predicting numbers of individual trees and their species, diameters, and heights for individual plots as is required for estimating forest structural diversity at the alpha scale. Thus, the bridges must be reductive which means that the reference definition thresholds must be the greatest minimum *dbh* threshold and the least plot radius among the NFIs whose estimates of s_{dbh} are to be harmonised. Bridges to convert estimates based on national definitions to estimates based on the reference definition must have two components, one to accommodate differences in minimum *dbh* thresholds and one to accommodate differences in plot radii. Whereas no additional information is necessary for the *dbh* threshold component of the bridge, the plot radius component requires information for an auxiliary variable, namely distances between individual trees and plot centres.

Despite the ability to construct such reductive bridges, the results may be considerably less than satisfactory because the harmonised estimates disregard such a large quantity of data. Two solutions appear possible, standardisation of NFI plot sizes and measurement protocols or collection of data using multiple definitions.

3.5 Summary

COST Action E43 has developed systematic, consistent methods for harmonising estimates for carbon pools and biodiversity indicators using NFI data. The methods focus on the two primary harmonisation components: reference definitions and bridges that produce estimates based on reference definitions using data collected under national definitions. The reference definitions are based on quantitative analyses of existing national and international definitions. The bridges are of three types: neutral bridges that are used when the scope of the national and reference definitions are comparable, reductive bridges that ignore some data satisfying national definition thresholds, and expansive bridges that compensate for data that is required by the reference definition but is missing when collected using the national definition.

The process of investigating, constructing, and agreeing to common definitions has motivated the NFIs of multiple countries to adopt them for operational use. When new inventory cycles are initiated, use of common definitions for basic attributes such as forest land, other wooded land, and growing stock volume, are likely to be adopted by NFIs, or at least they are likely be used simultaneously with national definitions to facilitate international reporting. Use of common definitions, together with the bridges developed by COST Action E43, will gradually lead to comparable international reporting.

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Chapter 4
Summary of Accomplishments

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4.1 Introduction

The overall objective of COST Action E43 was to enhance national forest inventories (NFI) for purposes of national and global reporting. In the process of accomplishing this objective the Action promoted scientifically sound methods for assessing forest resources, forest carbon pools and forest biodiversity. Beginning with international reporting requirements and the current status and practices

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of the NFIs, COST Action E43 focused on establishing reference definitions that could be commonly accepted by the participants and that would be applicable for international reporting. As explained in the previous chapters, these definitions are called reference definitions. However, common agreement was not achieved for a small proportion of proposed reference definitions, leaving need for further work. In addition to establishing definitions, techniques were developed to convert estimates based on national definitions to estimates based on reference definitions. These techniques can be viewed either as an intermediate step on the way to adoption of reference definitions or as permanent solutions if a country chooses not to use the reference definitions. This chapter briefly summarizes the main accomplishments of COST Action E43 and identifies future challenges.

4.2 Reference Definitions and the Comparability of Definitions

The NFIs are the main source of data for forest area, land-use change and carbon stock change estimates. Therefore, before constructing reference definitions, COST Action E43 conducted a comprehensive analysis of national definitions and their associated variables as used in European countries and the USA for estimating forest resources, forest carbon pools and biodiversity indicators. Definitions used for international reporting were also reviewed and assessed. In addition, WG2 of COST Action E43 investigated the methods currently adopted for the Good Practice Guidance (GPG) (IPCC 2006) for the United Nations Framework Convention on Climate Change (UNFCCC 2009), requirements for reporting for the Land Use, Land-Use Change and Forestry (LULUCF) sector, and Kyoto Protocol reporting requirements (Cienciala et al. 2008). An overview on procedures for constructing reference definitions is provided in Chapter 3.

Formulation of principles necessary for good reference definitions was recognized as an important first step (Chapter 3; Vidal et al. 2008; Vidal et al. 2010; Gschwantner et al. 2009). Vidal et al. (2008) provide a mathematical framework for constructing reference definitions that use multiple variables and associated threshold values. The concept underlying this framework, characterized as analytical decomposition, was formalized using a measure theoretic approach. Gabler et al. (2009) provide a second mathematical formulation for constructing reference definitions that use quantitative variables and associated threshold values. They used established mathematical expressions to describe the manner in which national definitions of forest deviate from an international reference definition and derived relevant cases. Case 1, which has three sub-cases, describes the situation for which the quantitative variables used in both the national and reference definitions are the same but with different threshold values (Table 4.1). Case 2, which also has three sub-cases, describes the situation for which at least some of the quantitative variables differ and includes the sub-case for which there are no common variables (Table 4.2).

The positive consequences of agreement on operational definitions cannot be over-emphasized. In particular, agreement on definitions that address practical

Table 4.1 Sub-cases for Case 1 where the set of quantitative variables in the reference definition (set $\chi^{(1)}$) is the same as the set in the national definition (set $\mathbf{X}^{(1)}$). $\tau^{(1)}$ and $\mathbf{T}^{(1)}$ are the sets of threshold values for the reference and national definitions, respectively. $\mathbf{V}^{(1)}$ is a subset of $\tau^{(1)}$ and contains the common threshold values for both the reference and the national definitions; Ø is the empty set

Sub-case	Formal description	Description text
1.0	$\mathbf{X}^{(1)} = \chi^{(1)} \wedge \mathbf{T}^{(1)} = \tau^{(1)}$	Quantitative variables to be applied and its threshold values are identical
1.1	$\mathbf{X}^{(1)} = \chi^{(1)} \wedge \mathbf{V}^{(1)} \neq \emptyset$	The same quantitative variables are used but at least one (but not all) threshold values differ
1.2	$\mathbf{X}^{(1)} = \chi^{(1)} \wedge \mathbf{V}^{(1)} = \emptyset$	The same quantitative variables are used but there are no common threshold values

Table 4.2 Sub-cases for Case 2 where the sets of quantitative variables in the reference definition (set $\boldsymbol{\chi}^{(1)}$) and in the national definition (set $\mathbf{X}^{(1)}$) are different. Thus, a subset of the intersection of sets $\boldsymbol{\chi}^{(1)}$ and $\mathbf{X}^{(1)}$, denoted $\mathbf{M}^{(1)}$, is used. $\mathbf{V}^{(1)}$ is a subset of $\boldsymbol{\tau}^{(1)}$ and contains the common threshold values for both the reference and the national definitions, where $\boldsymbol{\tau}^{(1)}$ is the set of threshold values for the reference definition; Ø is the empty set

Sub-case	Formal description	Description text
2.0	$\mathbf{M}^{(1)} \neq \emptyset \wedge \mathbf{V}^{(1)} \neq \emptyset$	There is at least one (but not all) common and identical quantitative variable and at least one (but not all) threshold values are identical
2.1	$\mathbf{M}^{(1)} \neq \emptyset \wedge \mathbf{V}^{(1)} = \emptyset$	The quantitative variables are partially the same, but all threshold values differ
2.2	$\mathbf{M}^{(1)} = \emptyset$	There are no common quantitative variables at all

Table 4.3 Number of reference definitions classified by agreement and WGs

Type of agreement	WG1	WG2	WG3	Total
Long-term agreement	41	4	4	49
Mid-term reference	0	11	18	29
Discussed with near future agreement likely	4	1	11	16
Discussed but near future agreement unlikely	0	0	5	5
Total	45	16	38	99

issues makes adoption much easier for NFIs. In the framework of COST Action E43 and within the three Working Groups (WG) approximately 100 definitions were constructed (Lanz et al. 2010). There were only five cases for which reference definitions could not be established (Table 4.3). In addition, there were 16 cases for which reference definitions were discussed, agreement was not reached, but is likely in the near future. Brief reference definitions are given in the Appendix; complete reference definitions for tree and its elements, forest area, and growing stock volume are reported in Gschwantner et al. (2009) and Vidal et al. (2008).

Definitions were grouped by 12 descriptive topic areas: (1) tree and shrub, (2) forest, other wooded land and other land with tree cover, (3) volume, (4) LULUCF land use categories, (5) afforestation, reforestation, deforestation (ARD), (6) carbon pools, (7) forest management and managed forests, (8) variables related to the choice between stock change and default methods for estimating carbon stock changes, (9) forest biodiversity, (10) components of forest biodiversity, (11) indicators of forest biodiversity, and (12) NFI attributes of biodiversity indicators.

Of the 22 definitions in topic area (1), long term agreement was reached for 19 definitions, and mid-term agreement was reach for the remaining three which were all related to tree crown. Seven definitions were constructed for topic area (2). Of these, long-term agreement was reached for four (forest, other wooded land, other land, and temporary unstocked forest areas) and agreement is likely in the near future for the remaining three (forest boundary lines, linear formations, open area). For topic area (3), long-term agreement was reached for definitions of the volume of growing stock and the living stem above the stump. Difficulties that were encountered related to defining coarse woody debris and its volume as well as dead wood. In particular, agreement was difficult for dead wood dimensions applicable for all reporting purposes including forest resources, greenhouse gases (GHG) and biodiversity indicators. For LULUCF land use categories (topic area 4), long-term agreement was reached for the definition of forest land, but only mid-term agreement was reached for the other five definitions (cropland, grassland, wetlands, settlements, other land). Results were similar for ARD definitions (topic area 5). For carbon pools (topic area 6), long-term agreement was reached for the definitions of above- and below-ground biomass and mid-term agreement for the other definitions (dead wood, litter, soil organic matter).

4.3 Bridges for Converting Estimates

Altering an estimate based on a national definition to bring it into conformity with a reference definition is not an easy task. Further, some countries desire to keep their national definitions to retain comparability with existing time series of estimates of their forest resources. When forest resource information has been collected using a national definition that differs from a reference definition, estimates should be adjusted to conform to the reference definition for international reporting purposes. The adjustment may be based on statistical methods, possibly with additional measurements, changing threshold values for the variables used in the definition, or expert judgement. These adjustment techniques were called bridges in COST Action E43. Bridges were characterized as reductive, expansive, or neutral depending on available data (Section 3.4). Ståhl et al. (2010) present a conceptual framework, provide examples of bridges, and propose a simple decision tree scheme to guide users in the construction of bridges (Fig. 4.1).

Issues related to forest area illustrate the difficulties in converting an estimate based on a national definition to an estimate based on a reference definition. When

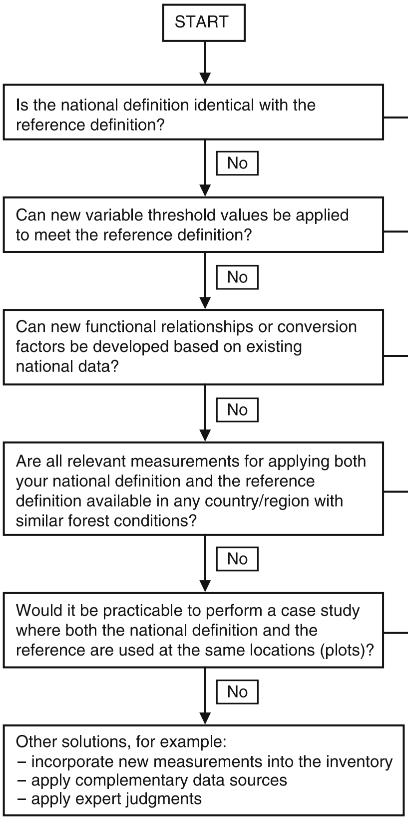

Fig. 4.1 A flowchart to guide users in the construction of bridges (Ståhl et al. 2010)

the minimum crown cover in a reference definition of forest is less than the minimum used in the national definition, construction of bridges for converting estimates may require collection of additional data which, in turn, may entail considerable effort and cost. Several case studies were conducted to analyse the effects of different definitions on estimates. Tomter et al. (2010a) investigated the effects on forest area estimates of different threshold values for core variables in definitions and different estimation methods. Tomter et al. (2010b) presented bridges for converting estimates of growing stock volume obtained with different diameter at breast height (*dbh)* thresholds to volume estimates corresponding to the reference definition. The effects of including or excluding stumps and tree tops on volume estimates were also addressed. Dunger et al. (2009) analysed the effects of differences in definitions of forest and differences in minimum *dbh* thresholds on carbon pool estimates. Finally, Gabler et al. (2009) investigated the effects of different minimum areas and minimum tree crown covers in definitions of forest on the decision as to whether sampling locations have forest or non-forest land cover.

4.4 National Forest Inventories and Harmonisation of Reporting

4.4.1 Harmonised Forest Resources Reporting

The efficiency of international reporting may be increased by taking full advantage of NFIs and strengthening their roles. In Europe, NFIs are established in almost every country and together survey more than 500,000 forest plots. NFIs play a primary role as national data providers and are essential sources of information for formulating national forest policies, planning large area forest management and forest industry investments, forecasting wood production and forest ecosystem monitoring. In the framework of the Ministerial Conference on the Protection of Forests in Europe (MCPFE), European countries and the European Union have agreed on 35 quantitative indicators describing the sustainability of forest management. Many of these indicators originate from NFIs and are reported through the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO) or the MCPFE (FAO 2004; MCPFE 2003).

WG1 of COST Action E43 analysed the current status of NFIs using four questionnaires that were distributed to actively participating countries. The first two questionnaires focused on general NFI practices, the third focused on measurement practices for small trees, and the fourth focused on *dbh* measurement and classification of volume and number of the stems by *dbh* classes. These questionnaires and their results served as important sources of harmonisation information.

COST Action E43 has had important impacts on European NFIs. Following the EFICS study (European Communities 1997) both Italy and France were still using national definitions for forest, but following COST Action E43 both countries now use the definition given in Chapter 3. In addition, the NFIs of the Nordic countries (Finland, Norway, and Sweden) now assess data simultaneously using both their national definitions and those of UNECE/FAO (1997), although Finland began using both definitions simultaneously before COST Action E43. Also, as evidence of confidence in the long-term sustainability of the reference definitions, beginning in 2009 Sweden has adopted the reference definition for forest as the new national definition. Finally, because of the influence of COST Action E43, the NFIs of many Eastern European countries are moving to sample-based inventories using the reference definitions constructed by the Action.

4.4.2 Harmonised Greenhouse Gas Reporting

UNFCCC and its Kyoto Protocol require annual reports of estimates of land use changes for the six land categories and related GHG pools. The majority of data used for the estimates comes from NFIs. WG2 of COST Action E43 investigated the current status of GHG inventories for the LULUCF sector in European countries with specific focus on the role of NFIs. The LULUCF inventory is an integral part of the reporting obligations under the UNFCCC and its Kyoto Protocol (Cienciala et al. 2008). The investigation was based on responses by GHG reporting experts in European countries to two questionnaires prepared by the Action. Two major conclusions were drawn: (1) definitions used to produce carbon pool change estimates vary widely among countries and are not directly comparable, and (2) NFIs play a key role for LULUCF GHG estimation and reporting under UNFCCC by providing the fundamental data needed for estimation of carbon stock changes involving living biomass, deadwood, litter and soil compartments. Dunger et al. (2009) demonstrated the effect of different definitions on the carbon pool change estimates. On the basis of this study, COST Action E43 has produced common definitions and practices that should lead to better use of European NFI data, improvement in European GHG reporting, and more comparable estimates.

4.4.3 Harmonised Biodiversity Reporting

Selecting variables applicable in assessing biodiversity with its many dimensions is a challenging task in large scale forest inventories. Assessing the abundance and the number of all species is impossible in practice. One goal of COST Action E43 was to make biodiversity components comparable over the vegetation zones, and to identify indicators that can be measured and estimated on the basis of information from NFIs. Surrogates or indicators have to be employed to study concepts and variables. Cost Action E43 made a thorough analysis of which forest inventory variables can be used to describe forest biodiversity and can be measured or assessed in a connection of large scale forest resource inventories using reasonable amount of resources. A list of key variables has been created. A book describing biodiversity assessment is under preparation by WG3, entitled ‘Contribution of National Forest Inventories for forest biodiversity assessment’ (Chirici et al. 2010a).

WG3 of COST Action E43 first developed a questionnaire on 41 variables associated with aspects of forest biodiversity. The variables were selected on the basis of participant suggestions, literature on biodiversity indicators, and current ecological knowledge (Winter et al. 2008; McRoberts et al. 2008).

The questionnaire variables were classified with respect to their ecological importance and their technical feasibility for monitoring in NFIs. Using these classifications, the variables were ranked with respect to their utility for NFI-based biodiversity assessments (Chirici et al. 2010b). The seven variables or group of variables (called essential features) turned out to be (1) the amount and quality of deadwood, (2) forest types, (3) forest structure (species composition, horizontal and vertical structure), (4) forest age, (5) composition of ground vegetation, (6) forest naturalness, (7) regeneration.

In total, 16 variables were assigned to these essential features and reference definitions were developed. The second questionnaire was used to evaluate the degree to which the variables are already harmonised. Following the assessment of the most important and feasible variables and the assessment of their existing degree of harmonization, WG3 developed methods for producing harmonised biodiversity estimates (McRoberts et al. 2010; Rondeux et al. 2010).

4.5 Knowledge Sharing to Support Future Work

COST Action E43 has promoted scientifically sound and validated methods for forest inventory designs, data collection and analysis by serving as a knowledge-sharing forum for forest inventory experts. Such a forum has been lacking in Europe and throughout the entire world. As a concrete example of the Action's role as an international knowledge-sharing forum, representatives of non-member countries also participated in COST Action E43 meetings, introduced their own inventories (Kasphor 2007; Kim 2007), and followed the work through presentations in other countries (Tomppo et al. 2006; IUFRO 2009). Sample-based NFIs have long traditions in some countries, whereas other countries have used data collected from stand-level management inventories as the basis for national forest resource monitoring and international reporting. During the course of COST Action E43, countries in the latter category, including some European participants in the Action and some from outside Europe, have begun implementing new sample-based inventories in a statistical framework.

Published articles in scientific journals together with reports by both participating and non-participating countries in the NFI Reports section of this book transfer knowledge developed by the Action to all interested bodies. The original aim of the book was to present the country NFI reports using a common template that included a history, use of NFI data, current basic estimates together with the definitions that were used, sampling designs, estimation methods, possibilities for providing estimates using the reference definitions and concluding with the influence of the COST Action E43 on the NFI and a future prospective. However, there is so much diversity in the histories, methods used and available estimates that it was impossible for all countries to follow the proposed template in every respect. Therefore, the NFI reports vary to some extent in length and content. Nevertheless, with its many NFI examples, this book will be an invaluable knowledge source for countries and organisations that are planning new inventories or enhancing existing inventories.

Despite the intensive work of COST Action E43, some unresolved issues remain. Reference definitions could not be found for all concepts, variables and parameters under consideration (Table 4.3). Further, some important concepts such as increment, drain, and error were not fully analysed. Because the process of adopting reference definitions and changing measurement practices will inevitably be slow, bridging techniques for converting estimates based on national definitions to estimates corresponding to reference definitions will be needed for many years. Thus, work remains to enhance and develop bridges. Fortunately, extensive sets of NFI data are now available to support and facilitate this work.

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National Forest Inventory Reports

Chapter 1
Austria

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1.1 Development of the Austrian National Forest Inventory

The first evaluation of Austrian forest resources after the World War II, the "Österreichische Waldstandsaufnahme", was conducted during 1952–1956. It covered the entire area of Austria and was based on aerial photographs and terrestrial assessments (Braun 1960). Securing the wood supply in the long-term and the recovery of forest resources were the predominant topics in forest politics and economics at this time. As the basis for decision-making, information on the existing forest resources were required. After this first assessment which was based on stand-level inventories, the concept of sample-based inventories gained more prominence.

Six sample-based National Forest Inventories (NFIs) have been completed, and field assessments for the seventh NFI (NFI7) are conducted during 2007–2009. An overview of the sample-based inventories is given in Table 1.1. NFI1 was based on a temporary systematic sampling grid with sample plots arranged in square-shaped clusters. The sampling intensity was adjusted to accommodate regional differences in forest characteristics. Both the grid size and the number of plots within a cluster varied by region. The main objective of NFI1 was an unbiased assessment of forest area, growing stock, standing volume of dead trees, increment and harvested volume. In addition to plot assessments, line sampling methods were also used (Braun 1969, 1974; Gabler and Schadauer 2008).

The subsequent NFI2 was also designed as a temporary inventory with a field measurement period of 10 years. The same distance between the sample clusters

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Table 1.1 Forest inventories in Austria

Inventory	Years	Method		Number of plots[a]
		Sample plots	Field assessments	
NFI1	1961–1970	Temporary	Continuous	48,408
NFI2	1971–1980	Temporary	Continuous	44,368
NFI3	1981–1985	Permanent	Continuous	22,236
NFI4	1986–1990	Permanent and temporary	Continuous	44,467
NFI5	1992–1996	Permanent	Discontinuous	22,236
NFI6	2000–2002	Permanent	Discontinuous	22,236
NFI7	2007–2009	Permanent	Discontinuous	22,236

[a]Number of distinct main sample plot locations for forest area and volume assessment. For the purpose of forest area estimation, or drain and growth estimation additional temporary plots were assessed in NFI1, NFI2, NFI3, NFI4, and NFI7.

and the same number of plots per cluster were used for the whole territory. Since NFI2, the clusters have been square-shaped with a side length of 200 m (Braun 1974). Additional variables were integrated into the assessments, in particular site descriptors and variables related to stand productivity.

Whereas NFI1 and NFI2 focused on assessments of the current status of forest resources, monitoring changes became more important later and provided the motivation for a permanent sampling grid. For NFI3 (1981–1985) a relocated and permanent sampling grid was established. The shape and size of the clusters were the same as for NFI2, i.e. squares with 200-m side-length and sample plots at the corners of the square. The inventory period was 5 years for collecting data in the field. Further, a small concentric circular plot was established at the centre of each sample plot for assessing trees with diameters at breast height (*dbh*) ranging from 5.0 to 10.4 cm. Trees with $dbh \geq 10.5$ cm were sampled as in former NFIs using the angle count method (Bitterlich 1948, 1952). For NFI4 (1986–1990) the permanent plots were remeasured for the first time. Additional data were collected on a temporary grid to evaluate the representativeness of the permanent grid. The permanent sampling design introduced new methods such as sub-sampling in the Austrian NFI. Models were developed for predicting tree height h and upper diameter $d_{0.3h}$, defined as diameter at 30% of the tree height. Due to the change from a temporary to a permanent sampling design the calculation of increment and drain, and the algorithm for error estimation were modified (Schieler 1988, 1997; Knieling 1994; Gabler and Schadauer 2008).

For NFI5 (1992–1996) the permanent sampling grid of NFI3 was used. The assessments had changed from a continuous to a discontinuous scheme. In addition to the traditional measurements, assessments of several new predominantly ecological aspects were integrated into the inventory (Schieler and Schadauer 1991). A special method for assessing regeneration was developed, and the abundance and frequency of tree and shrub species were recorded. Concerning dead wood survey, data on standing dead trees and lying dead wood were collected. Unusually shaped trees were assessed as part of the biological diversity assessment.

During the years 2000–2002 the field assessments for NFI6 were carried out. The inventory period was reduced to 3 years. The assessment of regeneration, lying dead wood, abundance and frequency of tree and shrub species was continued, in several cases with intensified and enhanced methods. New topics such as structural diversity of forests and the occurrence of rare tree and shrub species were covered. Particularly important in NFI6 were sustainability-related variables from which information relevant to the pan-European criteria and indicators of the third Ministerial Conference on the Protection of Forests in Europe (MCPFE) (2003) can be derived.

NFI7 (2007–2009) was designed to have a field measurement period of 3 years. Again, the scope of the Austrian NFI has broadened, and several new variables were implemented in the assessments to address sustainability, biomass, biodiversity and the protective capacity of forests. Definitions of several new variables are in line with the harmonization activities at the European level. For example, the forest definition of the Food and Agriculture Organization of the United Nations (FAO 2004) is used simultaneously with the national definition, and trees with $dbh < 5.0$ cm are recorded. NFI7 has moved towards landscape monitoring and has begun assessing additional variables related to areas surrounding forest plots (Gabler and Schadauer 2007).

1.2 The Use and Users of the Results

1.2.1 General Use

The NFI covers all forest land within Austrian territory. It is the largest monitoring program at national and sub-national level and an important source of information. It serves as the basis for decisions in forestry, forest economy and forest ecology related aspects. NFI results are the basis for forest policy decisions and are used to evaluate the consequences of those decisions. Currently the potential of forests producing fuel wood is of particular interest.

NFI data are used in reports on Austrian forest resources within the framework of international reporting; e.g., the Forest Resources Assessment program of the Food and Agriculture Organization of the United Nations (FAO), the MCPFE, and the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC). Because Austrian NFI data represent such a large area, it is a valuable data source for numerous scientific studies and research work:

- Forest growth simulator PrognAus (Ledermann 2006)
- Study on wood and biomass supply from Austria’s forests HOBI
- Remote sensing projects using Landsat images, and laser-scanning data in cooperation with the Vienna University of Technology
- Evaluation of protective functions of forests within ProAlp
- Study on the degree of naturalness (Jalas 1955; Grabherr et al. 1998) of Austrian forests

1.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

The Austrian NFI is the main source of data for estimating forest area, its changes, the three carbon pools (above-ground, below-ground, deadwood) and other wooded land for the greenhouse gas (GHG) reporting of the LULUCF sector within the UNFCCC. NFI data will play a key role in reporting LULUCF activities under Article 3.3 of the Kyoto Protocol. Reporting on emissions and removals of GHG under UNFCCC and the Kyoto Protocol is in the responsibility of the Federal Environment Agency of Austria.

The land use categories reported by Austria for the LULUCF sector are consistent with the IPCC guidelines (IPCC 2003). Area estimates for the land use categories forest and the land use changes from and to forest are based on NFI data. The areas of the other land use categories are mainly based on statistical data (Statistics Austria, Federal Office of Metrology and Surveying BEV) and special land use surveys (e.g. bog areas).

New variables related to land use are included in NFI7, because former inventories do not provide completely adequate information about land use conversions between IPCC land use categories. These additions are expected to yield more accurate estimates of emissions and removals from afforestation, reforestation and deforestation (ARD) activities for reporting under the Kyoto Protocol. All the LULUCF related carbon pool change estimates for forest biomass are based on the increment and the drain estimated by the Austrian NFI.

Estimates of carbon stocks in soils and litter are based on data from the Austrian forest soil survey. Because of the high uncertainty of carbon stock changes in forest soils, the Tier 1 method according to IPCC Good Practice Guidance (GPG) is used for the category forest remaining forest, which assumes no carbon changes in soils. A model study currently underway at the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) will provide, in the next few years, new estimates for the change of the carbon stock of the Austrian forest soils. The model includes NFI data.

1.2.3 The Role of NFI in Assessing the Status of Biodiversity

In the context of biodiversity, several relevant variables are assessed. The Austrian NFI collects data on the abundance and occurrence of tree and shrub species, on standing and lying dead wood, on unusually shaped trees, and on stand structure. It records the natural and actual woodland community as well as rare tree and shrub species. A regeneration monitoring with assessment of game browsing is carried out and data on protection measures against game impact are collected. Material for genetic analyses is collected. During NFI7 also woodpecker holes are recorded. A biodiversity monitoring program at the national level is underway. The NFI contributes data to five indicators: the naturalness of tree species composition, dead wood, regeneration, browsing, and the genetic diversity of silver fir.

1.3 Current Estimates

Estimates and standard errors of land classes and growing stock, increment and drain based on data from the NFI6 (2000–2002) are presented in Tables 1.2a and b. More detailed NFI results are available at http://web.bfw.ac.at/i7/oewi.oewi0002. As indicated, the given information is based on the national definitions of the Austrian NFI. Harmonized estimates can be expected from NFI7.

1.4 Sampling Design

The Austrian NFI uses a permanent systematic sampling grid of 5,582 clusters (Fig. 1.1) which was established in 1981–1985 and covers all land use classes. The

Table 1.2a Basic area estimates from the years 2000–2002 (NFI6)

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Productive forest (National definition)[b]	3,371	85.1	Forests available for wood production, includes protective forests with yield	44
Protective forest (National definition)[b]	473	11.9	Forests with protective function and without yield (in hardly accessible or inaccessible locations, on very poor sites)	19
Permanently unstocked parts of the forest (National definition)	116	2.9	Unstocked due to – Forest management (e.g. forest roads, timber yards) – Natural reasons	5
Forest land (National definition since 1961), productive forest and protective forest[c, d]	3,960	47.2	500 m^2 minimum area, 10 m minimum width, 30% crown cover of woody plants (including shrub species)	46
Other land	4,426	52.8	All land that is not classified as forest land	46
Total land area	8,386	100		–[e]

[a]Standard error.
[b]Productive forest and protective forest also include shrub-land according to the national definition.
[c]Forest land also includes 118,000 ha of shrub-land according to the national definition.
[d]Forest land in UNFCCC LULUCF reporting is the same as forest land based on national definition. NFI calculates areas only for forest land. The total area of the Austrian territory comes from Statistik Austria (2002).
[e]Assumed to be error free.

Table 1.2b Basic volume estimates in productive forests from the years 2000–2002 (NFI6)

Quantity	Estimate	Description	SE[a]
Growing stock[b]		Volume of trees with *dbh* $\geq$ 5.0 cm over bark, including the bole (wood and bark), and stem top, and excluding the above-ground part of the stump.	
Million cubic metre	1,095		17.3
m^3/ha	325		2.8
Annual increment of growing stock[b]		The mean annual increment represents the years between NFI5 (1992–1996) and NFI6 (2000–2002). It is the increment of surviving trees with *dbh* $\geq$ 5.0 cm over bark plus the ingrown trees into the small circular plot.	
Million cubic metre per year	31.3		0.5
m^3/ha per year	9.3		0.1
Annual drain[b]		The mean annual drain represents the years between NFI5 (1992–1996) and NFI6 (2000–2002). It is the drain of trees with *dbh* $\geq$ 5.0 cm over bark and is calculated as the volume of trees in NFI5 that were found to be harvested in NFI6.	
Million cubic metre per year	18.8		0.6
			0.2
m^3/ha per year	5.6		
Standing dead wood[b]		Volume of standing dead trees with *dbh* $\geq$ 5.0 cm over bark, including the bole (wood and bark), and stem top and excluding the above-ground part of the stump.	
m^3/ha	6.1		0.2

[a]Standard error.

[b]The given volume estimates refer to the area of productive forests which include shrub-land according to the national definition. NFI is main information source for the following carbon pool changes on forest land: above-ground biomass, below-ground biomass, dead wood, LUC areas from and to forest. It is by that an important information source for the estimates of the related biomass and soil C stock changes.

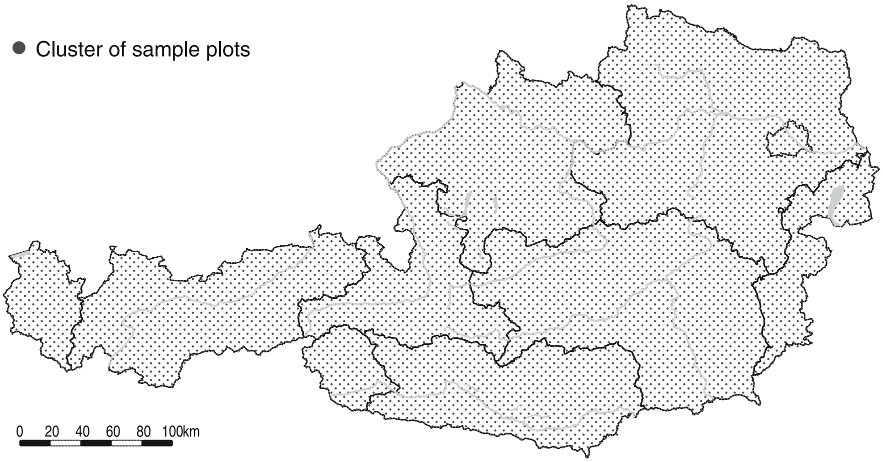

Fig. 1.1 The sampling grid of the Austrian NFI

distance between clusters is 3,889 km, and each cluster represents 15,125 km^2. A cluster consists of four sample plots whose centres are located at the corners of a square with side length of 200 m. The sides of the squares are oriented north-south and east-west. Forest sample plots that are not terrestrially accessible are assessed from remote sensing material and represent 182,000 ha. If required, additional temporary plots can be established.

1.4.1 Sample Plots

Each sample plot consists of a large circular plot, a small circular plot and an angle count plot (Fig. 1.2). The large circular plot has a radius of 9.77 m and an area of 300 m^2. Plots at the forest boundary are subdivided into 10%-shares of forest and non-forest. At least 10% of the 300-m^2 plot must have forest cover to be assessed. The large circular plot is the basis for forest area estimation in general and for ownership categories, management types, age classes, species mixture, and natural forest type. Many stand- and site-specific variables are assessed on the 300-m^2 plot. If a plot on forest land reveals dissimilar conditions such as stands of different age-classes, stand structures, tree species, management types, or different soil types, vegetation types, exposition, etc. then it is divided into sub-plots which are described separately.

The small circular plot has a radius of 2.6 m and an area of 21.2 m^2 and is used for data collection for trees with *dbh* between 5.0 and 10.4 cm. Trees with *dbh* of more than 10.4 cm are selected by the method of angle count sampling (Bitterlich 1948, 1952). A basal area factor of 4 is used for all inventory plots. When tree *dbh*s and distances to plot centres are near the limits for inclusion in or exclusion from the Bitterlich sample, the *dbh*s and distances are verified by measurement.

Multiple measurements are obtained on sample trees. Some variables are measured on all sample trees, whereas others are assessed only for sub-samples of trees. Because *dbh* is an essential inventory variable, it is recorded for all sample trees; tree height *h*, however, is usually measured only on a sub-sample that includes trees with *dbh* of at least 5.0 cm. For some inventories (e.g. NFI3 and NFI7), tree heights are measured on all sample trees for which *dbh* is measured.

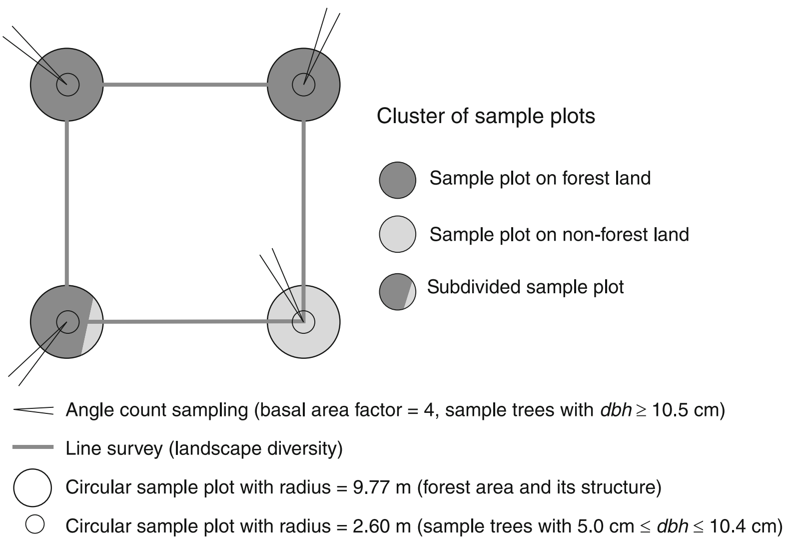

Fig. 1.2 Cluster with sample plots (according to Gabler and Schadauer 2008)

The measurement of the height of the crown base hk is also restricted to a sub-sample like the upper diameter $d_{0.3h}$. However, the upper diameter is not assessed for trees with $dbh < 10.5$ cm and trees that have a forked stem.

In addition to the plots at the corners of the square-shaped clusters, further assessments for special purposes are carried out in separate plots. These plots are located along the sides of the cluster or near the clusters. The sampling method depends upon the respective requirements and expectations.

1.4.2 Management

1.4.2.1 Personnel and Equipment

The BFW is obligated by law to conduct the NFI, and within the BFW, the Department of Forest Inventory is responsible for its planning, execution and evaluation. The Department of Forest Inventory includes the Unit of Inventory Design, Interpretation and Remote Sensing; the Unit of Assessment Methods and Survey; and the Unit of Logistics and Database. These three units have a permanent staff of 25 persons. The field work is accomplished mainly by temporary employees. Each field crew consists of three persons, a field crew leader with a university degree, a forester at the secondary forestry school level and a field work assistant. Field crews are equipped with portable computers for data storage. The location of field plots is supported by global positioning system (GPS) receivers. Distance and height measurements are carried out with Vertex. In addition to electronic devices, the field crews use conventional forest inventory equipment such as Bitterlich-relascope, calliper, and tape. Thematic maps and hard copy information are also part of the field equipment.

1.4.2.2 Quality Assurance

The Austrian NFI has implemented several steps for ensuring high quality data. The comparability of data from earlier inventories is of particular importance. At the beginning of each field season, field personnel attend a training period of several weeks. During the season technical questions are clarified in briefings at 2-week intervals. In addition experienced staff members support the field crews on demand. Field manuals provide detailed instructions for the work carried out by the field crews. In the framework of quality assurance approximately 5% of the field plots are revisited and reassessed by another crew shortly after the first assessment. Reassessed plots are selected randomly.

Data from previous inventories are stored in field computers. During recording, the current data are checked for plausibility by comparison with former data. In the data-checks, the consistency of data is examined and unexpected values are identified. A thorough examination of the data is done at the Department of Forest

Inventory by the means of comprehensive automated checking routines, methods of probability calculus and mathematical statistics.

1.5 Estimation Techniques

Estimates in terms of inventory outputs are mean values with their associated standard errors, as well as the up-scaled values for larger entities (Braun 1969). Gabler and Schadauer (2008) reviewed the history of methodological developments in the Austrian NFI since 1961 and compiled the estimation algorithms up to 2002. The following descriptions of estimation methods are simplified and condensed. Further and more detailed information are available in the report of Gabler and Schadauer (2008).

1.5.1 Area Estimation

Estimation of forest area is based on both the area of the Austrian territory and on data obtained from the circular 300-m^2 sample plots. The total area of Austria is obtained from Statistik Austria (2002) and is assumed to be error-free. On each circular plot the coverage of land use classes is assessed and recorded in 10%-shares. Area estimation is basically a ratio estimator following Laplace (1814) in which the number of favourable occurrences is divided by the number of possible occurrences. The proportion p of land area covered by forest is estimated as

$$p = \frac{\sum_{i=1}^{n} f_i}{\sum_{i=1}^{n} l_i} \tag{1.1}$$

where f_i is the number of 10%-shares covered by forest on sample plot i and l_i is the total number of 10%-shares on plot i regardless of their land use class. The possible number of 10%-shares on a sample plot is 10, except in the case that it is subdivided due to crossing the Austrian border. The forest area F is obtained by multiplying the area of the Austrian territory L by the proportion of 10%-shares covered by forest p:

$$F = L \times p \tag{1.2}$$

Similarly, the proportion of land area covered by forest can be calculated for regions, usually administrative units with known land area. The forest area calculation can also be stratified for categories such as ownership classes, management types, and further stand or site characteristics.

1.5.2 Volume Estimation

The Austrian NFI defines stem volume as the over-bark volume of a tree stem including the bole and the stem top and excluding the above-ground part of the stump. Normally, the Austrian NFI estimates standing volume per hectare and the total standing volume in productive forest. Estimates include the stem volume of standing trees with a minimum *dbh* of 5.0 cm. Standing volume can be divided into the volume of growing stock and the volume of standing dead wood. The same volume models are used for both living and dead standing trees. The stem volume of trees with 5.0 cm $\leq$ *dbh* $\leq$ 10.4 cm is obtained by means of

$$V = f(c_i, dbh, h) \tag{1.3}$$

where h is the tree height and c_i are regression parameters. The number of c_i (i = 1, 2, . . ., n) depends on tree species. For trees with *dbh* $\geq$ 10.5 cm the stem volume is estimated with models that additionally using the upper diameter $d_{0.3h}$ and the height to the crown base *hk* as explanatory variables:

$$V = f(c_i, dbh, h, d_{0.3h}, hk) \tag{1.4}$$

Due to sub-sampling, h and $d_{0.3h}$ are usually acquired partly from measurements and partly by predictions from models. The estimates of volumes of individual sample trees are converted into volumes per hectare for each sample plot. Because the Austrian NFI combines angle count sampling and sampling on fixed circular plots, the volumes per hectare for an individual plot i is equal to the sum of both sampling methods:

$$V/ha_i = V/ha_{acs} + V/ha_{fcp} \tag{1.5}$$

where V/ha_{acs} is the volume per hectare represented by the angle count sample (*dbh* $\geq$ 10.5 cm), and V/ha_{fcp} is the volume per hectare represented by the fixed circular plot with radius = 2.6 m and 5.0 cm $\leq$ *dbh* $\leq$ 10.4 cm. From the V/ha_i of individual sample plots i, the mean volume per hectare can be estimated for productive forest as sum of V/ha_i divided by the sum of 10%-shares covered by productive forest $f_i^{(\mathrm{prod})}$

$$\overline{V/ha} = \frac{\sum_{i=1}^{n} V/ha_i}{\sum_{i=1}^{n} f_i^{(prod)}} \tag{1.6}$$

Total volumes are estimated as the product of the estimate of mean volume per hectare $\overline{V/ha}$ and the area of productive forest $F^{(prod)}$. Further, volumes per hectare and total volumes for sub-strata within productive forest can be estimated.

1.5.3 Increment Estimation

Volume increment is defined by the Austrian NFI as the increase of tree stem volume over bark between two points in time, including the bole and the stem top and excluding the above-ground part of the stump. The methods of volume increment estimation of the Austrian NFI were investigated and developed by Schieler (1997). Increment, *Inc,* consists of the components survivor growth G_S and ingrowth, *I*. Ingrowth, *I,* is the stem volume of trees that have reached a minimum size of $dbh \geq 5.0$ cm (= *dbh*-threshold). For each individual sample plot *i,* the survivor growth G_S and the ingrowth *I* are estimated and added:

$$Inc_i = G_{S_i} + I_i \tag{1.7}$$

The volume growth of harvested trees and of trees that have died from natural causes is excluded from increment estimation. Volume increments are estimated as mean annual increase between two consecutive NFI periods. The increments of individual trees are converted into mean values per year and per hectare for each sample plot *i*. For angle count sample trees, the volume increment per hectare is obtained by referring to the *dbh* at the time of the previous measurement. Plot-individual increments per year and ha are averaged similarly to formula (1.6) by dividing the sum of increments *Inc* on all sample plots *i* by the number of 10%-shares covered with productive forest. The mean increment per hectare is multiplied by the forest area to obtain the total increment.

1.5.4 Drain Estimation

Drain as defined by the Austrian NFI is the removal of tree stem volume between two successive NFI periods. Drain consists of the stem volumes of cut trees *C* and trees that have disappeared from the collective of sample trees due to mortality or natural causes *M*. *C* and *M* are equal to the stem volume at the time of the previous measurement. The increment of these trees between the two consecutive NFI periods is not included in the drain estimated by the Austrian NFI. For each sample plot *i* the drain can be estimated from

$$D_i = C_i + M_i \tag{1.8}$$

Similar to increment estimation, the plot-individual drain is converted into values per year and ha. Subsequently, the mean drain per hectare is estimated and multiplied by forest area to obtain the estimate of total drain.

1.5.5 Error Estimation

The method of error estimation applied by the Austrian NFI since 1986, the "quotient formula", was proposed by Schieler (1988) referring to Loetsch and Haller (1964). It replaced the formerly applied "quadruplet-method" by Matérn (1960) which was much more resource intensive in terms of programming and data organization. In a comprehensive comparative study, Schieler (1988) demonstrated that the decrease in accuracy is negligible when the "quotient formula" is used instead of the "quadruplet-method". The errors of estimates are calculated on the basis of clusters.

1.5.6 Specific Estimation Questions Related to LULUCF Reporting

Estimation of land use changes from and to forest land in the LULUCF sector are mainly based on the detailed data of NFI6 (2000–2002) and the cumulative data for these land use changes (LUC) from the NFI periods before.

Austria applies IPCC's default method for the estimation of carbon stock changes in living biomass. The increase in carbon stock of forests is estimated on the basis of volume increment estimated by the Austrian NFI. The carbon loss of forests is estimated based on the drain estimated by the NFI. In recent years, branch biomass models were developed (Weiss 2006) and applied to NFI data to account for carbon stock changes for these tree elements.

The estimate of the natural mortality of trees is based on the NFI estimates of standing dead wood. The Austrian NFI does not collect specific data for estimating the carbon stock change in litter and soil. Carbon stocks in soil and litter are reported as being constant in forests (IPCC GPG Tier 1). Carbon stock in soil and litter is reported as change only in case of land use conversion from and to forest.

1.6 Options for Estimates Based on Reference Definitions

The status of harmonization of the Austrian NFI is presented in Table 1.3. In NFI7, forest area is assessed on the basis of both the national and reference definitions of COST Action E43 which means that estimates will be available based on both definitions. The national definition of volume of growing stock does not correspond with the reference definition, because the stem volume of trees with $dbh < 5.0$ cm is not included in the national definition. For the estimation of above-ground biomass, additional models such as branch biomass models are applied (Weiss 2006). Also, estimation of the below-ground biomass relies on models. The assessment of dead wood volume for the recent NFI7 is not consistent with the reference definition

Table 1.3 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	Both the national definition and the reference definition are employed in the field
Growing stock volume	Yes	No	NFI	The stem volume of trees with *dbh* < 5.0 cm is not included in the national definition
Above-ground biomass	Yes	Yes	NFI, models	
Below-ground biomass	Yes	Yes	NFI, models	
Dead wood volume	Yes	No	NFI	In the national definition the minimum length = 1.3 m, whereas the reference definition uses a threshold of 1.0 m
Dead wood volume by decay stage classes	Yes	No	NFI	The national definition applies five instead of four decay stage classes
Afforestation Deforestation Reforestation (Kyoto 3.3)	Yes	Yes	NFI	
Forest type	Yes	No	NFI	Although the definitions are different, the forest type according to the reference definition can be derived from NFI data

because the minimum length is 1.3 m. Moreover; dead wood is classified using five decay stages as per Hunter (1990) instead of the four classes required by the reference definition. The estimation of the areas of afforestation, reforestation and deforestation are consistent with the reference definition. A national definition is applied for the assessment of forest type, although forest type according to the reference definition can be deduced from NFI data. In general, nearly all estimates according to the reference definition may be computed from Austrian NFI data. However, estimation of the growing stock volume according to the reference definition will require an additional model.

1.7 Current and Future Prospects

The NFI7 marks a broadening in the range of topics covered by the NFI. Several recently added topics are considered in the field work. An additional plot for small trees was introduced in the field assessments. Further, the assessments of afforestation and deforestation for Kyoto Protocol reporting were enhanced. An important issue is the estimation of biomass in tree elements, such as branches and leaves. Particular efforts by the Austrian NFI are made in the field of remote sensing. Since May 2007 a forest-layer constructed using the k-NN method (Tomppo and Halme 2004; Koukal et al. 2007) is available for the Austrian territory. The potential of laser-scanning data in forest resources assessment is a further important issue in terms of remote sensing.

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Chapter 2
Belgium (Walloon Region)

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2.1 Development of the Regional Forest Inventory (RFI) in Wallonia

Belgium is organized as a federal state and forest inventories are the responsibility of the regions (Wallonia, Flanders and Brussels). Each region has developed its own inventory procedures more or less independently, although the first regional inventory launched by the Walloon region has provided the main elements in terms of sampling design and basic variables to be measured. Thus, strong similarities can be identified among the three regions which enable generally reliable estimates of the importance and the evolution of the Belgian forest over time.

Wallonia is the most wooded region, representing around 80% of the total Belgian forest. In 2004, it consisted of 544,800 ha, which corresponds to a woodland cover of 32.3%. Forests in Wallonia are characterized by very scattered ownership, great diversity of stand types, species compositions, sites and growing conditions.

The Walloon forest resources were enumerated from 1846 to 1980 using a national decennial census on agriculture and forests based only on land registry analyses. Very rough estimates of volume were made by the forest administration for public forests and by designated experts for forests in private ownerships. The approach was not very reliable for a variety of reasons: the objectives and variables were not well defined, the investigation methods were not homogeneous, there was a gap between the land registry statute and the field reality, and important delays occurred between data collection and the availability of first results for private forests. Further, statistical shortcomings resulted from using rough estimates and responses to questionnaires that were greatly influenced by the intentions and opinions of respondents.

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Table 2.1 The forest inventory in Belgium (Walloon region)

Inventory	Years	Method	Number of plots
Census	1846–1980 (every 10 years)	General census based upon questionnaires, samples rules not clearly defined	No plots (land registry)
RFI1	1978–1981	Test survey samplings	~300
RFI2	1984–1988	Systematic sampling – Temporary plots – Variable-area circular plots (~15 trees)	~11,000
RFI3 (1)	1994	Systematic sampling – Permanent plots – Three fixed-area concentric circular plots	~11,000
	1994–2008	One-tenth plots measured each year	~1,100 per year
RFI3 (2)	1997	Additional plots radius 12 m (vegetation survey)	All the plots concerned
RFI3 (3)	1998	– Additional plots radius 36 m (forest functions, structure, damages, etc.) – Four satellites (regeneration micro-plots) – Deadwood variables (in one of the three plots comprising the mean diameter tree) – Use of electronic encoders	All the plots concerned
RFI-3 (4)	2000–2001	– Re-measurement after 5 years – Use of GPS	~2,200
RFI4	2008–2018	Start of the second cycle: Half of the plots re-measured after 5 years and the other half after 15 years	~1,100 per year

In 1978 new responsibilities were given to the regional entities including forest policy and management of natural and forest resources. As a result, the first attempt to use an inventory based on sampling methods (Table 2.1) was carried out during the period 1978–1981. Various tests were made to determine the feasibility of a quite new approach based on a sampling design that involved choosing the type and size of plots, the sampling intensity and the type of data to be collected. Between 1984 and 1988, a regional inventory was officially carried out by the University of Liège – Gembloux Agro-Bio Tech on a contractual basis. This inventory used temporary, variable-area circular plots installed on a systematic 1,000 × 500 m grid. The plot radius was selected so that the number of trees measured on each plot remained nearly constant (15 trees). The aim was to give a representative picture of the forest and its growing stock. Later, in response to the growing importance of sustainable management, the objectives assigned to the inventory were extended to biodiversity assessment and additional specific observations and measurements were introduced (Rondeux1999b).

Taking advantage of this first successful experience, a new inventory was formally set up in 1994 (Lecomte et al. 1994; Rondeux and Lecomte 2001). The methodology was modified to permanent sampling units consisting of three concentric circular plots for measuring growing stock; other plots for describing ground vegetation, the general structure of stands and forest health; and a cluster of four circular sub-plots for assessing natural regeneration.

A permanent forest resources inventory unit was created in 1996 as part of the regional "Nature and Forest Administration" with scientific supervision handled by the Unit of Forest and Nature Management of Gembloux Agricultural University.

After 1981, three initial goals were defined: (1) to undertake a statistical analysis of timber resources; (2) to meet specific requests from wood users, private and public owners, regional, national or international organisations, etc.; and (3) to provide the guidelines for developing and adjusting a regional forest policy by providing relevant, reliable and unbiased information.

As in other European countries, the inventory has grown in conjunction with the increasing demand of the major forest users and more societal requirements, especially the increasing demand for multifunctional forest data, development and monitoring of sustainable forest management.

2.1.1 Summary of the Major Events Regarding the Walloon Forest Inventory

1846–1980: General national census of agriculture and forest using different methods for private and public ownerships.
1980–1984: Preliminary tests of statistical methods
1984–1988: First regional forest inventory based upon a systematic sample with temporary, variable-area sampling units (RFI2) (1 plot/50 ha)
1994–2008: Permanent systematic forest inventory using three concentric sample plots and other plot sizes for vegetation and regeneration assessments
2008: Start of the second cycle with sampling units re-measured after 5 or 15 years using a predetermined scheme

2.2 The Use and Users of the Results

2.2.1 National Users

The users are above all the forest administration and forest authorities in charge of regional forest policy, scientific research (for very diverse research purposes needing spatial reference data) and various forest organizations. The data are also useful not only for administration levels (municipalities, public owners, etc.), nature conservation agencies and forest industries but also for assessing forest regulations and new silvicultural approaches.

Data are used for environmental decisions where special algorithms or supplementary calculations are necessary to satisfy increasingly sophisticated information requirements. If the first hesitating steps are far in the past, now special attention must be paid to avoid use of data for inappropriate purposes, particularly very specialised requests with objectives for which the type and the precision of the data collected are not appropriate.

The scope of the inventory is to provide data not only for estimating the current state of the forest but also for change and scenario analyses. Most information requirements concern data on land cover and land use, sustainable forestry, environmental monitoring (Koestel et al. 1999; Lecomte et al. 1999), carbon stocks evaluation, adequacy of species and site conditions in relation to global change, etc. In short, it is becoming a multi-resource inventory (Lund 1998; Rondeux and Lecomte 2005).

2.2.2 International Reporting

The RFI is continuously solicited for answering questions and providing data for international statistical reports. The RFI is the principal source of information for reporting to international organisations or conventions, such as FAO's and UNECE/FAO's Forest Resources Assessments procedure (TBFRA 2000, FRA 2005), the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests), Ministerial Conference on the Protection of Forests in Europe (MCPFE) and OECD in the frame of the Convention on Biological Diversity (CBD). It is used to produce information on forest health, biodiversity and carbon pools for the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC).

There is also a strong relation between the Walloon RFI and the Great-Duchy of Luxembourg NFI. Indeed, the University of Liège – Gembloux Agro-Bio Tech is deeply involved in the implementation of the inventory and in providing results under the supervision of the forest administration of Great-Duchy of Luxembourg.

2.2.3 The Increasing Role of RFI in Assessing Biodiversity

Since 1994, the RFI has been an efficient tool for responding to the increasing demand for regional biodiversity assessments. Biodiversity is described through four key components in the RFI: ground vegetation, deadwood, forest edges and stand structure. Issues from the Helsinki and Lisbon ministerial conferences on the protection of forests (MCPFE 1996) have been taken into account to collect data for calculating indicators dealing with biodiversity, soil and water protection, forest vitality, health status, etc. The main variables and characteristics collected or calculated are:

- *Listings* (*relevés*) of all types of vascular plants in each specific vegetation plot (carried out in a 12 m radius plot, each plant is characterized by a coefficient composed of two digits: the first concerns abundance-dominance and the second sociability-dispersion). The data collected provide useful information for Natura 2000 site monitoring diagnosis. Biotopes are briefly described on the basis of key variables of habitats elaborated at the regional level. These observations were introduced for all plots since 1997.
- *The volume of deadwood* snags, fallen logs (stem parts) and branches, standing logs comprising (or not) branches and logging residues; fallen logs of at least 1 m length and 20 cm circumference are considered. Standing deadwood is measured according to the same rules applied to living standing trees. Lying deadwood is assessed in one of the three main plots depending on the mean circumference of standing living trees. Species category and stage of decay are also recorded. These measurements have been carried out for all plots since 1998.
- *The transition zone* between forest and open areas (edge) is described in terms of structural elements, density, specific composition and presence of particular habitats (deadwood, veteran trees, etc). A forest edge is considered every time the centre of a sampling unit falls in productive forest and for which the 18 m radius plot overlaps an open area (meadow, clear cut, road, etc.).

Other information on biodiversity assessment can be found in Rondeux (1999b), Rondeux and Sanchez (2009) and Sanchez et al. (2007). RFI data are sometimes used to describe natural and semi-natural biotopes, regardless of their state of naturalness, ecological value and their potential versus actual management. Carbon stock is evaluated from total volume per hectare (volume comprising stem and branches to an upper limit of 22 cm circumference). In the first step, green cubic volume is converted to dry weight (biomass) using factors (UNECE/FAO 1985) that vary from 0.35 to 0.50 according to the different components: species, wood under bark, over bark, other non wood aerial biomass, stumps and roots. In the second step, carbon stock is estimated by multiplying the dry weight of the biomass by a factor fixed at 0.45. Carbon amounts are estimated both for trees above ground and stumps as well as for roots (estimated to be roughly equal to total aerial volume $\times$ 0.20 $\times$ 0.50 for broadleaved trees or 0.40 $\times$ 0.45 for conifers) (Husch et al. 2003).

2.2.4 Other Outcomes of the RFI

Since its beginning, the inventory data has increasingly been used in fields other than those already described. Particularly meaningful and useful applications include important storm damage evaluations in 1990 and the study of the adequacy between soils and species (in relation to global changes). Genetic improvement has also been enhanced by analyzing stands exhibiting significantly different levels of productivity (top height at a reference age) on similar soil and environmental conditions. In addition, plot remeasurement data is used to address the component of forest management sustainability dealing with the balance between harvesting and growth rates.

More recently, the RFI has played a central role in giving a general overview of forest conditions (silviculture, growing stock, biodiversity's status, etc.) in the frame of a regional forest certification process.

Since its implementation, RFI data has also been very useful for additional applications: game damage assessment (Lecomte et al. 1992; Rondeux and Lecomte 1997a), beech disease evaluations (Rondeux et al. 2002), soil fertility assessments, Kyoto reporting at the national level, biodiversity quality assessments and Natura 2000 site delineation and classification.

In the future, the web site related to the RFI will include general results on forest evolution (areas, growing stock, biodiversity, etc.).

2.3 Current Estimates

The basic area estimates are given in Table 2.2a and basic volume estimates in Table 2.2b. RFI definitions are briefly given in the tables as well. The typology of the inventoried areas – or forest – is defined as follows and partially drawn from UNECE/FAO (1997) recommendations: wooded land managed for forest objectives comprising at least 0.1 ha in extent and including trees with a forest canopy of at least 10% (with a minimum height of trees of 5 m at maturity). Different elements are also part of the forest area such as: tree alignments, mud, moors, roads, open areas, clear cuttings, shrub-lands, plantations and wooded zones in which the trees are less than 5 m height and crown cover less than 10% (Lecomte et al. 1997).

Table 2.2a Basic area estimates from years 1996–2004

Quantity	Estimate (1,000 ha)	Percent	Associated definition	SE[a] (%)
Total region area	1,686.6	100		
Forest land	544.8	32.3	10% crown cover with minimum height of trees of 5 m at least 0.10 ha	0.15
RFI coverage			All land including forest (so named in land use)	
Productive forest land	477.8	28.3	Comprising growing stock	0.50
With trees measured	384.5	22.8		
Non-productive forest land	67.0	4.0	Roads, mud, moors, pools, clear cuttings	1.75

[a]Standard error.

Table 2.2b Basic volume estimates from the years 1996–2004

Quantity	Estimate	Description	SE[a]
Volume of growing stock (productive forest) (million cubic metre)	109.2	Stem volume to an upper circumference limit of 22 cm	2.21%
Volume of growing stock per hectare (productive forest) (m^3/ha)	228.4		n.a
Annual increment (productive forest) (million cubic metre per year)			n.a.
– Broadleaved stands	1.162		
– Conifers stands	2.567		
Annual increment per hectare (productive forest) (m^3/ha per year)			n.a.
– Broadleaved stands	5.111		
– Conifers stands	16.32		
Volume of deadwood (productive forest) (million cubic metre)		For lying dead wood	n.a.
– Standing	1.477	Minimum length 1 m	
– Lying	2.231	Minimum circumference 20 cm	

[a]Standard error.

2.4 Sampling Design

The ongoing inventory is a single-phase, non-stratified inventory using a systematic sampling design with plots at the intersections of a 1,000 m (east-west) × 500 m (north-south) grid. Points falling outside the forest are also taken into account in order to identify the land use and to evaluate changes in forest area over time.

Approximately 11,000 permanent sample plots have been established in forest areas. Remote sensing techniques are only used as complementary sources of information (maps, administrative documents, etc.) before visiting the sample points and more frequently in order to qualify a point as inside or outside the forest area.

One-tenth of the 11,000 permanent sampling units are remeasured each year according to a predefined scheme. The ground sampling intensity of 0.2% is one of the greatest in Europe. Sample plots to be remeasured are uniformly distributed throughout the territory so that annual forest resource estimates for the entire region can be obtained on the basis of measurements of 10% of the plots.

More recently, a new sampling design has been proposed according to a predefined scheme ensuring that the whole territory is uniformly covered. When the system has been completely implemented (RFI-4, Table 2.1), 50% of the visited plots per year will be re-measured after 5 years (increment calculation period) while the other 50% will be measured after 15 years (playing, to some extent, the role of temporary plots). When this procedure will be achieved, those plots re-measured on a 5-year-cycle or on a 15-year-cycle are revisited respectively 15 years or 5 years later. For a given point there is thus an alternation of intervals (short period becoming long and vice versa).

2.4.1 Sample Plots

In the inventory design, each sampling unit consists of concentric circular plots. (Fig. 2.1) comprising:

- Three main circular concentric plots with radii of 18, 9 and 4.5 m; on these three concentric plots tree circumferences (C) of living trees are measured as follows: trees with $C \geq 120$ cm are measured on the concentric plot with radius 18 m; trees with $70\text{ cm} \leq C < 120$ cm are measured on the concentric plot with radius 9 m; trees with $20\text{ cm} \leq C < 70$ cm are measured on the concentric plot with radius 4.5 m.
- Standing dead trees are measured in the same way as living trees while lying deadwood is measured on the same plot on which standing trees of the same mean circumference would be measured.
- Near the plot centre general observations related to physical soil properties (texture, drainage, depth, etc.) are collected; and furthermore for 10% of the productive forest plots, 21 soil samplings are collected for qualitative and quantitative soil analysis such as pH, cation exchange capacity, etc. These 21 soils sampling points are located as follows: one near the plot centre, three on the axes N-S and E-W (every 3 m from 6 to 15 m) and two in the azimuths 45°, 135°, 225° and 315° at 6 and 15 m from the plot centre.

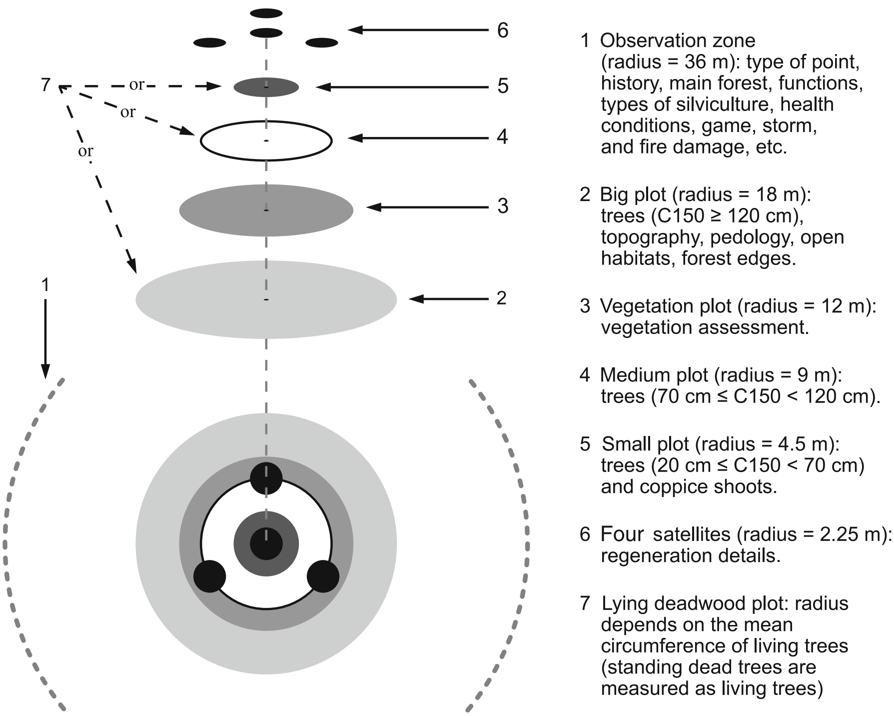

Fig. 2.1 General scheme of a sampling unit and nature of main data or information collected

- On the concentric circular plot with radius 18 m, in cases of edge, the intersection of the plot and the types of stands or land uses are measured and described before shifting the plot into the dominant type.
- One cluster of four circular sub-units especially set apart for regeneration measurements (radius of 2.25 m each), one of them being centred on the centre plot itself.
- One circular plot with radius 12 m used to describe all vascular plants (abundance, frequency, etc.).
- One circular area with radius 36 m (0.4 ha) for a visual diagnosis of health conditions, game, storm and fire damage, the general quality appraisal of trees, the main forest functions, the types of silviculture, etc.

2.4.2 Field Measurements

Since 1998, portable data recorders (HUSKY until 2005 and Panasonic tablet PC currently) have been used with dedicated software. Field measurements are divided into stand level data and tree level data. Stand level data are assigned to the following main thematic groups:

- General data and administrative information such as ownership, administration level, date, and crew identification;
- Plot identification data including plot number, coordinates, administrative references;
- Stand variables including tree species, structure, age, stage of development, silviculture;
- Site data including land use class, topography (altitude, slope, exposure), soil characteristics and ground vegetation (see Section 2.3)

At the tree level, the measured variables include circumference at 1.5 m above ground for standing living and dead trees, origin and length of lying deadwood, age of softwood, etc. Standing trees are measured when circumference at 1.5 m is at least 20 cm. Measurement of circumference at 1.5 m is the common rule in Wallonia, so conversion equations must be used to convert circumference at 1.5 m to diameter at 1.3 m. For both artificial and natural regeneration, the assessment of seedlings is only done by height classes. Other attributes gathered in the field include forest management intensity, damages and diseases (syndrome, time and intensity), microhabitats, natural hazards, tourist-recreational activities, infrastructures linked to forest activities or functions.

2.4.3 Management, Personnel and Equipment

The RFI is managed by the Walloon forest administration (General Directory of the Natural Resources and of the Environment, Division of Nature and Forests) and more precisely by a team consisting of one engineer and three technicians who are responsible for all the field measurements and operations dealing with data processing. The crew receives scientific support based on an agreement between the Regional Ministry of Agriculture and Gembloux Agro-Bio Tech. Scientific support work is done by an engineer and a computer scientist on renewable 1-year contracts. Cooperation with other scientific institutions also exists (e.g., for soil and ground vegetation investigations).

Field equipment is mainly selected for measuring trees and includes instruments such as Vertex for height measurements, pocket-sized GPS for identifying plots centre or retrieving them over time, field computers for collecting, controlling and transferring data, borers for taking soil samples, etc.

A particular effort has been made since 1998 to use electronic field recorders to help organize field operations and to check the encoded data (Rondeux and Cavelier 2001). Data are directly encoded on a tablet PC and automated procedures are used to verify the coherence of registered data. After the data is transferred into the main Microsoft Access database, data for each sample plot are again verified by the inventory staff engineer. Finally, an automated verification procedure takes into account the calculated variables to verify the likelihood of the results.

In the office, only a small network of personal computers linked to various electronic devices are used. Currently, this seems to be the best solution because of its great flexibility.

2.5 Estimation Techniques and Data Processing

2.5.1 Areas

A variety of area estimates are used in the estimation of other variables such as stand types, species composition and growing stock. Areas are estimated using the dot grid method (Zöhrer 1978) in which a grid is placed over the area (map) for which an estimate of area is sought. The grid covers all wooded areas (green colour on maps associated to particular symbols) and consists of rectangular 0.04×0.02 m cells at the map scale of 1:25,000. All dots that fall within the forest area are counted and, at this scale, each dot represents $0.04 \times 0.02 \times 25{,}000^2 = 500{,}000\ \text{m}^2 = 50$ ha.

2.5.2 Volumes

Volume tables based on regression models (Dagnelie et al. 1999) are available for twelve species (nine for broadleaves and three for conifers). Various types of volume can be estimated using three types of “entries”: (1) single-entry based on circumference (C) at 1.5 m (or at 1.3 m) above-ground, (2) double-entry based on circumference (C) and tree height (H), (3) single-entry based on circumference (C) of trees and fixed dominant height (HD) of the stand to which they relate (Rondeux 1999a). The mathematical form of the three types of models used can be expressed as: $V = f(C, C^2, C^3)$; $V = f(C, C^2, C^3, H, C^2.H)$ and $V = f(C, C^2, C^3, HD, C^2.HD)$. The stem volume of a tree corresponds to the volume of the stem wood over bark and above the stump level to the top of the tree. Other models are used to estimate the volume of branches, the thickness of the bark, the circumference (1.5 m) of a tree in relation to the circumference of the stump, etc.

Stem volumes of trees are given over bark and under bark, above ground level to different limits expressed in lengths or circumferences (more precisely percentage of the circumference at 1.5 m), volume of branches to an upper circumference limit of 22 cm. Taper curve models giving circumference at different heights can also be used to estimate any stem volume based upon any limit. Only models providing stem and branch volumes to the limit of 22 cm are currently used in the RFI. By adding the two volumes obtained from the specific models, the "total" volume of a tree can be estimated. Volumes of fine wood (branches with a circumference less than 22 cm) are estimated in percentages of the above-ground volumes if total volume estimates are needed. That is the case (not used until now because of lack of validation) for biomass and carbon stock estimation through indirect methods like conversion factors (Husch et al. 2003).

Volumes of standing and lying deadwood are estimated using volume models for standing trees or formulas (cylinder – Huber formula) for lying pieces of wood with a minimum circumference of 20 cm and a minimum length of 1 m.

2.5.3 Increment

Because permanent sample plots will be periodically re-measured at 5 or 15 year intervals, it is possible to evaluate the increment of the growing stock as well as the evolution of the forest (areas, types, structures, stages of development, species, biodiversity, vitality, etc.). Specific algorithms have been elaborated for taking into account "ingrowth", meaning that the sizes of the trees to be measured are selected based on the size of the concentric circular plots. The concentric circles on which trees are measured can change between two successive measurements depending on their growth.

Gross growth, including or excluding ingrowth, is estimated, and the increment of the trees that have died or have been cut between measurements are added to the increment for the survivors present at the beginning and at the end of the fixed measurement interval. All the details for estimating increment are given in Hebert et al. (2005). Volumes and basal areas are estimated by species, stand and forest types, site fertility classes, age classes (conifers) or stages of development (hardwoods). In the context of monitoring sustainable forest management, the removals/increment ratio is calculated using data for removed trees (thinnings, regeneration cuttings) every time increments are reported.

2.5.4 Error Estimation

For areas and volume (or basal area), estimates of standard errors are based on two methods. The first is based on area estimation by dot grid, and the second on sampling error for volume. A standard error that represents the sampling error (in %) is systematically estimated according to the Zöhrer method (Zöhrer 1978) taking into account the number of points counted and the general shape of the zones to be estimated. For the total forest area, the sampling error is 0.15% or 800 ha (at a 95% confidence interval, considering the number of counted points and the great variation in the ownerships, parcel sizes, and stand composition of the Walloon forest) (Rondeux 1991). In the second method, formulas for random sampling have been used. In the case of systematic sampling, as used in the RFI, due to the large distances between sampling units and consequently the low probability of correlation between observations of the variables, formulas for random sampling have been used. Thus, sampling errors for volumes, basal areas and number of trees can also be estimated.

2.5.5 Data Processing and Analysis

Data encoding is done on a hierarchical basis at three levels: the sampling unit, the tree species and the individual tree. Therefore, it is possible to answer very different questions for which the majority are only reliable at those levels. The processed data are grouped by sets corresponding to sampling units (stand types, stand densities); individuals (number of stems, basal areas, various volumes, biomass, carbon stock); and species (basal area percentage, mean and top circumferences, dominant heights, site quality). More than 40 tables are used: 20 concern initial or processed information, 14 are "dictionaries" and 10 are "working tables". Requests are formulated at sampling unit, species or tree levels and generally on "à la carte" deliverables. Results are presented in various formats including graphs, maps, and tables.

2.6 Options for Estimates Based on Reference Definitions

Table 2.3 presents a brief summary of the status of harmonisation in the RFI. The estimates for all parameters can be obtained from the RFI except "deadwood volume by decay stage classes". Indeed, the national definition of deadwood

Table 2.4 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Quantity	ND	RF	Responsible	Remark
Forest area	Yes	Yes	RFI	ND (0.1 ha) ≠ RF
Growing stock volume	Yes	Yes	RFI	ND = RF
Above-ground biomass	Yes	Yes	RFI	ND = RF
Below-ground biomass	Yes	Yes	RFI	ND = RF
Deadwood volume (=$DW_{10\ cm}$)	Yes	Yes	RFI	ND (6.4 cm) ≠ RF bridging function
Deadwood volume by decay stage classes	Yes	No	RFI	ND (three classes) ≠ RF
Afforestation Deforestation Reforestation (Kyoto 3.3)	Yes	Yes	RFI	ND = RF
Forest type	Yes	Yes	RFI	ND (regional vegetal associations) ≠ RF Label to Label

considers three classes instead of the four considered by the COST Action E43 reference definition. Note that circumference at 1.5 m above the ground level is used instead of diameter at 1.3 m to define the size of a tree.

The RFI and the Gembloux Agro-Bio Tech are working very closely to adapt definitions when necessary.

2.7 Current and Future Prospects

Some attempts are made to construct digital maps instead of simply adding qualitative and quantitative information to existing maps for each grid sample point (Rondeux and Lecomte 1997b) obtained from high resolution aerial photographs. The digital maps enable studies of the usefulness of stratification (i.e. on a forest structure basis) and take advantage of combining inventory data and their spatial references. Such an approach will probably be very useful to save time, to produce new spatial information related to the forest area evolution and to continuously improve the methodology.

2.8 Cost Action E43 and Its Influence on RFI

When COST Action E43 was launched, the RFI was already organized generally taking into account international conventions and rules. However, the action has given a very good overview of the forest inventories in Europe and abroad. It has thus been possible to “situate” the RFI into this European context thanks to the numerous outputs of the Action (reference definitions, measurements protocols, type of collected variables, etc). As stated during the duration of the Action, most of methodological choices made since the beginning of the RFI appear to be reinforced.

The most important elements that have been brought to light during the COST Action E43 concern thresholds of measurements, integration of European forest types, the method used to assess deadwood and, to some extent, the size of the sample plots referring to the associated variables. In order to be in agreement with other European countries concerning the variables to be collected, COST Action E43 has contributed once again to recommend the use of diameter at breast height (*dbh* at 1.3 m) instead of circumference at 1.5 m, commonly used in Belgium. Nevertheless, it is likely that conversion tables will still be a topical question for a long time.

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Chapter 3
Brazil

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3.1 Development of the National Forest Inventory of Brazil

In the 1980s, Brazil carried out its first and only National Forest Inventory (NFI). The objectives were to produce information about timber stocks of planted and natural forests (Brena 1995; Machado 1984), as has been the case for the majority of the earliest national inventories around the world (Holmgren and Persson 2002). Since then, only regional forest inventories have been carried out to address particular demands for information for purposes such as government planning strategies. More recently, some states have taken the initiative in setting up state forest inventories aimed at monitoring forest resources. However, these initiatives are completely independent of the NFI with respect to methodology and timing. Despite the fact that the states' initiatives are positive and, eventually will be more detailed, an NFI is ideally the most appropriate alternative to produce information on forest resources at the national level.

The process of designing a new NFI started in 2005 when the Ministry of Environment conducted a national workshop to identify the main components and methodological approaches to be considered in the project. Then, a technical committee was designated to coordinate a participatory approach to establish a nationwide project. A second national workshop was held in December 2006 to present the first version of the project. The conceptual basis for the project has considered the contributions of experts and interest groups from different institutions and regions through workshops as well as international collaboration with more experienced countries.

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The national and global strategic importance of the Brazilian forest resources, as well as the lack of reliable information at national level, are among the motivations that led the Ministry of Environment to propose a new NFI. Brazil is the largest country in Latin America, occupying 8.8 million square kilometre of which approximately 4.8 million square kilometres are covered by forests (FAO 2005).

The NFI of Brazil is conducted by the Brazilian Forest Service (BFS) of the Ministry of Environment. The BFS was created in 2006 with the aim of promoting sustainable forest production through forest management in public forests, as well as promoting forest development at national level. One of its legal responsibilities is to implement a national forest information system of which the NFI is one of the most important components.

The NFI has not been implemented in the field yet, but the field manuals and tests of the methodology in each of the six biomes are in final phases. Field implementation of the NFI is expected to start in 2009.

3.2 The Uses and Users of the Results

Despite the importance of forest resources, the country does not have a regular national forest assessment to support public formulation of forest policies aiming at forest conservation and sustainable use. Since the later 1980s, the most important government initiative for forest monitoring system is the INPE’s (National Institute of Spatial Research) deforestation monitoring program (Brasil/INPE 2000) that annually reports deforestation rates for the Amazon region through satellite image analysis. This program serves as an important tool for controlling agencies and as indicators of loss of forest cover. The recent completion of the vegetation mapping effort of the Ministry of Environment (Brasil/MMA 2007) was also a step forward in producing forest information at the country scale, although national vegetation mapping should be a regular government program.

However, the NFI will contribute information on forest stocks, composition, health and vitality, as well as the patterns of change in time by comparing estimates from successive inventory cycles. These estimates may serve to support the design of regional and national policies based on updated and reliable data, to identify strategies and opportunities for sustainable use of the forest resources by the forestry sector, and also to keep society and politicians informed on the national forest resources situation. Further, NFI information can be used to address the increasing demand by international organizations and agreements for forest information related to biodiversity, climate change, amongst others.

3.3 Methodological Framework

The main purpose of the NFI is to generate information on forest resources, both natural and plantations, to support the formulation of public policies and projects aiming at forest development, use and conservation. The NFI will be nationwide and multi-source, reporting information on forest resources in a 5-year measurement cycle. The project is composed of information components from five sources, as follows:

1. Vegetation mapping
2. Sample plots for tree measurements and forest evaluation
3. Interviews for socioeconomic evaluation
4. Landscape plots
5. Associated programs

3.3.1 Vegetation Mapping

A vegetation mapping scheme with 5-year updates based on topographic maps at a scale of 1:250,000 and CBERS (Chinese-Brazil Earth Resource Satellite) satellite images, or similar data, has been proposed. The vegetation map will serve as the basis for field sample plot selection, as well as to support estimation of areas of different post-stratification criteria such as biomes, vegetation classes, states, and species groups. A recent vegetation mapping of the natural vegetation (Brasil/MMA 2007), carried out in each of the six Brazilian biomes and based on Landsat satellite images from 2002, will serve as the first NFI edition. Forest types are classified according to the Geographic and Statistics Brazilian Institute classification – IBGE (Brasil/IBGE 1992).

3.3.2 Tree Measurements and Forest Evaluation

The sampling design for field data collection will be based on clustered sample plots distributed over a systematic grid of 648 × 648 degrees which, at the Equator corresponds approximately to a 20 × 20-km grid (Fig. 3.1). Plots on forest and non-forest sites will be measured, as well as land-use classes within plots will be mapped. A denser grid of 10 × 10-km or 5 × 5-km can be adopted whenever states wish to invest in higher intensity sampling for increased precision for forest types of high economic or ecological value or state forested areas for which the national sample size is too small. Fixed-area sampling units will be grouped in clusters of four rectangular sample plots, at azimuths of 90° and distances of 30 m from the central sample point, with sizes and shapes determined on the basis of biome characteristics. Trees with $dbh \geq 10$ cm are selected and measured on 20 × 50-m sample plots. In the Amazonian biome, 20 × 100-m plots are used to increase selection of larger trees ($dbh \geq 40$ cm). In each sample plot, saplings and seedlings are measured on 10 × 10-m and 5 × 5-m nested sub-plots. At the central point of each cluster, soils are sampled and two perpendicular 10-m transects are used to collect data on down dead woody material. Data collection on sample plots includes measurement of quantitative and qualitative forest variables,

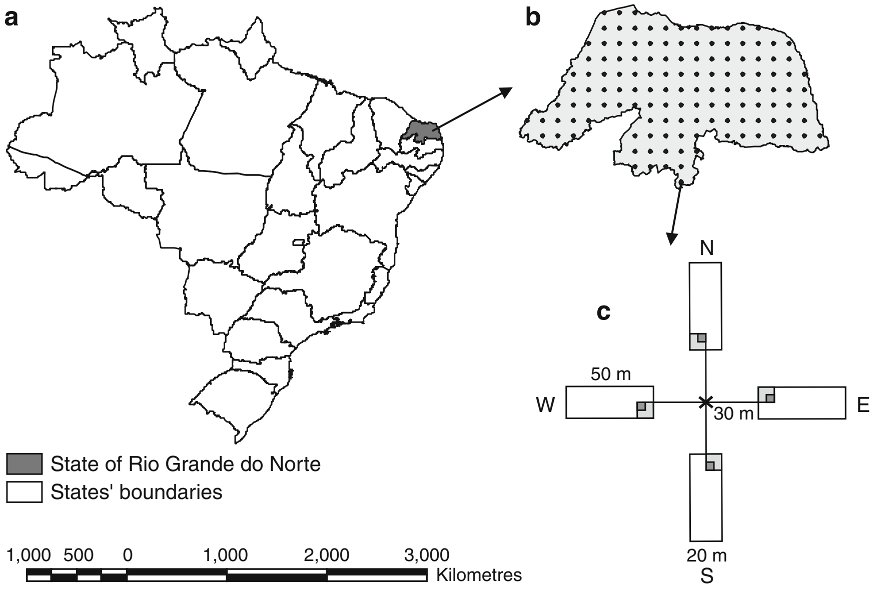

Fig. 3.1 Brazil map (**a**) showing the State of Rio Grande do Norte, and details of the sampling design: 20 × 20-km base grid (**b**) laid out over the state and the basic cluster sample plot design (**c**) with plots (20 × 50-m), and the nested sub-plots for saplings (10 × 10-m) and seedlings (5 × 5-m)

measurement of the classical dendrometric variables, species identification, and measurement of qualitative variables that are useful for forest ecosystem characterization.

3.3.3 Interviews for a Socioeconomic Survey

Simultaneously with measurement of each sample plot, an expedited socioeconomic survey has been proposed to be conducted nearby. The survey is based on two to four interviews aimed at gathering data that describe how local communities view and use their available forest resources, to describe their perception of the forest resource's use and conservation, and to inform them about national forest incentive programs.

3.3.4 Landscape Scale Plots

Using the same framework as for the NFI systematic sampling grid, an additional sampling grid with a 40 × 40-km interval will be used to collect data at the landscape level. The 10 × 10-km sampling units located at the grid intersections will be assessed by interpreting higher resolution satellite images instead of field measurement. Among the landscape variables to be analyzed are forest fragmentation, changes in forest cover and land use, and the condition of permanent protected areas along rivers and water bodies as required by law. The aim is to support the design of restoration programs.

3.4 NFI Associated Programs

The component of associated programs aims at supporting the NFI with improved methods and procedures, as well as producing complementary data and information that, because of their nature, are not collected in the sampling framework described above.

The main associated program is the Research and Development Program, which will be of particular importance for the initial editions of the NFI, because several components of the NFI demand incorporation of research and methodological procedures. For example, development of the field manual is based on consideration of state of the art vegetation measurement protocols and analyses in each biome, as well as models for volume, biomass and carbon estimation that will be required to process data. A second associated program will be a training program aimed at providing human resources able to satisfy the NFI standard quality requirements. A third associated program is the quality control program which aims at establishing procedures for data quality control and checking a fraction of the measured sample plots. A fourth associated program will be set up by the Forest Service to produce annual forest indicators, based on secondary data gathered from different sources. At least three forest-related indicators have been proposed for annual monitoring at the national level: (1) area of natural forest under sustainable management; (2) area of plantations, and (3) forest growth and yield data, based on permanent sample plots already established in every biome (Oliveira et al. 2005). These indicators will be recorded annually, but analyzed for the NFI 5-year measurement cycle as one of its results. Additional associated programs may be designed according to the needs and priorities identified in the context of NFI purposes.

3.5 Institutional Framework and Strategies for Implementation

The general coordination of the NFI will be led by the Forest Service from its headquarters in Brasilia, the Brazilian capital. The main activities of the BFS are administrative and technical support, management of the information system, and establishment and refinement of technical procedures aimed at adopting national standards. Further, the BFS will maintain a permanent strategy of communication which includes contact with national and international groups dealing with forest assessment. Considering the size of Brazil and the diversity of its forest resources, such a national project requires contributions from different national institutions in an appropriate institutional framework. Therefore, technical consultative committees at national and state levels will be established to support the Forest Service for designing guidelines and planning consistent with regional particularities. Temporary ad hoc committees, bringing together experts on specific themes such as sampling, biodiversity, remote sensing, and socioeconomic topics, may be established whenever a high level of knowledge support is required to assure the success of the NFI. The project will be based on partnerships with other institutions, which will coordinate specific components of the project, in order to supply the Forest Service with the required data to produce the NFI results. Examples of such institutions include the IBGE, the INPE, and Embrapa Forestry, the forest branch of the Brazilian Agricultural Research Corporation (Embrapa) which coordinates the research program to support the NFI. Universities will take part through the quality control program, and private companies or organizations will be involved in field data collection through business contracts.

3.6 Future Prospects

The field manuals with detailed procedures appropriate for each of the six biomes are in the final phase of completion. These procedures are based on the core methodology proposed during the national workshops, specifics of tree measurements in each biome when required and, most importantly, field tests of the entire NFI methodology in each biome at an experimental scale. Although the general methodology is the same, unique aspects of forest types in each biome may require particular measurement methods, as well as confirmation that plot sizes and tree measurements have been harmonized, identification of logical constraints, and checking for code inconsistencies. Simultaneously with the field tests, development of procedures for interviews (socioeconomic survey), development of the information system, and higher resolution image interpretation for landscape plot analysis are ongoing. A technical cooperation project between BFS and FAO (2008) is conducted to complete the methodological tests. As soon as the field tests are finished, the NFI can be implemented at the country scale by contracting executing agencies or private companies for field data collection.

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Chapter 4
Canada

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4.1 Development of Canada's National Forest Inventory

As a major forest nation, Canada must have reliable, current and consistent information on the extent and nature of its forests to enable the sustainable management of these resources. Authoritative information on forest change is also required to support the development of policy to address immediate needs as well as new and emerging issues such as climate change impacts and possible adaptive strategies.

In Canada, the provinces and territories have the constitutional responsibility for forest management of provincial and territorial Crown land (71% of Canada's land base). They develop legislation, regulations, policies and practices to support their management obligation. A number of inventory systems are employed to support forest management including reconnaissance inventories (exploratory inventories for strategic purposes), forest management inventories (detailed, intensive forest inventories of management units for planning or evaluation purposes), and operational inventories (intensive inventories of specific areas for operational harvest planning).

Unlike most forest nations, Canada does not have a National Forest Inventory that is mandated through legislation. National Forest Inventory activities have been achieved through interagency collaboration, facilitated by all provinces and territories working with the federal government, primarily through the Canadian Council of Forest Ministers (CCFM) (2009). The manner in which Canada has gathered, compiled and reported nationally on forest resources has continually improved. Prior to 1981, the National Forest Inventory consisted of a compilation of information based on questionnaires completed by provincial, territorial and federal forest

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management agencies. In 1981, a computer-based system known as Canada's Forest Inventory (CanFI) was developed to summarize detailed data contributed by the management agencies (Canada's National Forest Inventory 2009). CanFI was compiled about every 5 years by aggregating provincial and territorial forest management inventories and reconnaissance level information. Stand-level data provided by the provincial and territorial management agencies were converted to a national classification scheme, and then aggregated to the map sheet, provincial and national levels for storage, analysis and reporting. The most recent (and final) version of CanFI was compiled in 2001 and the results were published in 2006 (Power and Gillis 2006).

The CanFI approach was cost effective because it was based on existing data. The process was well established and accepted by forest management agencies, and provided detailed information on Canada's forests that was consistent with information contained in forest management inventories. While this approach had many advantages, the Canadian Forest Inventory Committee (CFIC) (Canada's National Forest Inventory 2009) acknowledged in the mid-1990s that the CanFI approach to a national forest inventory would not be able to address evolving needs. The CFIC was a subcommittee of the CCFM National Forestry Database Program Steering Committee, and was comprised of the managers of forest inventory from federal, provincial and territorial governments. The CFIC has been replaced by the NFI Task Force which reports to the CCFM Information and Knowledge Working Group. CFIC acknowledged in the mid-1990s that the CanFI approach to a national forest inventory would not be able to address evolving needs because CanFI was based on forest management inventories that were

- Collected to different data standards both within and across jurisdictions, making ecosystem assessment and comparisons at a regional level difficult
- Unavailable for large areas of forest within many jurisdictions
- Providing a static picture of the forest resources, while forest ecosystems are constantly changing

CanFI did not contain consistent information nationally, did not reflect the state of the forest at a given point in time, and could not be used to track the nature and rate of changes to the resources over time.

Recognizing that measuring change is fundamental for accessing and reporting performance measures around forest health and sustainability, the CFIC acted as a catalyst in the development of a new forest measurement and monitoring system to address the limitations of CanFI and to meet new business demands. A new National Forest Inventory (NFI) was designed in the late 1990s and is being implemented to provide:

- Timely data reflecting the state of the forest at a defined time
- National data based on uniform definitions, collected to the same quality standards
- Data that reflect consistent and complete area coverage
- Data suited for accurate assessments of ecological change

- Data on non-timber forest resources
- Statistical rigour (credibility)

The NFI, which replaces CanFI, a periodic compilation of existing information from across the country, has a plot-based design consisting of permanent observational units located on a national grid. The purpose of the NFI is to assess and monitor the extent, state and development of Canada's forests and sustainability of forestry in a timely and accurate manner (Anon. 1999). By collecting and reporting information to a set of uniform standards, it allows for consistent reporting across the country on Canada's land base to establish a baseline of the state of Canada's forest resources and how they are changing over time. Describing the forest resources in terms of their basic characteristics provides the flexibility for the NFI to address both immediate needs and unforeseen emerging issues. In addition to providing consistent estimates for traditional forest inventory attributes, the NFI provides a framework for collecting additional data relevant to sustainable forest management (e.g., socioeconomic indicators), as well as data related to forest health (e.g., insect damage, disease infestation), biodiversity, and forest productivity.

4.2 The Uses and Users of the Results

The results from the NFI will be shared with collaborators and the public, and will be used to inform domestic forest policies and positions, to support science initiatives, and to help meet regional, national and international reporting commitments.

The NFI was established between 2000 and 2006. The data have been compiled and are being analyzed to produce baseline statistics. Inventory data and reports from the new inventory, as well as complete documentation, are available on the NFI website (Canada's National Forest Inventory 2009). The baseline NFI report, providing information on the key NFI attributes will also be produced in 2009. The list of the key NFI attributes is as follows:

- NFI Attribute
- Total forest area
- Area by forest type
- Area of forest type by age class
- Area of forest types by protection status
- Area of other wooded land by protection status and type
- Area of age classes by protection status
- Area and percent of forest land managed primarily for protective functions (watersheds, flood protection, avalanche protection, riparian zones)
- Regeneration and afforestation area by type
- Area of surface water in forests
- Number of forest dependent species
- Number of native and exotic species in forests
- Origin (local/non-local) of seedlings in regenerating areas
- Area available for timber production

- Area converted to non-forest use
- Area and severity of disease infestation
- Area and severity of fire damage
- Area of forest disturbance
- Area and percent of forest land with significant soil erosion
- Total biomass by forest type, age, succession stage
- Total volume of growing stock by tree species on forest land
- Area and volume of plantations (both native and exotic)
- Current annual increment of volume growing stock (gross and net)

The ongoing measurement of the NFI is underway, and is designed to provide inventory data and an assessment of the current status and change of the forest resources on a 5-year cycle. The list of key attributes will expand as new data needs emerge.

The NFI provides data and information to national assessments (e.g., the annual State of Canada's Forests reports, and Criteria and Indicators of Sustainable Forest Management in Canada (Canadian Council of Forest Ministers 2009)) and international processes, e.g., United Nations Food and Agriculture Organization (FAO) Global Forest Resources Assessment (FRA 2008) and Canada's Report on the Montréal Process Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (The Montreal Process 2009). The NFI also undertakes special analyses of the NFI data to satisfy client needs. For example, NFI data are being analyzed to prepare Canada's Ecosystem Status and Trends Assessment for the Canadian Council of Resource Ministers. NFI data will also be analyzed to report on the forest resources within Canada's boreal region. Finally, NFI data are provided to a number of other public and private organizations. NFI field plot data are used to reduce uncertainty in national estimates related to changes in carbon content of biomass, detritus and soil stocks provided in the annual report on national greenhouse gas emissions and removals from managed forests. It has long been argued that one of the few benefits of higher concentrations of atmospheric CO2 is enhanced growth of trees; data gathered from NFI field plots, including over 3,300 tree cores, are being analyzed to look for this and other potential impacts of global change across a range of species and Canadian ecosystems.

4.3 Design of Canada's National Forest Inventory

A key requirement of the NFI was that the design is sufficiently flexible to allow the implementing agencies to integrate the NFI into their existing or planned inventories. So, while the design can be flexible, the data resulting from the inventory must be consistent. The required data consistency and design flexibility are achieved through the development of a simple core design and by allowing variations in the implementation of the design. For example, plot size and shape may vary, but the same attributes must be measured to the national standards. Plots must also be established in a statistically defensible manner and there must be enough of them to achieve an acceptable level of precision. The core design of the NFI has the following essential elements:

- A network (grid) of sample plots across Canada to ensure complete coverage; Stratification of the sample plots by terrestrial ecozone (Agriculture and Agri-Food Canada 2009)
- Varying sampling intensities among the strata so that each ecozone is adequately sampled for statistical reliability
- Estimation of area and other attributes from remote-sensing sources (photo plots) for consistency and timeliness, and to reduce cost
- Estimation of species diversity, wood volumes, and other desired data from a field plot based sub-sample for attributes not available from photo plots
- Estimation of changes over time from re-measurements of all sample plots at regular intervals

The target population is Canada's entire land base, whether vegetated or not. The population is assumed to consist of an infinite number of points that are stratified for reporting purposes into 15 terrestrial ecozones (Ecological Stratification Working Group 1995; Gillis et al. 2005). The terrestrial ecozones are illustrated in Fig. 4.1 Sub-populations (NFI units) are created for estimation purposes by

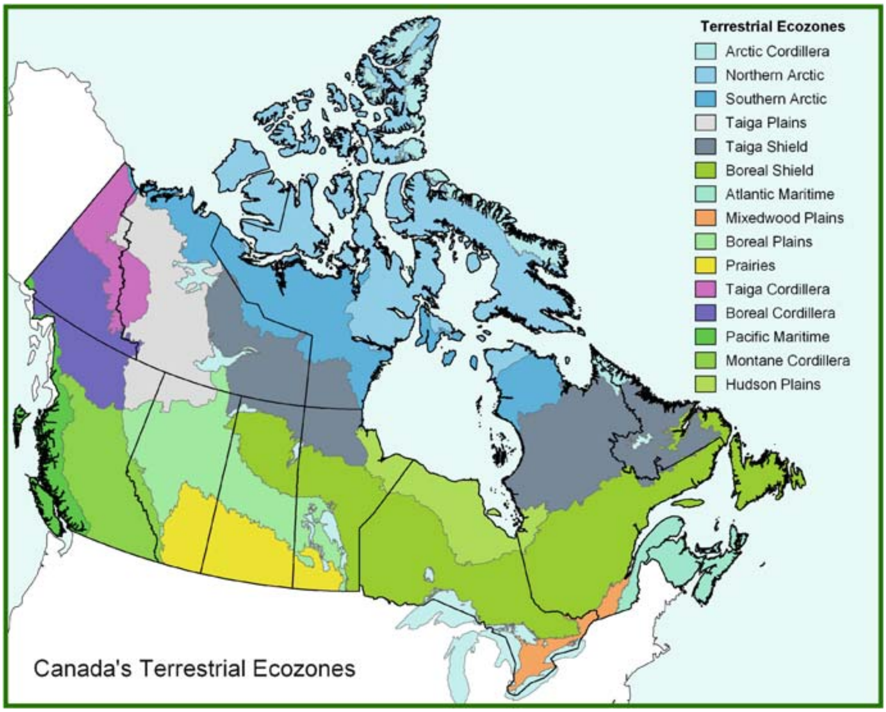

Fig. 4.1 Canada's terrestrial ecozones

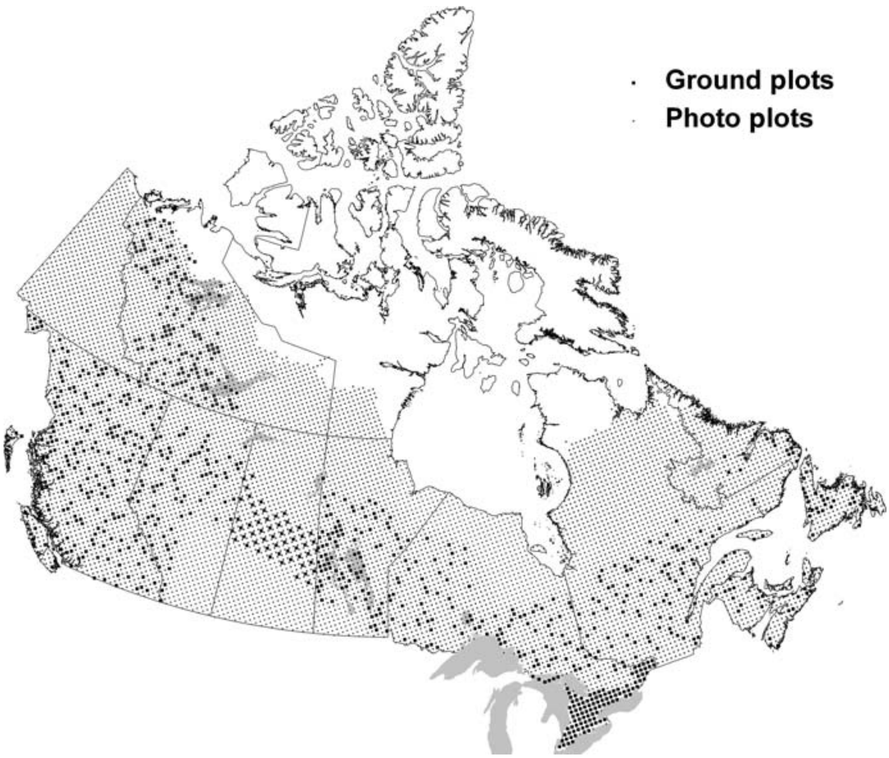

Fig. 4.2 Representation of Canada's National Forest Inventory photo and field plot grid

partitioning ecozones by provincial or territorial boundary. This partitioning allows for variations in sampling designs and data collection methods provided for in the design.

The sampling design described in Gillis et al. (2005) consists of two components (Fig. 4.2):

1. A systematic sample of points across Canada, with a photo plot installed at each sample point
2. A random sub-sample of the systematic sample within selected ecozones, with a field sample established near the sub-sample point

All potential sample locations reside on a 4 × 4-km network. To provide reliable area statistics, the objective is to survey a minimum of 1% of Canada's land area. The preferred sampling density is a 20 × 20-km grid of sample plots (the 20 × 20-km grid is nested within the national 4 × 4-km network).

Fig. 4.3 An example of a 2 × 2 km NFI photo plot (1:20,000 mid-scale aerial photograph)

4.3.1 Photo Plots

Photo interpreted attributes constitute the core data set in the NFI. To achieve the 1% objective, a 2 × 2-km photo plot is located at each sample location on the 20 × 20 km grid. Photo plots are identified on conventional, medium scale, aerial photography, and delineated and classified in full according to land cover classes and other forest stand attributes (Fig. 4.3).

At each of the photo plots, four layers of information are collected:

- Land cover – from aerial photography or other high-resolution remotely sensed data
- Land use – from aerial photography, other remotely sensed data, maps or other data sources
- Ownership – from maps or other data sources
- Protection status – from maps or other data sources

Table 4.1 A summary of the NFI attributes

NFI photo plot attributes	NFI field plot attributes
Forest polygon	Site information
– Land-cover classification	– Land cover
– Sand structure	– Plot origin
Stand layer	– Plot treatment
– Species composition	Large tree list
– Age	– Individual species description
– Height	– Volume
– Crown closure	– Growth
– Volume	– Biomass
Origin	Small tree list
Treatment	– Species
Disturbance	– Biomass
Land use	Shrub and herb
Ownership	– Species
Protection status	– Percent cover
	– Biomass
	Woody debris
	– Volume and biomass by diameter and decay class
	Soil
	– Soil features
	– Soil horizon information
	– Carbon content

The information recorded for land cover is a five-level classification, and includes land base, land cover, landscape position, vegetation type, density class, and stand structure. Vegetated treed polygons are further classified according to species composition, crown cover age, height and volume. Information on stand origin, treatment, or disturbances is also recorded.

Photo plots are delineated and classified separately for land use, ownership and protection status. Predominant and secondary categories (industrial, forestry, agriculture, conservation, infrastructure, settlement, recreation and national defence) are assigned to each land use polygon. The ownership categories include crown, private, federal, territorial, municipal and aboriginal. Protection status is assessed using the International Union for Conservation of Nature (IUCN) protection categories I to VI (Dudley and Phillips 2006). The attributes estimated from the interpretation of aerial photographs are listed in Table 4.1.

There are approximately 18,850 photo plots (1 plot per 39,000 ha). There are no photo plots located in the arctic ecozones; only overall area totals will be obtained. There will be no attempt to break the area of the arctic ecozones down by classifier.

4.3.2 Field Plots

In addition to information collected from photo plots, the NFI design calls for the establishment of 1 field plot for every 10 photo plots, with a minimum of 50

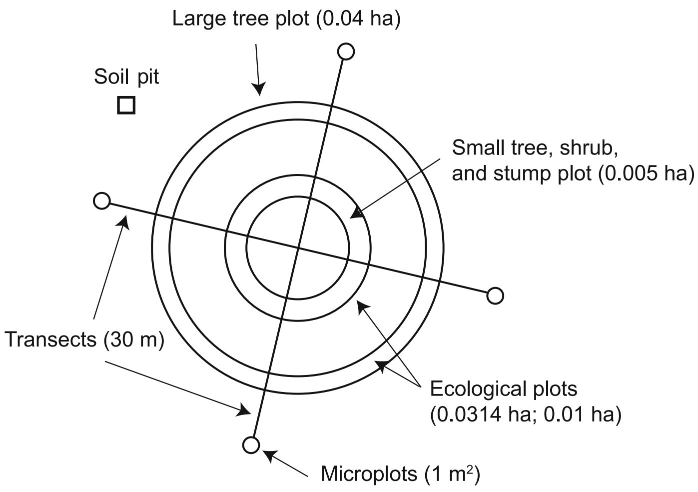

Fig. 4.4 NFI field plot design

forested field plots per terrestrial ecozone. No field samples were established in the Hudson Plains, Taiga Shield, Taiga Cordillera, Prairies, and Arctic ecozones.

Approximately 10% of the photo plot locations were selected at random for field plot sampling. The field plots were, in most cases, located at the centre of the photo plots. Whenever the randomly selected location fell on a permanently non-treed area, a substitute sample location was chosen, again at random. The non-treed locations maintain their status as NFI field plots and, although no measurements were taken, the locations were retained in the analysis. Measurements of field plots are synchronized as much as possible with the interpretation of photo plots.

The field plot design (Fig. 4.4) consists of two transects for assessing woody debris and surface substrate; four microplots for destructive sampling of understory vegetation, forest floor organic material and soils; two ecological plots for assessing biodiversity; a soil pit for describing soils according to the Canadian System of Soil Classification; a large tree plot; and a small tree, shrub, and stump plot.

Variables and data collected from field plots complement the variables and data from the photo plots. Variables measured in the field include a list of all species of plants occurring on a plot, mortality due to stresses (fire, insects, and diseases), total aboveground biomass, and mass of all woody debris. The field plots also contain information that is not normally collected in forest inventories, such as forest floor organics and soil carbon. Variables measured in the field are also listed in Table 4.1.

There are approximately 1,150 permanent field plots established in forested land across Canada (approximately 1 plot per 269,700 ha). Detailed descriptions of the NFI sample plots are available on the NFI website, including data collection guidelines, data dictionaries and compilation procedures.

4.3.3 Monitoring Strategy

The NFI is ongoing and changes will be estimated by repeated sampling of the photo and field plots. The re-measurement strategy includes a 10-year cycle and provides for periodic (5-year) reporting. The strategy is to sample plots across the entire population. With this strategy, the set of the sample plots is divided into subsets (panels), and each sample plot is systematically assigned to one panel. The main advantage of this method is that each panel represents a valid sample of the population that can be used to calculate change estimates and allows the cost to be equally distributed over time. To provide 5-year reporting, two national panels were established where one panel of photo and field plots is measured every 5 years. Plots in the other panel are monitored for major disturbances and updated as required. A representative sample is obtained by producing spatial balance within a panel where the distance between plots is maximized.

4.4 Estimation Techniques

The main objective of the NFI is to estimate area and attribute totals and their associated variances by classifier class at the terrestrial ecozone and national levels. This is achieved by estimating the totals for individual NFI units (smaller geographic units defined by ecozones within provinces or territories) by classifier class, and then summing these individual unit totals and their associated variances to the ecozone and national levels. For example, the totals from the Pacific Maritime Ecozone in British Columbia and the Pacific Maritime Ecozone in the Yukon are summed to provide totals for the Pacific Maritime Ecozone. The methods used, described in Cochran (1977), are similar to a ratio-of-means estimator, which is a biased estimator, but whose bias is usually trivial with large sample size (>30). This common approach to estimation results in consistency and ease of implementation.

4.4.1 Area Totals for Photo Plots

Area estimation methods are outlined below for a classifier class within an NFI unit. These estimation methods are applicable to any area classifier:

1. Obtain from photo plots the area classified into the *k*th classifier class in the *i*th photo plot (a_{ki}) of total plot area a_{Ti} ($i = 1, 2, 3, \ldots, n$) within an NFI unit.
2. Calculate the average proportion of area of the kth classifier class from all the photo plots within the NFI unit:

$$\hat{p}_k = \frac{\sum_{i=1}^{n} a_{ki}}{\sum_{i=1}^{n} a_{Ti}} \tag{4.1}$$

3. Estimate the variance of the estimated area proportion of the kth classifier class:

$$\hat{\text{var}}\,(\hat{p}_k) \doteq \frac{1}{\bar{a}_T^2}\left(\frac{\left[\sum_{i=1}^{n} a_{ki}^2 - 2\hat{p}_k \sum_{i=1}^{n} a_{ki}a_{Ti} + \hat{p}_k^2 \sum_{i=1}^{n} a_{Ti}^2\right]}{n(n-1)}\right) \tag{4.2}$$

4. Estimate the relative standard error (SE) (%) also called coefficient of variation, (CV) (%) of the estimated area proportion of the kth classifier class:

$$SE\,(\hat{p}_k) = \frac{\sqrt{v\hat{a}r(\hat{p}_k)}}{\hat{p}_k} 100(\%) \tag{4.3}$$

5. Obtain independently the total area of the NFI unit from GIS:

$$A = NFI\_unit\_Total\_area(\text{ha}) \tag{4.4}$$

6. Estimate the total area A_k (ha) in the kth classifier class in the NFI unit:

$$\hat{A}_k = A\hat{p}_k \tag{4.5}$$

4.4.2 Tree Attribute Totals from Photo Plots

Estimation of attributes totals based on data from photo plots is similar to estimation of area totals:

1. Obtain from the photo plots the t''_{is}, the polygon average or per-hectare values and corresponding polygon areas a_{is} (s = 1,2,3, . . ., S) from the ith photo plot of area a_{Ti} (i = 1,2,3, . . ., n). Estimate the attribute plot total, x_{ki} , for the ith plot within an NFI unit as (Note: the x_{ki} is set equal to zero if the polygon does not belong to the kth classifier class):

$$x_{ki} = \sum_{s=1}^{S} (t''_{is} a_{is}) \tag{4.6}$$

2. Calculate the estimated unit average or per-hectare value for the kth classifier class from all the photo plots within the NFI unit:

$$\bar{x}_k = \frac{\sum_{i=1}^{n} x_{ki}}{\sum_{i=1}^{n} a_{Ti}} \tag{4.7}$$

3. Estimate the variance of the estimated photo plots average or per-hectare value:

$$\hat{\text{var}}(\bar{x}_k) \doteq \frac{1}{\bar{a}_T^2}\left(\frac{\left[\sum_{i=1}^{n} x_{ki}^2 + \bar{x}_k^2 \sum_{i=1}^{n} a_{Ti}^2 - 2\bar{x}_k \sum_{i=1}^{n} x_{ki} a_{Ti}\right]}{n(n-1)}\right) \tag{4.8}$$

4. Estimate the relative standard error of the estimated average or per-hectare value for the kth classifier class:

$$SE(\bar{x}_k) = \frac{\sqrt{v\hat{a}r(\bar{x}_k)}}{\bar{x}_k} 100(\%) \tag{4.9}$$

5. Estimate the photo-based total in the kth classifier class in the NFI unit:

$$\hat{X}_k = A\bar{x}_k \tag{4.10}$$

4.4.3 Estimates from Field Plots

The approach to estimating attribute averages or totals for a classifier class in an NFI unit is similar to that for estimating tree attributes from photo plots. That is, we post-stratify the field plots into a classifier class, estimate the population average (per hectare) in the classifier class, and then multiply this estimated average by the land area of the NFI unit. The formulas are similar to Eqs. 4.6–4.10, except that field plot areas are used in place of photo plot areas and polygon areas. Attributes estimated in this way from field plots not only include tree attributes, but also estimates of downed coarse woody debris, soil carbon content, and surface substrate material.

Estimates can also be calculated using data from various combinations of photo plots, field plots and auxiliary information (e.g., satellite imagery) if certain pre-conditions and assumptions are met, but this requires somewhat more complex estimation techniques. Changes to the above methods also are required if there are missing plots or the sampling design or sampling density changes within a NFI unit. These involve more complex equation forms or weighting procedures, most of which are derived from Cochran (1977).

4.4.4 Change Estimation

The main objective is to estimate periodic change in area and other attribute totals and their associated variances, by classifier class at the ecozone and national levels. The estimated periodic change in the area total for a classifier class is obtained by multiplying the estimated periodic change in proportion of area in a given classifier class (based on photo plots) by the known NFI unit total area. Similarly, the estimated periodic change in tree or other attribute totals is obtained by multiplying the estimated average or per-hectare periodic change in a classifier class by the total area of the NFI unit.

For example, the estimated change in area proportion can be obtained by calculating the change in area of a classifier class (Δa_{ki}) and substituting this, and change in proportion ($\Delta \hat{p}_{tk}$), into Eqs. 4.1–4.5.

The change estimation techniques necessarily get more complex depending on the sequence of plot measurement over time and if changes or updates in NFI plots are based on modelled data. In this case, rather complex mixed estimation techniques can be implemented (Van Deusen 1996). This is a summary of the core set of estimation methods. All of the information on Canada's NFI sampling scheme and the complete set of estimation techniques and their variations can be obtained from the NFI website.

4.5 Governance

In Canada, the federal government is committed to provide science and programs to support policy initiatives. On behalf of other jurisdictions, it takes a leadership role to provide information on Canada's forests to national (Canadian Council of Forest Ministers 2009) and international inquiries (such as the FAO Forest Resources Assessment and reports on climate change). Management of Canada's forest lands is primarily a provincial and territorial responsibility. Successful collaboration between the provincial and territorial jurisdictions and the federal government is essential to a credible national forest inventory.

The NFI is implemented through the CCFM. Currently,

- Information and Knowledge Working Group approves work plans for the re-measurement of the sample plots and the dissemination of NFI data and information
- NFI Task Force develops work plans, oversees implementation, and provides guidance and technical direction
- NFI Project Office, supported by Natural Resources Canada – Canadian Forest Service, manages the NFI by

  – Developing the standards and procedures for data collection
  – Coordinating the operational field implementation

– Conducting analysis and reporting
– Provinces and territories are responsible for developing work plans and collecting and providing data.
– The CCFM National Forest Information System provides infrastructure for data storage, management and delivery.

The NFI Project Office is comprised of six permanent and three support employees. These include a manager; a forest inventory specialist, who leads the analysis, supported by an analyst; an information management specialist supported by two system developers; two foresters who coordinate the field component (photo and field plots); and one geo-spatial analyst. The Project Office receives part time research and analysis support from scientists within the Canadian Forest Service. Data collection is the responsibility of the provinces and territories. Approximately 150 permanent or temporary staff or forestry consultants across Canada are involved in the data collection component of the NFI, including quality assurance.

4.6 Future Prospects

The NFI has been established through a joint effort by federal, provincial and territorial governments. The baseline data are being analyzed and initial results released in 2009. However, it is a static picture of the current state – without an ongoing re-measurement of field and photo plots, so any changes to the forest in terms of area, volumes, disturbances, carbon, or land use over time cannot be tracked. This means that we cannot track progress towards sustainable forest management on a national scale using the CCFM Criteria and Indicators, nor report internationally to organizations like the FAO on how our forests have increased or decreased in area over time. A re-measurement strategy and framework that would enable Canada to estimate change has been developed, but the funding for re-measurement has not been fully identified.

The long-term goals of the program are as follows:

- To secure and maintain commitment from federal, provincial and territorial collaborators on the implementation of the NFI following a 10-year inventory cycle and a 5-year re-measurement and reporting strategy
- To implement the 5-year re-measurement strategy to estimate how the extent and state of Canada's forests are changing over time
- To increase client satisfaction through timely reporting and by making information publicly accessible on the NFI website
- To increase collaborator participation through increased alignment with provincial and territorial forest inventory and monitoring programs
- To increase efficiency through improved data capture and analysis approaches

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Chapter 5
China

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5.1 Development of China's National Forest Inventory

The rate of change in China's forests is significant and may occur over short periods due to nation-wide reforestation and afforestation activities, implementation of key forestry programs, active silvicultural management, the impact of natural disturbances (e.g. snow and ice disasters) and forest policies. The National Forest Inventory (NFI) serves as a powerful information resource and a tool for forestry and related decision making policies, as well as for regional, national, and international forest statistics. In China, data is collected from systematically distributed permanent sample plots in the field every five years. Each province constitutes a separate sampling unit. The seven NFIs (NFI1 from 1973 to 1976, NFI2 from 1977 to 1981, NFI3 from 1984 to 1988, NFI4 from 1989 to 1993, NFI5 from 1994 to 1998, NFI6 from 1999 to 2003 and NFI7 from 2004 to 2008) have been continuously updated and upgraded.

NFI1 was implemented with county or forest management units as a basic unit (Xiao 2005). Most provinces used a random sampling method to select temporary sample plots, but sub-compartment survey methods were also employed (MOF 1977). Data for all counties and state forest enterprises were aggregated to generate provincial statistics that were subsequently aggregated to generate national statistics. The continuous inventory system based on systematic sampling with permanent sample plots was established in most provinces during NFI2 (MOF 1983) and is still used. The sampling unit used in the most provinces is a single plot. Sample size was determined in each province which was regarded as a population. Fixed

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area plots are used for most provinces. The shapes of plots are rectangular or square with sizes ranging from 0.0667 ha (one Chinese mu or 667 m^2) to 0.08–0.1 ha. Uniform guidelines on inventory variables, techniques, accuracy and output were produced in 1982 for nation-wide consistency of inventory methods and standards (MOF 1982). In the modified technical standard in 1994 (MOF 1994), the NFI period was clarified as five years from the NFI4 (MOF 1996). Inventories will be conducted in one fifth of the provinces every year. A new sampling design was tested in Jiangxi Province within the United Nations Development Programme (UNDP) supported project CPR/91/151 from 1993 to 1997 (UNDP 1998), which was called two-stage sampling for stratification.

The combination of remote sensing and field investigation proved to be efficient and more accurate in terms of area estimates. This new sampling design was widely adopted during the NFI6 (SFA 2005). Landsat5-TM and Landsat7-ETM are the most applicable remote sensing data source for the NFI. In the newly released national technical guideline for the NFI7 (SFA 2004), the number of variables assessed increased, and more attention is being paid to ecological parameters such as the status of forest health, ecosystem diversity, forest disturbances, and forest functions. Table 5.1 shows the development of NFIs (MOF 1977, 1983, 1990, 1996; SFA 2000, 2005; Xiao 2005)

The Department of Forest Resources Management of the State Forestry Administration (SFA) administers the NFI. The NFI is implemented by inventory institutions at various levels, which include the National Central Forest Inventory Institute with the Northeast Forest Inventory Centre in Beijing, four other regional centres and provincial forest inventory institutes. These institutes include the entire forest inventory network. Regional institutes are responsible for examining the working plan, technical guidelines, quality control, data analysis, and resulting reports of the NFI in their respective provinces. Specific surveys are conducted by the provincial inventory institutes. The output is officially released by SFA every 5 years.

Table 5.1 National forest inventories in China

Inventory	Years	Method	Number of field plots	Number of RS plots
NFI1	1973–1976	Random sampling method, temporal plots	–	–
NFI2	1977–1981	Systematic sampling using permanent and temporal plots	140,000	–
NFI3	1984–1988	Systematic sampling using permanent and temporal plots	256,000	–
NFI4	1989–1993	Systematic sampling using permanent and temporal plots	184,479	90,227
NFI5	1994–1998	Two-stage stratified sampling	227,200	106,300
NFI6	1999–2003	Two-stage stratified sampling	415,000	2,844,400
NFI7	2004–2008			

5.2 The Use and Users of the Results

5.2.1 General Use

The NFI serves as a powerful information source and tool for forestry and related policy decision making and strategic planning at provincial, regional and national levels, and traces changes on increment and cutting. The forestry land classification system in China is listed in Table 5.2. However, the NFI also covers land cover classes that include deserts and wetland, so it generates information on wetland protection and efforts to mitigate desertification. The information on forest resources is released by Forest Resource Statistics or news conferences. It also provides country reports for international organizations such as the United Nations Food and Agriculture Organization (FAO) Forest Resources Assessment process (FRA 2008), Global Bamboo Resources Assessment (International Network for Bamboo and Rattan 2009), biodiversity conservation report for (IUCN 2009) and sustainable forest management report for Montréal process (The Montreal Process 2009). Therefore, users of inventory data include forestry and environmental policy makers, forest managers, forest industry decision makers, research scientists, and international organizations.

5.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

China released its Initial National Communication on Climate Change in 2004 which is stipulated by the United Nations Framework Convention on Climate Change (UNFCCC) (PRC 2004). It reported the 1994 national greenhouse gas

Table 5.2 Forestry land classification system in China

Level I	Level II
Forested land	Arbor forest
	Mangrove forest
	Bamboo forest
Open forest	
Shrub land	Special shrub land
	Other shrub land
Unclosed forest	Young plantation
	Natural regeneration land
Nursery	
Non-forested land	Cutover land
	Burnt land
	Others
Forest suitable land	Wild land suitable for afforestation
	Sand land for afforestation
	Others

inventory where land use changes and forestry was included. The greenhouse gas inventory of Land Use, Land-Use Change and Forestry (LULUCF) mainly covers changes in forest and other woody biomass stocks, including the removals of carbon dioxide due to the growth of living trees (forests, open forests, scattered trees and "four-sides trees" – trees growing in the house side, village side, roadside and waterside), bamboo stands and commercial stands, and carbon dioxide emission caused by biomass loss in forests, and carbon dioxide emission caused by conversions of forest land to other land classes. The NFI and annual forest resource monitoring provides basic information on land use and land use change, changes in forestry and ecological preservation and declaring land for construction. It also provides useful information for the national action plan on climate change which was issued in 2007.

5.2.3 The Role of NFI in Assessing the Status of Biodiversity

Generally, the NFI produces information on the number and distribution of forest types and tree species. China has numerous types of forest, boasting a variety of conifer forest, mixed forest of conifer and broadleaved trees, deciduous forest, broadleaved evergreen forest and tropical forest, and their various secondary types. According to the classification system adopted in the "Vegetation of China" (Wu 1980) there are 210 forest formations, 36 bamboo forest formations and 94 shrub, or bush formations (with the exception of semi-shrub and herb formations), in China. There are about 2,000 species of trees and 6,000 species of shrubs in China which include floral components with global, tropical, temperate, pan-Mediterranean and Chinese native distributions. The investigation of ecosystem diversity has been introduced in the guidelines for the NFI7 (2004–2008), and species diversity investigation was also advocated if possible. The main items include area and proportion of forest or vegetation types by age class and measures that could be formulated using the Shannon and Simpson indices. This information provides data source for China's national report on implementation of Convention on Biological Diversity (2009).

5.3 Current Estimates

The definitions of the basic concepts employed in the Chinese NFI are given in Tables 5.3a and b together with the basic area, volume and increment estimates for years 1999–2003 (NFI6). Unfortunately, the standard errors are not available.

NFI is main information source for the following carbon pool change estimates: above-ground biomass, below-ground biomass, dead wood, litter, soil organic matter (litter and soil, NFI together with models and flux measurements).

Table 5.3a Basic area estimates from years 1999–2003 (NFI6)

Quantity	Estimate (1,000 ha)	Share (%)	Description
Forest land	174,909.2	18.21	Forest land of arbour species spanning more than 0.0667 ha with a crown cover of more than 20%
Other wooded land	107,894.2	11.24	
Other land	675,080	70.32	
Forest land in UNFCCC LULUCF reporting	174,909.2	18.21	
Forest land	174,909.2	18.21	Forest land of arbour species spanning more than 0.0667 ha with a crown cover of more than 20%
Open forest land	5,999.6	0.62	Land of arbour species with crown cover of which is between 0.10 and 0.19, and more than 0.0667 ha in size
Shrub land	45,296.8	4.72	Canopy cover ≥30% with purpose of shrub land or protection forest
Unclosed forest	4,893.6	0.51	Areas under afforestation that are temporarily un-stocked areas, but can reach the thresholds of forest land during 4 years; and size is more than 0.0667 ha
Nursery land	270.9	0.03	Land for seedling production
Non-forested land			Cut-over area, burnt land and other non-stocked land
Forest suitable land			Wild land suitable for afforestation, sand land for afforestation and others
Forestry roads (national)			
Forestry land	282,803.4	29.46	
Other			
Total Land Area	960,000	100	

Table 5.3b Basic volume estimates from years 1999–2003 (NFI6)

Quantity	Estimate	Description
Growing stock volume on forest land (million cubic metre)	12,456	
Growing stock volume per hectare on forest land (m^3/ha)	84.73	Volume of growing stock on forest land excludes non-timber product forest and national prescriptive shrub land divided by forest land, excludes non-timber product forest and national prescriptive shrub land
Annual increment of growing stock of trees on forest land and other wooded land	497,000	
Annual increment of growing stock of trees per hectare on forest land (ref. def) (m^3/ha per year)	3.55	
Annual drain on FOWL, average 2001–2005	365	
Dead wood volume (million cubic metre)		Minimum length, 1.3 m; minimum diameter, 10 cm
Carbon in above-ground biomass[a] ($Pg=10^{15}g$)	4.636	
Carbon in below-ground biomass[a] ($Pg=10^{15}g$)	1.460	
Carbon in dead wood[a] ($Pg=10^{15}g$)	0.918	

[a]Carbon data is for the year 2005 (FAO 2005).

5.4 Sampling Design

Systematic sampling was the main method in the NFI. Two-stage sampling for stratification has been widely adopted since the NFI6. The sample size for field plots was determined in each province which was regarded as a population. The pattern and number of remote sensing plots are determined by the density and pattern of field plots. The number of remote sensing plots is specified as no less than four times the number of field plots (Zhang and Wang 2007).

5.4.1 Sample Plots

Fixed area plots are used for most provinces. The shapes of plots are rectangular or square with sizes ranging from 0.0667 ha (one Chinese mu) to 0.08–0.1 ha. Concentric or cluster plots were used for some provinces. For example, two concentric circular plots with a radii of 14.57 m (trees with diameter at breast height, *dbh*, $\leq$ 40 cm) and 25.23 m (trees with *dbh* $>$ 40 cm) were used in Tibet whereas four plot clusters were used for the plain subpopulation in Henan Province, and five plot clusters were used for the plain subpopulation in Hubei Province.

The first inventory system on forest resources and ecological status was attempted in Guangdong Province in 2002 covering biomass, carbon storage, the state of forest health, the state of forest naturalness, biodiversity, soil erosion, and soil fertility as well as conventional variables such as area and volume (Wang 2004). In the newly released national technical guidelines for the NFI7 (SFA 2005), the number of variables measured or recorded increased to 70 from 35 in 1994 (Table 5.4). More attention is being paid to ecological variables such as the state of forest health, ecosystem diversity, forest disturbances, and forest functions. All trees with *dbh* $>$ 5 cm will be numbered to identify them for re-measurement. *Dbh*s of all trees and heights of approximately four to five selected trees will be measured. Azimuths and distances of all trees will also be recorded for stem mapping.

Table 5.4 Main variables surveyed in NFI plots in China

Sampling components	Variables assessed on field plots
Land use and cover	Land use type, vegetation type, forest function type
Site and soil	Elevation, aspect, slope, slope position, soil type, soil depth, humus depth, litter depth
Stand characteristics	Tree species (group), origin, age, age class, crown cover, mean *dbh*, mean tree height, stem density, stand volume, community structure, stand storey, naturalness, accessibility, vegetation cover, shrub cover, mean shrub height, herb cover, mean herb height
Ecological state	Wetland type, desertification type, forest health class, forest disaster
Others	Location, plot number, land tenure, forestry program type, plot type, land-use change reason

For remote sensing plots, ecological variables such as vegetation type, state of naturalness, biodiversity, the state of forest health, wetland type, and desertification type have been introduced in the ongoing NFI7.

5.4.2 Management

5.4.2.1 Personnel and Equipment

The NFI is conducted in one fifth of the provinces each year. For example, NFI8 will be initiated in Jilin, Shanghai, Zhejiang, Anhui, Hubei, Hunan and Shanxi provinces in 2009. Forest inventory institutes at different levels are involved in the inventory, but staffs from provincial institutes are the main forces that have to be trained before the inventory begins. Approximately 20,000 persons participated in NFI6.

Global positioning system (GPS) receivers are used for locating the plots. Handheld computers or personal digital assistants along with GPS devices and professional inventory software have gradually been introduced in fieldwork since NFI6 from 1999 to 2003. This equipment can display, record, and annotate maps directly in the field and reduce manual errors while facilitating data recording and quality control.

5.4.2.2 Quality Assurance

The NFI guidelines provide the standards for the organization, number, content, and evaluation of quality checks to ensure the quality of resource statistics generated through NFIs. Inventory institutes at different levels have their own quality control divisions. Regional forest inventory institutes are responsible for reviewing the quality of forest inventory work by their own inventory teams and by provincial inventory institutes. Similarly, provincial forest inventory institutes review the quality of the work conducted by their inventory teams and others. The quality control teams assess the preparation before the NFI as well as the quality of fieldwork and in-house data processing. The preparation work covers technical scenarios, operational guidelines, field tables, equipment, and training. Field work checks have been implemented by sampling 5% and 1.5% of field sample plots for provincial and regional levels, respectively, and there have been at least 20% of field sample plots for overlap. All inventory records are reviewed. The guidelines specify the tolerance errors for measured items. When the quality control team found quality standards were not met, the sample plots had to be re-measured. The final quality assessment is summarized using weights of 70% and 30% for field and in-door work, respectively.

5.5 Estimation Techniques

The estimation methods presented here are given in SFA (2005) and Xiao (2005).

5.5.1 Area Estimation

Area is estimated by the following equations based on the systematic sampling method:

$$p_i = \frac{m_i}{n} \tag{5.1}$$

$$S_{p_i} = \sqrt{\frac{p_i(1-p_i)}{n-1}} \tag{5.2}$$

where n is the total number of plots, m_i is the number of plots for land use type i, the land types include vegetation types, forest types and other land use types. p_i is the sample proportion of land use type i, S_{pi} is the standard error of the sample proportion of land use type i.

$$\hat{A}_i = A \cdot p_i \tag{5.3}$$

where $\hat{A}_i$ is the estimated area of land use type i, A is the total land area.

$$\Delta_{A_i} = A \cdot t_\alpha \cdot S_{p_i} \tag{5.4}$$

where Δ_{p_i} is the error limit of the estimated area of land use type i. and t_a is a t-value. The confidence interval of the area of land use type i is: $\hat{A}_i \pm \Delta_{A_i}$.

$$P_{A_i} = \left(1 - \frac{t_a \cdot S_{p_i}}{p_i}\right) \cdot 100\% \tag{5.5}$$

where, P_{A_i} is the sampling precision of the estimated area of land use type i.

5.5.2 Volume Estimation

The mean volume value (average volume) of land use type i is:

$$\overline{V_i} = \frac{1}{n}\sum_{j=1}^{n} V_{ij} \tag{5.6}$$

where, V_{ij} is the volume at plot j for land use type i.

The sample variance is calculated as:

$$S_{V_i}^2 = \frac{1}{n-1}\sum_{j=1}^{n}\left(V_{ij} - \overline{V_i}\right)^2 \tag{5.7}$$

and

$$S_{\overline{V_i}} = \frac{S_{V_i}}{\sqrt{n}} \tag{5.8}$$

The volume estimate for land use type i is:

$$\hat{V}_i = \frac{A}{a}\cdot\overline{V_i} \tag{5.9}$$

where A is the total area, a is plot area, $\hat{V}_i$ is the estimated volume of land use type i.

The error limits of the volume estimate are

$$\Delta_{V_i} = \frac{A}{a}\cdot t_\alpha\cdot S_{\overline{V_i}} \tag{5.10}$$

where t_α is reliability index, estimation interval of the total volume is: $\hat{V}_i \pm \Delta_{V_i}$ sampling precision:

$$P_{V_i} = \left(1 - \frac{t_\alpha\cdot S_{V_i}}{\overline{V_i}}\right)\cdot 100\% \tag{5.11}$$

5.5.2.1 The Volume Increment and Its Estimated Accuracy

- The estimated average net volume increment of the permanent sample plot:

$$\bar{\Delta} = \overline{V_2} - \overline{V_1} \tag{5.12}$$

where $\overline{V_1}$, $\overline{V_2}$ are the average volumes of the first and second occasions.

- The variance estimate of the net volume increment:

$$S_\Delta^2 = S_{V_2}^2 + S_{V_1}^2 - 2RS_{V_2}\cdot S_{V_1} \tag{5.13}$$

where $S_{V_2}^2$, $S_{V_1}^2$ are the volume variance of the first and second occasions, R is the correlation coefficient of the two occasions.

The standard error of the average net volume increment:

$$S_{\bar{\Delta}} = \frac{S_{\Delta}}{\sqrt{n}} \tag{5.14}$$

Correlation coefficient:

$$R = \frac{S_{V_1 V_2}}{S_{V_1} \cdot S_{V_2}} \tag{5.15}$$

The estimated value of the total volume increment:

$$\Delta_{tvi} = \bar{\Delta} \cdot \frac{A}{a} \tag{5.16}$$

where A is the total area and a is plot area.

The error limitation of the estimated value of the total volume increment:

$$\Delta_{\Delta_{tvi}} = t_{\alpha} \cdot S_{\bar{\Delta}} \cdot \frac{A}{a} \tag{5.17}$$

where t_{α} is reliability index, estimation interval of the total volume increment is: $\Delta_{tvi} \pm \Delta_{\Delta_{tvi}}$ sampling precision:

$$P = \left(1 - \frac{t_{\alpha} \cdot S_{\bar{\Delta}}}{|\bar{\Delta}|}\right) \cdot 100\% \tag{5.18}$$

where, t_{α} is reliability index, is the sampling precision $P < 0$, then let $P = 0$.

Test statistic:

$$t = \frac{|\bar{\Delta}|}{S_{\bar{\Delta}}} \tag{5.19}$$

if $t > t_{2\alpha}(t_{2\alpha} = 1.645$ when $\alpha = 0.05)$ we can determine whether or not the volume of second accession is increased according to $\bar{\Delta}$ value; if $t \leq t_{2\alpha}$, we can determine that there is no significant differences of the volume of two occasions, they are nearly the same.

5.5.3 Increment Estimation

Estimation of the increment of the volume of the growing stock and its reliability is presented in this section.

The average growth of the plot:

$$\bar{g} = \frac{1}{n}\sum_{j=1}^{n} g_j \tag{5.20}$$

$$\bar{g}_i = \frac{1}{n}\sum_{j=1}^{n} g_{ij} \tag{5.21}$$

where, g_j is the growth of plot j, g_{ij} is the growth of plot j land use type i, $\bar{g}_i$ is the average growth value of land use type i.

Total growth estimate:

$$\hat{G} = \bar{g} \cdot \frac{A}{a} \tag{5.22}$$

$$\hat{G}_i = \bar{g}_i \cdot \frac{A}{a} \tag{5.23}$$

where, $\hat{G}_i$ is the growth value of land use type i.

Total growth rate:

$$P_{\hat{G}} = \frac{\hat{G}}{(V_1 + V_2)} \cdot \frac{2}{t} \tag{5.24}$$

where, t the interval of the two occasions ,V_1, V_2 are the total volume of the first and second occasions.

Standard deviation, error and estimation accuracy:

$$S_g = \sqrt{\frac{\sum\left(g_j - \bar{g}\right)^2}{n-1}} \tag{5.25}$$

$$S_{\bar{g}} = S_g/\sqrt{n} \tag{5.26}$$

$$P_{\bar{g}} = \left(1 - \frac{t_\alpha \cdot S_{\bar{g}}}{\bar{g}}\right) \cdot 100\% \tag{5.27}$$

where, t_α is reliability index, n is plot number.

The calculation method of the standard deviation, error and sampling precision of others growth are the same.

5.5.4 Drain Estimation

The average drain of the plot is

$$\bar{c} = \frac{1}{n}\sum_{j=1}^{n} c_j \tag{5.28}$$

$$\bar{c}_i = \frac{1}{n}\sum_{j=1}^{n} c_{ij} \tag{5.29}$$

where, c_j is the drain of the plot j, c_{ij} is the drain of the plot j, land use type i, $\bar{c}_i$ is the average consumption of land use type i.

The total drain is:

$$\hat{C} = \bar{c} \cdot \frac{A}{a} \tag{5.30}$$

$$\hat{C}_i = \bar{c}_i \cdot \frac{A}{a} \tag{5.31}$$

where $\hat{C}_i$ is the estimated drain of land use type i.

Drain rate:

$$P_{\hat{C}} = \frac{\hat{C}}{(V_1 + V_2)} \cdot \frac{2}{t} \tag{5.32}$$

where, t the interval of the two occasions ,V_1, V_2 are the total volume of the first and second occasions.

Standard deviation, standard error and sampling precision:

$$S_c = \sqrt{\frac{\sum (c_j - \bar{c})^2}{n-1}} \tag{5.33}$$

$$S_{\bar{c}} = \frac{S_c}{\sqrt{n}} \tag{5.34}$$

$$P_{\bar{c}} = \left(1 - \frac{t_\alpha \cdot S_{\bar{c}}}{\bar{c}}\right) \cdot 100\% \tag{5.35}$$

The calculation method of the standard deviation, standard error and sampling precision of others consumption are the same.

5.6 Options for Estimates Based on Reference Definitions

Table 5.5 presents a brief summary of the status of harmonization. Note that forest is assessed in the field on the basis of both national definition and FAO FRA 2005 definition which is near COST Action E43 reference definitions. Tree level measurements for volume estimates and volumes correspond to the reference definition.

Table 5.5 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	ND ≠ RF, both are employed in the field
Growing stock volume	Yes	Yes	NFI	ND = RF
Above-ground biomass	No	No	NFI, models	ND = RF
Below-ground biomass	No	No	NFI, models	ND = RF
Dead wood volume	Yes	Yes	NFI	ND = RF
Dead wood volume by decay stage classes	No	No		ND = RF
Afforestation Deforestation Reforestation (Kyoto 3.3)	Yes	Yes	NFI, statistics	ND = RF
Forest type	Yes	Yes		Can be derived from NFI data

The national definition of forest type describes site fertility. The reference definition forest type can be derived from other variables.

5.7 Current and Future Prospective

Although China has already developed an integrated forest inventory system that provides valuable information for forest resource statistics, macro-decision making, and national and international reporting, it still faces several challenges from expanding information requirements at both national and international levels as well as corresponding expanding requirements for improving inventory techniques (Lei et al. 2009).

5.7.1 Continuing Challenges

5.7.1.1 Expanding Information

The need for improved forest resource information is growing at both national and international levels and is driven by concerns about the environment (biodiversity, global climate change, and desertification, for example) and forest management issues (sustainable forest management, non-timber products and functions, harvesting, and protection). China attaches great importance to global environmental issues and has signed important international treaties and conventions related to forests such as the Convention on Biological Diversity, the United Nations Convention to Combat Desertification (UNCCD), the RAMSAR Convention on Wetlands, the UN Framework Convention on Climate Change, and the Kyoto Protocol. International organizations require countries to provide updated and reliable information on forests and forestry, one example being the FAO's State of the World Forest and Global Forest Resources Assessment. Forest inventory must, therefore, satisfy the increasing information demands of both national and international communities.

China's forestry development strategy has expanded from timber production to promoting protection of existing natural forests and the restoration of degraded forest ecosystems. China launched the Three-North Shelterbelt Program in 1978 and several key forestry programs since 1998 that play a significant role in improving ecological conditions, facilitating agriculture and rural development while increasing the incomes of farmers. This contribution to development progress and subsequent benefit to the entire country should be assessed for macro policy making decision. To meet the goals of sustainable forestry and sustainable forest management, the nation is required to increase its monitoring efforts. More variables must be measured across larger spatial and temporal scales than in the past. China is launching a new nationwide forest tenure reform in collective-owned forest regions that will clarify, strengthen, and secure forest land use and tenure rights, tree utilization rights, and responsibilities of households. The longest period for contracted forest land management rights is 70 years. This will be a trigger for sustainable forest management and sustainable rural development.

The current forest inventory system cannot fully satisfy the new information requirements, particularly on ecological states and processes. Additionally, data is often collected for the sake of data collection while less effort is made towards further processing and analysis with the exception of forest area, volume of growing stock, increment, and harvest. The translation of data into information is not yet good enough to facilitate planning, management, and the formulation of policies. For example, although permanent sample plot data is the best option for establishing growth and yield models, it is not widely used nor is it updated in a timely fashion in China. Both broader data collection and deeper data analysis are therefore needed.

5.7.1.2 Inventory Methods and Techniques

Although the forest inventory system has been continuously improved, gaps still exist and much remains to be done. China's NFI system was developed to collect information on forest area and on growing stock. New features such as forest ecosystem diversity, the state of forest health, and ecological functions were gradually added, but the system could be improved to provide more information on ecological states and functions such as biodiversity, carbon sequestration, soil and water conservation, and the state of forest health. Because each NFI is conducted in approximately one fifth of the total number of provinces each year, national data is produced by aggregating forest resources data of all provinces for different years. Consequently, inventory data ages differ within the inventory database itself. For example, at the time the country report is published, the inventory data is already 5 years old for those provinces that were surveyed in the first year of the NFI. The periodic NFI makes the immediate estimates of the effects of catastrophic events such as ice storms, typhoons, fire, and insect infestations invalid while at the same time it is difficult to meet the needs of rapid forest change results from the point of implementation of forestry programs to the report on the State of World's Forest (FAO 2009) published every 2 years.

A further problem is the lack of a link between the NFI system and other national forestry systems such as the forestry program inventory, the desertification inventory, the wetland inventory, and the wildlife and plant inventory. The latter systems are not within the same sampling frameworks as NFI. There are also overlaps and inconsistencies in variables, techniques, and technical standards. Although the NFI adapts two-stage stratified sampling with remote sensing plots and field plots, the pattern and number of remote sensing plots are determined by the density and pattern of field plots. The number of remote sensing plots is specified as no less than four times the number of field plots. Precision and accuracy of image interpretation were not as good as expected being insignificantly higher than the systematic sampling produced by NFI6 in Hunan, Hubei, Guizhou, and Guangxi provinces (Zeng 2004). Remote sensing primarily contributes to spatially mapping forests except for area and volume estimations in inaccessible regions within Tibet, Xinjiang, Qihai, and Gansu provinces. It is therefore concluded that remote sensing plots are used inefficiently. China is one of the few countries to adopt the one separate plot method as a sampling unit in most of its provinces and consequently has suffered from lower investigation and information deficiency. The need to harmonize forest information at an international level is also growing to make estimates of current status and trends of forest resources among nations directly comparable (Vidal et al. 2008).

5.7.2 Potential Improvements

The scope of forest inventory has broadened with the change in the role of forests and forestry development. New variables, variable causal factors and inventory tools, techniques, and systems have been introduced to address both national needs and the need for common reporting on an international level. Because all forest related data collection is primarily implemented by forest inventory institutes, the segregation and inconsistency among forest related inventories (e.g., the NFI, the wild animal and plant inventory, the wetland inventory, and the forestry program inventory) should possibly be replaced at a national level by better integration and harmonization. The future system may incorporate comprehensive variables in a uniform and harmonized sampling design. Integration will be complicated and difficult since none of single inventory designs is appropriate to be applied to all inventories (Leech 1998), but the potential to integrate sampling methods, data standards, and data sources exist. Multiple stage sampling is a good way to combine remote sensing and field observation as well as different inventory systems. Many possibilities exist to improve the accuracy for some estimates in the NFI (e.g., stem volume and tree species classification) by combining remote sensing data with field data or combining data from different sensors (e.g., hyper-spectral imagery and LiDAR). Statistically sound estimation methods are still needed based on current two-stage post stratification sampling to increase the precision of large area inventory estimates. However, most attributes cannot be estimated to an acceptable level of accuracy using remote sensing data (Landsat TM, for example) for the NFIs in China, and therefore field assessments continue to be the primary option for the foreseeable future. Because China has an evolving but continuous and statistically reliable permanent sample plot inventory system, great possibility and potential exists to add new types of information to what is being collected in the form of plant species diversity, forest regeneration, the state of forest health, dead wood and wood debris, and soil organic carbon. Further, given that field sampling is the preferred approach to forest inventory while access is often arduous, the benefits from the considerable effort to reach field sample locations should be maximized by also collecting data on many variables while being there. Clustered plots or compound plots are a good way to facilitate this approach. For example, a guideline on biomass model development for NFI has been proposed in NFI8 (2009–2013).

The conversion from a periodic to an annual inventory has the potential to provide updated information, meet the requirements of information gathered in a timely fashion, and vary the reporting periods of the independent national inventories and those by international organizations. Random, systematic, and block designs on the selection of annual inventory plots can be tested (Liu 2006). Further, it is possible to link the NFI (Level I inventory) with the forest management planning inventory (Level II inventory) in the same year by applying an annual forest inventory. Growth modelling is also an option to realize the updating procedure at least in part (Ge et al. 2004). New enhanced sampling designs should be tested before application. More attention should be given to data analysis to enrich the inventory output that will not only produce information on conventional variables such as area and volume but also on ecological variables such as biomass, carbon stock, soil and water conservation, and recreation. Models on forest growth and yields as well as biomass and carbon accounts that are particularly based on NFI and permanent sample plot data are necessary. Users that require forest information should have open and easy access to data to ease the flow of these services to the society in general.

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Chapter 6
Croatia

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6.1 Introduction

Croatia extends through the Dinaric, Pannonian and Adriatic regions. The total land area is 5,659,400 ha plus 3,106,700 ha of sea area. Due to the variability in topography, climate and vegetation, Croatian habitats have great ecological diversity with more than 5,000 plant species. Forests are the dominant natural vegetation type and cover approximately 37% of the land area; broadleaved forests cover approximately 80% of forest land, coniferous forests cover approximately 13%, and mixed forests cover approximately 7%. More than 60 forest associations and 59 tree species range from lowland flooded forests, mountain forests, and characteristic evergreen maquis in the Mediterranean region. Dominant tree species are Common beech (*Fagus silvatica* L.), Pedunculate and Sessile oak (*Quercus robur* L. and *Q. petraea* (Matt.) Liebl.), Silver fir (*Abies alba* Mill.), Common hornbeam (*Carpinus betulus* L.) and Narrow-leaved ash (*Fraxinus angustifolia* Vahl.).

Forest inventory and management legislation in Croatia extends back to the eighteenth century. Close-to-nature management has been used following sustainability and naturalness ideas. Therefore, more than 95% of forests are modified natural (natural with human influence) and semi-natural. Most forests (approximately 85%) are even-aged with regular management and the remainder, including Silver fir, are uneven-aged forests managed for selective harvesting.

Forests are mostly state-owned (81%), and are managed by the state-owned company "Hrvatske šume" ("Croatian forests") Limited. The entire country is divided into 16 Forest Administrations and 171 Forest Offices. According to estimates, approximately 10% of forest areas are inaccessible because of landmines left from the war in the 1990s.

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Forest is defined by Croatian Forest law as land with tree cover occupying areas greater than 0.1 ha. The Croatian definition of the broad term 'Forest land' includes both 'forest' as defined before and also 'other forest land'. 'Other forest land' includes all areas that are potentially appropriate and planned for growing forests and would mostly be included in forest as defined in the Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (e.g. FAO 2006). 'Other forest land' is often mistaken as 'other wooded land'; however, there is no category that would match 'Other wooded land' as defined by FRA.

For the Croatian National Forest Inventory (CRONFI), a minimum size of 0.5 ha consistent with FRA definition is used. Forest land includes forest nurseries and seed orchards inside forests, smaller openings, protected forests, and shelterbelts larger than 0.1 ha and wider than 20 m. Separate forest tree groups, forest nurseries outside forests, wind shelterbelts narrower than 20 m, tree alleys and parks inside the settlements are not considered forests.

6.2 History of Forest Inventory in Croatia

The first forest area mapping and structure estimates date back to the eighteenth century, while organized forest inventory in Croatia dates to the end of the nineteenth century when inventory methods and management plans were prescribed by law. The Control method of continuous inventory and management was introduced in 1931 for selection forests, but was never accepted because of its complexity: total census of all trees with diameter at breast height (*dbh*) > 20 or 30 cm, depending on management objectives, and 5–10% sampling intensity in extensively managed stands every 10–15 years. In 1937, sampling using 20-m wide strips with the proportion of the measured area of 2–10% depending on stand size was prescribed for trees with *dbh* > 10 cm.

After World War II, inventories for management plans were prescribed for all forests in the country regardless of ownership. The inventories featured sampling with the proportion of the measured area of 2–10% for trees with *dbh* > 10 cm, strips 5–20 m wide, quadratic or circular plots of 50–2,000 m^2 depending on stand type and age, height measurements, and total censuses for mature stands at the time of felling. Stands younger than 40 years were not measured. Angle count sampling (Bitterlich 1948) for assessing basal area was also introduced, and increment was measured by continuous inventories and increment cores.

In 1968, stand volume inventories were prescribed as total censuses for mature even-aged stands, uneven-aged stands and small stands up to 1 ha. Even-aged stands aged 20–40 years and coppice stands were sampled.

Regulations from 1981 prescribed sampling with varying intensities from 1% to 10% of area depending on age and stand structure for all stands, except even-aged stands up to 20 years (no measurements) and even-aged stands before felling (total census). Similar regulations remained until the present with a 10-year management plan cycle and a 20-year inventory cycle for all management units in state ownership. However, most private stands, which are generally small, have neither been systematically managed nor inventoried.

In 2006, an even more intensive inventory was introduced using a fixed 100×100-m sampling grid with permanent concentric circular plots for all state owned forests. However, the scheme was not well accepted in forestry practice and was abandoned in 2008.

Because the first CRONFI has not been completed yet, data for the FRA country report for Croatia are from the State General Forest Management Plan which is compiled every 10 years and is based on stand-wise management plans for all management units ("bottom-up approach"). Results dating from the 1996 General Forest Management Plan were used for the FRA 2005 (FAO 2005).

6.3 Development of the Croatian National Forest Inventory

The Croatian National Forest Inventory (CRONFI) was stated by the Croatian Government as one of the aims of the National Forest policy and strategy, and prescribed by Forest Law in 2005. The aim of CRONFI is better forestry planning and was defined as multi-purpose with data collection accommodating the multiple needs of forest policy and practice, forest ecology, wildlife management, environment and nature protection, wood industry, and also for state and international organizations needs.

CRONFI covers all forests, regardless of ownership, and includes protected forests. The main results are estimates of forest areas, volume of growing stock and volume increment of forest resources. The Ministry of Regional Development, Forestry and Water Management is responsible for the inventory, and implementation is coordinated by the Faculty of Forestry, Zagreb. The first Croatian NFI started as a pilot project in 2005 and has continued until the present. The expected end date of the first inventory and completion of data analysis is 2010. The planned time between two inventories is 15 years, with a period of 2 years for inventorying the entire area of the Republic of Croatia.

6.4 Sampling Design

CRONFI uses two-phase sampling based on satellite detection for forest areas and terrain classification for the whole country. In the first phase, a basic 1×1-km grid is used for interpretation of plots using the CORINE forest classes whose 25-ha spatial resolution was improved using the 9-ha spatial resolution of the national classification of habitats. The second-phase sample consists of a terrestrial inventory of a sub-sample of first-phase forest plots.

6.4.1 Satellite Data

Images from the IRS 1D satellite (panchromatic IRS pan and multispectral LISS III) were used for total forest area mapping of the entire country and stratification based on the CORINE 0.5-ha minimum areas. The images were required to satisfy forest inventory criteria: visible and infrared part of spectrum, complete coverage in a single year, and satisfactory spatial resolution. Photo-interpretation of approximately 30,000 plots of 25 m radius on a 1 × 1-km grid using satellite images was scheduled as part of the pilot project in the first CRONFI, but it has not been conducted because of lack of time and funding.

6.4.2 Terrestrial Inventory

The second-phase terrestrial inventory is designed as two-stage sampling. The sampling design combines both systematic and random components. In each 4 × 4 km quadrate of 1 × 1 km grid, one of the grid intersection points is randomly selected as the first stage. At that point, a quadratic tract consisting of a cluster of four plots is established. The plots are located at the corners of squares with north-south and east-west oriented sides of 150 m length (Fig. 6.1).

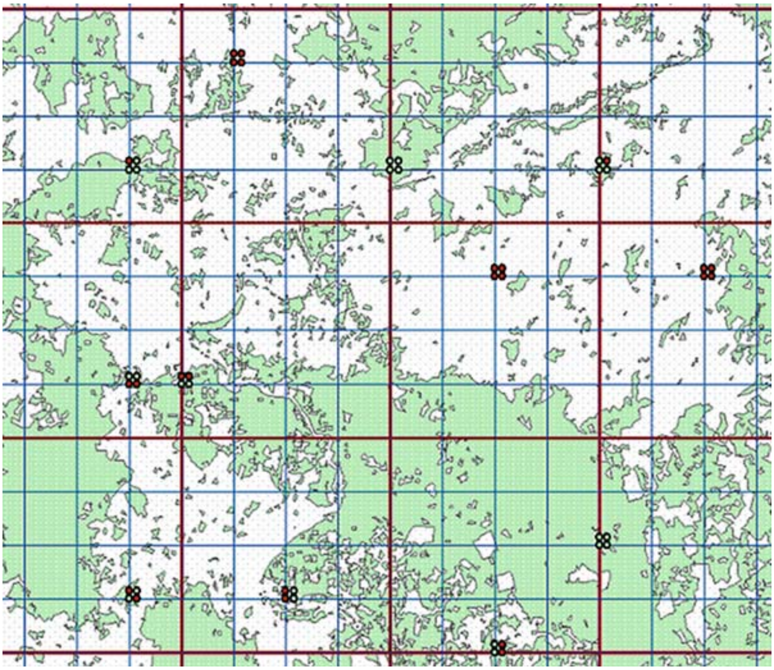

Fig. 6.1 Choice of tract position (four circular plots) on 1 × 1 km grid

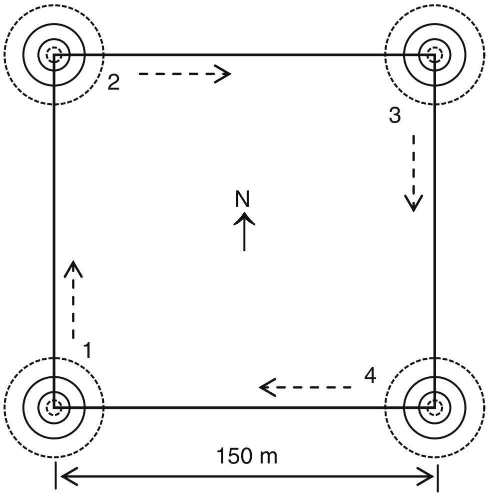

Fig. 6.2 Tract with four concentric circles for terrestrial measurement

The tract size is selected to be comparable with the resolution of the satellite images for identification purposes and operationally efficient for field measurement. Concentric circular plots in the corners of the tract constitute the second-stage sample (Fig. 6.2). The tract is measured if at least one plot is defined as forest. Approximately 2,000 tracts were planned. The definition of forest used in CRONFI is consistent with the FAO and COST Action E43 definitions, although the minimum area of 0.1 ha according to the Croatian Forest Law is different.

The quadratic tract has an area of 2.25 ha on which land cover classes are visually estimated and road types are recorded and mapped. Plot positions are determined using a global positioning system (GPS) device with an allowable error of 10 m from the proposed map position. Plot centres are permanently marked with iron bolts driven into the soil and additionally secured by three markers (signs on the trees, rocks etc.). Sample plots consist of up to five concentric circles of different radii for various variables and tree diameter sizes. Circles with 3.5-m radius are for measurement of trees $5.0 \leq dbh < 10.0$ cm in the Mediterranean region, for even-aged stands up to 20 years of age, for all uneven-aged stands, and for coppice stands. All trees with $dbh \geq 10.0$ cm are measured on 7-m radius circles, trees with $dbh \geq 30.0$ cm are measured on 13-m radius circles, and trees with $dbh \geq 50.0$ cm are measured on circles with 20-m radius.

All descriptive variables are observed on a circle of 25 m radius. An additional non-concentric plot with 2-m radius located 10 m north of the plot centre, is used for estimating regeneration with measurement of trees with $1.0 \leq dbh < 10.0$ cm. Approximately 70 variables are measured or assessed on each plot of which 50 are plot-level and 20 are tree-level variables. Plot-level variables include plot accessibility, stand origin, silvicultural treatment, age, vertical structure, species mixture, development stage, naturalness, crown cover, biotic and abiotic damages, soil, litter, ownership, and harvesting characteristics. A panoramic photo (angle 360°) is taken on every plot by wide-angle digital camera positioned at the plot centre.

The position of each sample tree is recorded using azimuth, distance and slope from the centre, in addition to species, *dbh* overbark and height measurement. Additionally bark thickness is measured and tree quality, damages, and defoliation are estimated. Stumps are recorded as well, with *dbh* estimated for calculation of felled volume. The diameter, decay class and type (coniferous or broadleaved) of deadwood are recorded on 13-m radius plots and volume is estimated using volume models based on *dbh* and total tree height. The abundance of ground vegetation is estimated in percentages. Data such as volume of live and dead biomass and soil depth needed for biomass estimation and carbon sinks are recorded by CRONFI.

A forest road survey is performed by estimating width, length and category of roads on the entire tract area.

Local forest service and forest management plans are additional sources of information. The terrestrial inventory is accomplished by seven field crews composed of three members each. Measurement of one tract per working day is prescribed, regardless of field conditions and number of measurable plots. On average 140 tracts are completed monthly in the April–October measurement season. The pilot project average time for plot measurement is 1 h, and the average time spent on the tract including travel to the tract, plot measurement and walking between plots is approximately 6 h. On average, three plots were measured per tract, making a total of approximately 6,000 measured plots. Approximately 5% of the terrestrial plots are remeasured for data quality control purposes.

The basic equipment used by terrestrial crews includes:

- GPS device (Trimble GeoXT)
- Suunto compass (360°)
- Vertex hypsometer/telemeter
- Calliper (100 cm with mm scale precision)
- Wide-angle digital photo camera
- Mensuration tape for circumference
- Bark gauge
- Iron bolts (20–30 cm) for marking permanent plot centres
- Topographic/ortophoto maps of scale 1:10,000 (or 1:5,000) with marked tract and plot position

6.5 Estimation Techniques

The CRONFI sampling design is stratified cluster sampling. Results can be analysed based on different strata (bioclimatic zones, forest types, regions, Forest administrations, counties etc.).

6.5.1 Area Estimation

Area and borders between strata are estimated by complete area classification on satellite images with anticipated accuracy of 90% and forest boundary error less than 20 m. Although photo-interpretation on images and comparison of results with field measurements was planned, it has not been performed for the whole country in the first CRONFI.

6.5.2 Volume Estimation

Tree volume is defined as volume over bark for stem and branches to 3 cm diameter on the thinner end. Tree volume is calculated using volume models (tables) developed for most tree species using *dbh* and total tree height as explanatory variables. Because all sample trees are measured for *dbh* and height, plot volume is calculated as a sum of all tree volumes depending on species. Volume is estimated for the entire area of stratum or country using two-stage estimation.

6.5.3 Volume Increment Estimation

Because the first CRONFI is still in progress and because no cores are taken, increment cannot be calculated. Estimates can be calculated currently from NFI data based on volumes and increment series (increment per cents) from management plans for different species and forest types. Statistically sound data with estimated errors will be known after the second measurement on the same permanent plots.

6.5.4 Error Estimation

Based on pilot project results, standard error of 3% at 95% confidence level for mean volume per hectare at the state level is expected. However, extremely variable strata with fewer sample plots will result in considerably lower precision.

6.6 Data Management and Reporting

Field data are recorded on paper forms and later transferred to a computer database. All data are stored at the responsible Ministry. The CRONFI computer database (using SQL) and software for data processing and reporting are still under construction and are being tested. Results will be presented for integrated, multi-purpose applications in the form of tables and maps employing a geographic information system (GIS) for administrative units (16 Forest administrations, 20 counties), five bioclimatic zones, species composition classes (broadleaved, conifer, mixed) and for the entire state.

Because CRONFI has just started, future inventories will surely include more variables and additional estimates according to available funds and national and international requirements. CRONFI will be the main information source and tool for a large-area forest management planning and forest industry at the national level. It will provide forest resource information for national and international statistics such as the FAO's Forest Resources Assessment (FRA) (FAO 2006) and the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2007). It should also produce information on forest health status and damage, biodiversity and carbon pools and changes in these for the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC 2007).

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Chapter 7
Cyprus

Loizos Loizou

7.1 Development of Forest Inventories in Cyprus

Cyprus has a long forestry tradition dating back to 1873 when M. De Montrichard prepared a report on the forest resources of the island. In 1878, another French forester prepared reports on the state of the forests and made recommendations for their future management (Polycarpou 1959). However, no National Forest Inventory (NFI) was carried out in Cyprus, although many operational inventories were designed and performed at the local level (Cyprus Forest Department 1994, 2003).

In 1897, the first inventory was designed and carried out based on sample plots which were established in various areas of the forests (Polycarpou 1959). The main objectives of the first inventory were to estimate the volume of growing stock, volume increment and diameter and height growth through stem analysis.

The second forest inventory was performed during 1922–1924. Randomly located sample plots at a sampling proportion of 5% by area were introduced (Peonides 1978). The main purposes of this inventory were to estimate timber volume, volume increment and allowable cut.

In 1936, the Department of Forests carried out an inventory of State Forests using systematic sampling (Peonides 1978).

In 1953, a new inventory method for State Forests featuring 2.7 ha, randomly located, permanent circular sample plots was introduced. The plots were measured every 10 years. The main purpose of this inventory was to provide forest planners the necessary quantitative and qualitative information for management planning.

In 1980, a great effort was made to modify the entire forest inventory and forest management regime. A new "Continuous Forest Inventory" method based on sampling was introduced. This inventory system was used for the Calabrian pine (*Pinus brutia*) dominated forest areas of the productive main State Forests with an area of 43,200 ha (Cyprus Forest Department 1994). The total forest area is 172,800

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ha. Aerial photographs were used to classify the State Forests stocked with Calabrian pine into productive and non-productive classes and artificial regeneration area.

For management purposes, the productive pine forests, dominated by Calabrian pine, were grouped into two Management Units: Management Unit I covers 16,200 ha, and Management Unit II covers 27,020 ha.

Until the present, the productive area was inventoried three times using randomly selected circular units of 0.2 ha: 1981–1982, 1991–1992 and 2001–2002. The Management Units were considered as two entirely separate units for sampling purposes.

The foremost aims of the two inventories of the exploitable area in 1981–1982 and 1991–1992 were:

- To provide estimates of timber volume and other relevant statistics used in forest management planning
- To provide data for calculation of annual allowable cut
- To monitor forest changes and trends

Field work for the forest inventory (2001–2002) was augmented by collecting information on the ecology and environment of the productive areas as a means of monitoring ecosystem changes and trends (Cyprus Forest Department 2003).

In 1996, a forest inventory was conducted for Tripylos Nature Reserve in which the protected endemic species Cyprus cedar (*Cedrus brevifolia*) is distributed. The protected area covers 823 ha. Stratified random sampling was applied with circular permanent sample plots of 0.1 ha. The main purposes of this inventory were to estimate the present state of Cyprus cedar and to establish a grid of permanent sample plots for monitoring ecosystem changes and trends (Cyprus Forest Department 2000).

In 2005, a forest inventory for non-productive areas was carried out to collect information for all State Forests. The method was the same as that used for the inventory of productive forests so that the two sets of results would be statistically compatible. The non-productive areas were grouped into Management Units as the productive areas: Management Unit I covers 6,403 ha, and Management Unit II covers 16,512 ha.

The Department of Forests has exclusive responsibility for forest inventories including planning the design, methods, field measurements, calculating estimates, and publications.

7.2 The Use and the Users of the Results

7.2.1 General Use

The main objective of forest inventories in Cyprus is to obtain qualitative and quantitative information about the forest resources and their physical environment for a specified time. Their main goal is to report the status of the forests with respect to volume and volume distribution by diameter classes, volume increment, number of stems, regeneration, and expected changes and trends. Because of increasing multiple uses of forest resources in recent years, the inventory aims have been expanded to include collection of information that can be used to evaluate the potential of the forests for wildlife habitat and other uses.

The forest inventory provides information for national and international reporting to bodies such as the Food and Agriculture Organization of the United Nations (FAO) and its Forest Resources Assessment and the Ministerial Conference on the Protection of Forests in Europe (MCPFE).

7.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

For the last 5 years, information gathered by the various forest inventories has been used either directly or indirectly to estimate carbon pools. In future forest inventories, the field work will be augmented with the variables necessary to estimate parameters related to LULUCF under the United Nations Framework Convention on Climate Change (UNFCCC).

7.2.3 The Role of Forest Inventories in Assessing the Status of Biodiversity

Many forest variables assessed by the forest inventories are related indirectly to biodiversity such as diameter distribution, height distribution, age distribution and volume distribution as well as numbers of trees and regeneration. In addition, since 1995 information for the following variables were collected in order to broaden the forest biodiversity assessment:

1. All shrubs found in a circle with a radius of 10 m from the centre of the sample plot are recorded and the percentage of the shrub cover of each shrub species is estimated.
2. The crown cover of the main stand is estimated and recorded in one of the following classes: 0–30%, 31–60% and 61–100%.
3. Stand type is recorded and classified into one of two classes: pure or mixed. In mixed stands, neither the coniferous nor the broadleaved component accounts for more than 75% of tree crown cover.
4. The stand origin is recorded as artificial or natural regeneration.
5. Stand structure is recorded as even-aged, uneven-aged, or all-aged.
6. The degree of erosion is described and classified into one of the following classes: none, negligible, medium or intensive.
7. Trees with resin signs are recorded.
8. All information regarding fauna and historical monuments are recorded.

7.3 Current Estimates

The basic forest resources estimates are given in Tables 7.1a and b. The forest area estimate can be given on the basis of the reference definition of COST Action E43 (Table 7.2).

7.4 Sampling Design

For management purposes, State Forests are divided into two main categories: productive and non-productive forests. Also, each category is divided into two

Table 7.1a Basic area estimates

Quantity	Estimate (1,000 ha)	Percent	Description
Forest land	172.8	18.7	Spanning more than 0.5 ha with trees higher than 5 m and a crown cover of more than 10%, or trees able to reach these thresholds in situ. Land predominantly under agricultural or urban use not included.
– State	107.0	11.6	
– Private	54.0	5.8	
– Hali land	11.8	1.3	Scattered land throughout the island, not regularly exploited for the last 300 years. Never been claimed by anyone due to heavy property and farming taxes imposed by the Ottoman administration. Later on, declared as common lands and ownership passed to state. Some have been naturally forested. Periodically, part of these areas are declared as state forests.
Other wooded land	213.8	23.1	Not classified as forest, spanning more than 0.5 ha with trees higher than 5 m and a crown cover of 5–10%, or trees able to reach these thresholds in situ or with a combined cover of shrubs, bushes and trees above 10%. Land predominantly under agricultural or urban use not included.
– State	50.7	5.5	
– Private	144.3	15.6	
– Hali land	18.8	2.0	
Other land	538.5	58.2	All land that is not classified as forest or other wooded land.
State forest land	107.0	11.6	
– Productive state forests	43.2	4.7	All forested areas with Calabrian pine of the Permanent Forest Reserve and of the National Forest Park which can be cultivated by machinery. Includes all stands with tree crown cover above 10% and area of more than 1 ha.
– Non-productive state forests	22.9	2.5	
– Other state forest areas	40.9	4.4	
Total land area	925.1	100	

Table 7.1b Basic volume estimates

Quantity	Estimate (million cubic metre)
Growing stock in productive forests (2001–2002)	
– Management Unit I	0.95
– Management Unit II	2.13
Growing stock in non-productive forests (2005)	
– Management Unit I	0.28
– Management Unit II	0.57
Annual increment of growing stock in productive forests	
– Management Unit I	0.01
– Management Unit II	0.03
Annual increment of growing stock in non-productive forests	
– Management Unit I	0.003
– Management Unit II	0.02

Table 7.2 The availability of estimates based on national definitions (ND) and reference definitons (RD)

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	Department of Forests	ND = RF
Growing stock volume	Yes	No	Department of Forests	
Above-ground biomass	No	No	Department of Forests	
Below-ground biomass	No	No	Department of Forests	
Deadwood volume	Yes	No	Department of Forests	
Deadwood volume by decay stage classes	No	No	Department of Forests	
Afforestation Deforestation Reforestation (Kyoto 3.3)	No	No	Department of Forests	
Forest type	No	No	Department of Forests	

Additional definitions are:
Permanent Forest Reserve: an area designated for wood production.
National Forest Park: area designated for the provision of special services, mainly recreation.

Table 7.3 Sampling information of the Cyprus forest inventory

Stratum	Management Unit	Year	Number of plots	Sampling intensity (%)
Productive forest	I	1981–1982	600	0.7
		1991–1992	750	0.9
		2001–2002	750	0.9
	II	1981–1982	700	0.5
		1991–1992	900	0.7
		2001–2002	900	0.7
Non-productive forest	I	2005	110	0.3
	II	2005	210	0.2

Management Units, and these units are considered as two entirely separate units for sampling purposes.

Since 1980, the Department of Forests has adopted simple random sampling without replacement. The number of plots for each Management Unit was computed based on the intended relative standard error of the number of stems, ±5% for productive areas and ±10% for non-productive areas. The number of plots and sampling intensity (100 × area of the plots/forest area) in each forest inventory are shown in Table 7.3.

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Chapter 8
Czech Republic

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8.1 Development of the Czech National Forest Inventory

Information on forests and forestry in the former Czechoslovakia (the Czech Republic since 1993) was traditionally based on stand-wise forest inventories usually conducted as a part of forest management planning procedures. The first country level reporting was performed prior to World War II and provided data on standing volume and forest condition. However the quality of the source data varied because they were often based on estimates. After World War II, the forest inventory was initiated by the project called Forest Inventory 1950. During the war, forest management plans were neither revised nor renewed and so there was an urgent need to do so. Based on Decree No. 3021 of the Ministry of Agriculture of November 8, 1948, forest management plans were renewed. A limited additional field survey was conducted, and country level data for 1950 were produced. In the following decades, country level data were collected using an aggregation of data for local stand-wise inventories.

Together with Forest Inventories conducted at 10-year intervals, data for so-called Permanent Forest Inventories were collected every year. Permanent Forest Inventories included the main parameters characterizing forest condition and were also based upon stand-wise inventories conducted as a part of forest management planning. Hence, the aggregated data were produced annually from actual, valid management plans. The management plans were renewed every 10 years.

In 1979, the preceding inventories were succeeded by the Comprehensive Forest Management Plans (presently referred to as Comprehensive Information on Forest),

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based on the same principles as the Permanent Forest Inventories. These were updated on an annual basis by summarizing the data from individual forest management plans. Comprehensive Forest Management Plans were in operation until 1998, when they were replaced by "Information on the Status of Forests".

In 1995, the new Forestry Act of the Czech Republic (Act No. 289/1995 Sb.) adopted an option for a new inventory that would be based upon an independent survey with no direct link to forest management plans.

In 1994 the Institute of Forest Ecosystem Research Ltd. (IFER) began developing and testing methods for a new statistical forest inventory. The project was funded by the Czech Ministry of Agriculture, lasted until 2000, and ended with the complete methodology for a statistical forest inventory based upon international experience and national requirements. IFER tested the methodology in two pilot experiments covering 80,000 ha. During the following years IFER complemented the methodology with comprehensive technology supporting field data collection and other forest inventory activities.

In June 2000, the preparatory period was finished by Government Regulation No. 193/2000 Sb., declaring the execution of a forest inventory for the period from 2001 to 2004. This regulation shifted the context of the forest inventory to a new level – the inventory approaches treating forests as an integral part of the environment within its ecosystem relations. Together with the production function the new forest inventory would also deal with other characteristics of the forest environment.

The new forest inventory is the responsibility of the Czech Ministry of Agriculture and is carried out by the Forest Management Institute, Brandýs nad Labem (FMI), which covers fieldwork, data processing and reporting.

With the new forest inventory the time series of country level data, based upon aggregated data from forest management plans, has ended. The new inventory data cannot be directly compared with data from the previous inventories resulting in a whole range of factors that must be considered when comparing the results of these inventories.

The field survey of the new forest inventory took place during 2001–2004.

In 2006, IFER finished a project for the Ministry of Agriculture aiming at preparation of methodology for the second cycle of forest inventory. That project was carried out in co-operation with FMI. Currently there is no official decision regarding repeated inventories but it is expected that it will be in a 10-year cycle.

8.2 The Use and Users of the Results

8.2.1 General Use

The National Forest Inventory (NFI) based on statistical sampling (2001–2004) delivered information that is substantially different from information collected previously. As a consequence of new methodological approaches the data differ in structure, spectrum of forest indicators and in some cases also in estimates. Therefore the incorporation of the new forest inventory data into various national and international reporting processes is laborious and difficult to link to previously reported information on forests.

Forest inventory data serves as a valuable information source for national policy makers and the regional state administration of forests. Additionally the NFI results served as a basis for formulation of the new National Forest Program – the key national strategic document on forest development.

The NFI data have been directly used for reporting in the European System of National and Regional Accounts, for the "Report on forestry of the Czech Republic". So far, NFI data have not been used for international reporting to the Food and Agriculture Organization of the United Nations (FAO), Ministerial Conference on the Protection of Forests in Europe (MCPFE) nor United Nation's Framework Convention on Climate Change (UNFCCC).

8.2.2 The Use of NFI Data in UNFCCC Inlcuding Kyoto Reporting

Emission reporting under the UNFCCC and its Kyoto Protocol is the responsibility of the Czech Ministry of Environment. The technically responsible body for compiling emission inventory data for the Land Use, Land-Use Change and Forestry (LULUCF) sector is IFER. IFER is a part of the National (Emission) Inventory System, which is coordinated by the Czech Hydrometeorological Institute. So far, NFI data has not been used for UNFCCC and Kyoto reporting. With data for only one inventory cycle available (2001–2004), this resource is not directly usable for detecting carbon stock change in forests. Nonetheless, the data for the first cycle would be suitable for several other purposes, such as constructing better country-specific biomass expansion factors for individual tree species. Unfortunately, FMI, which is responsible for conducting the NFI in this country, blocks release of tree-level data for the analyses needed. Effective utilization of statistical forest inventory data in the near future would also require several methodological adjustments, taking into account the specific needs of the carbon (emission) inventory. These plans are under consideration. So far, no decision has been made on NFI2, as of October 2007. Undoubtedly, once the data of the repeated NFIs are available, IFER will insist on a full utilization of this resource for the use in emission inventory.

Currently, the primary source of activity data on forests for the purpose of UNFCCC and Kyoto reporting remains the stand-level data of Forest Management Plans (FMP), which are administered centrally by FMI. With a 10-year cycle of forest management plans, the annual update of the FMP database is related to 1/10 of the total forest area scattered throughout the country. The information in FMP represents an ongoing national stand-wise type of forest inventory. This resource provides information on both growing stock and forest area. The latter is an inherent part of the annually updated cadastral information system of the country, which is used to detect areas of all land use categories and land use change as required under UNFCCC and Kyoto Protocol.

8.2.3 The Role of NFI in Assigning the Biodiversity Status

Until now, NFI data has not been used for any international reporting, which also includes biodiversity. Information on forests provided in the reports of the Czech Republic to the Convention on Biodiversity (CBD), as well as to MCPFE, is based on the database of Forest Management Plans (FMP) administered by FMI which was described above.

The Czech NFI program aims at providing information usable for biodiversity assessment. For this purpose, the first NFI cycle (2001–2004) included tens of indicators. These indicators will be also used in the future NFI campaigns.

8.3 Current Estimates

Tables 8.1a and b present the basic area and volume estimates from the first cycle of the Czech NFI conducted from 2001 to 2004. All estimates correspond to the national definitions given in those Tables. It is expected that harmonization of definitions with COST Action E43 will be considered for the next NFI.

Digitized and orthorectified aerial photographs were used for preliminary estimates of land cover and decisions about forest/non-forest. Those inventory plots clearly outside forests were not visited.

The technical specifications of the photos are:

- Scale of image: 1:23,000
- Ground resolution: 50 cm
- Year of flight: 1998–2001
- Position accuracy of aerial photos: ±5 m
- Color depth: 8 bit of gray shades
- Interpretation: manual using visualization by geographic information system (GIS, software Topol)

The Czech NFI covers the whole area of the Czech Republic, and estimation of forest cover is one of its key aims.

The forest border line is characterized by the trees taller than 1.3 m with spacing less than 12 m. Forest stand is defined by the minimum canopy closure (0.2) and minimum area (400 m^2). The categories of non-stocked forest land are explicitly defined.

Table 8.1a Basic area estimates from the years 2001–2004

Quantity	Estimate (1,000 ha)	Description	SE[a]
Forest land	2,752	The category 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.	n.a[c]
Forest stands area	2,705	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%.	10
Non-stocked forest land	47	The category is defined as follows: forest aisles wider than 4 m, unpaved forest roads wider than 4 m, paved forest roads not wider than 4 m, forest nurseries on forest land, seedling nursery, etc.	3.7
Forest roads (m/ha)	14.9	The basic criteria for determining the class of forest roads are the parameters given by ČSN Forest Roads Network (1996), mainly the type of road pavement, width of the road crown, road gradient and the radius of the horizontal curve.	n.a.[c]
Total land area	7,887	Total land area of the Czech Republic includes all types of land.	–[b]

[a]Standard error.
[b]Assumed to be error free.
[c]Not available.

Table 8.1b Basic volume estimates for the years 2001–2004

Quantity	Estimate	Description	SE[a]
Growing stock million cubic metre	900	This category includes the stock of timber to the top of 7 cm over bark, including dead trees (m^3 under bark)	10
Mean growing stock m^3/ha	332.7	This category represents the stock of timber to the top of 7 cm over bark, including dead trees, per 1 ha (m^3/ha under bark)	3.5
Dead wood million cubic metre	18	This category comprises the wood mass of dead trees lying on the ground, of broken tree tops, branches, harvest residues, unprocessed old timber, etc.	0.7

[a]Standard error.

8.4 Sampling Design

Field data collection methodology was developed within a pilot project conducted by IFER. This methodology was then used and adjusted by FMI, which described the methodology in two manuals, "Methodology of Field Data Collection" and "Work Procedures". The handbook "Methodology of Field Data Collection" has two Appendices: "Natural Forest Species Composition by Forest Types and Natural Forest Areas" and "Field-Map Project Structure". "Work Procedures" has two parts, namely "Office Work" and "Field Work".

8.4.1 Sample Plots

Inventory plot:

- Grid size: 2 × 2 km
- Two circular plots in each grid cell
- The position of the first inventory plot is randomly shifted a maximum of 300 m from the center 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 (Fig. 8.1)
- Number of plots: approximately 39,000 of which approximately 14,000 are in forests
- Number of primary (field) variables per plot: approximately 150
- 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

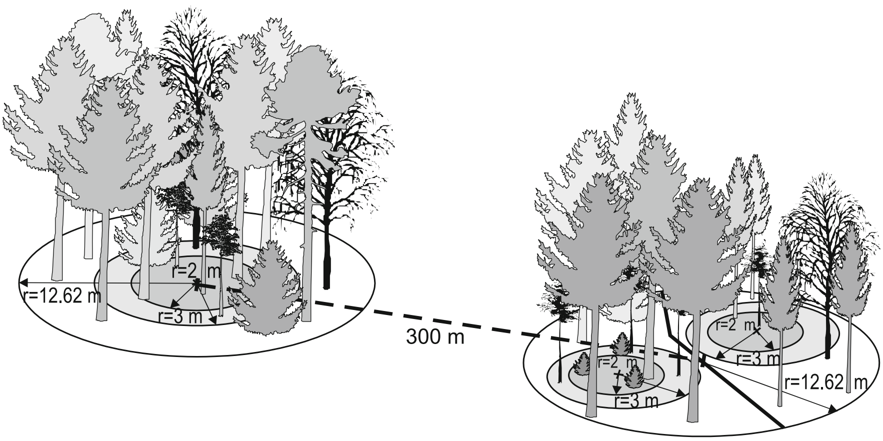

Fig. 8.1 A 300 m transect between plots with a duplex

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) $\geq$12 cm; additional two concentric circles are established in the center of gravity (location of maximum distance to segment boundaries) 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 $\geq$10 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 counts by species and height classes
- Deadwood on the ground: length and mid-diameter of all dead logs within the plot with minimum diameter of 7 cm at the smaller end; coverage of dead branches and smaller debris; number and size of stumps
- Forest site: several variables describing growing conditions, ecosystem structure etc.
- Damage: several stand and tree attributes
- Lichens: occurrence of epiphytic lichens
- Soil sampling: mixed soil sample at every first plot of the duplex is analyzed for basic nutrients, C/N, pH
- Inventory of forest roads, forest edges and small water streams is performed using the survey on 300 m transect between plots within a duplex. Shapes which intersect transect line are recorded i.e. mapped and described

8.5 Management

8.5.1 Management and Personnel

The NFI in the Czech Republic is set by Act No. 289/1995 Sb., on Forests and Amendments to some Acts (The Forestry Act) and the Government Regulation No. 193/2000 Sb. They declared the implementation of the forest inventory for the period from 2001 to 2004.

The NFI in the Czech Republic is conducted by FMI which is also responsible for NFI data management and data processing.

The first NFI cycle was conducted over 4 years, using 18 four-member field crews. Two additional inventory teams were established for field checks.

8.5.2 Measurement Technology

Data collection in the field was based on the Field-Map technology described below. The technology set-up was equipped by the Field-Map software with data exchange to the central database server using MS SQL. Field-Map software was developed by the IFER. Field-Map is a comprehensive tool for collecting field data using electronic measurement devices. The following electronic measurement devices were used in the first NFI cycle:

- Field Computer Hammerhead P-233
- MapStar – an instrument for measuring absolute horizontal angles used for sighting tree location and navigation
- Forest Pro – laser rangefinder designed for measuring horizontal distances, inclination, tree height, etc.
- Global positioning system (GPS) Trimble Geoexplorer 3 for providing geographic coordinates
- Mantax electronic caliper for measuring tree diameters
- Handheld data collector PSION for descriptive information on trees
- Metal detector GARRETT to locate inventory plot position for control or repeated sampling

8.5.3 Quality Assurance

NFI employees participating in the NFI were trained prior to the first NFI cycle. Every field worker passed an examination on NFI methodology and working processes. During the practical examination, field workers had to demonstrate the practical operation of field technology. Training and verification of NFI workers during the whole first NFI cycle was conducted annually. A special program for data verification was developed to control formal and logical accuracy of measured data directly after the measurement. It also permitted immediate corrections. Another thorough quality control phase took place after sending data to FMI.

Two special teams carried out the quality control measurements. One team was composed of FMI employees who checked 5% of all inventory plots. The second team was represented by an independent company which checked another 5% of sites. Altogether, measurements of 10% of the inventory plots were verified.

8.6 Estimation Procedures

The whole estimation procedure used by FMI is described in detail in the NFI of the Czech Republic 2001–2004 (FMI 2007).

8.6.1 Area Estimation

The total area of the Czech Republic was taken from the Real Estate Cadastre system. The area of forest (forest stands according to methodology NFI and non-stocked forest land) was located by scanning the forest borders. For scanning forest borders, orthophotomaps from years 1998–2001 were used.

8.6.2 Volume Estimation

Growing stock volume includes all trees with *dbh* > 7 cm including dead trees. The estimated volume is over bark. Merchantable volume under bark is then calculated using the conversion factors for coniferous and broadleaved tree species. Tree volume was calculated using the volume tables of the FMI based on tree *dbh* and tree height. The heights of trees that were not directly measured (approximately 15% of trees in inventory plots) were predicted using height models calibrated on a species/plot/region level.

Growing stock volume z on sub-plot is estimated as

$$z = \sum_{j=1}^{m} v_j \tag{8.1}$$

where V_j is tree volume on the sub-plot and m is the number of trees on the sub-plot.

8.6.3 Estimation of Average Volume per Hectare

Average volume per hectare, denoted $\overline{zh}$ is estimated as,

$$\overline{zh} = \frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} p_i}, \tag{8.2}$$

where z_i is volume on the sub-plot, p_i is the sub-plot area and n is the number of sub-plots.

8.6.4 Estimation of Total Volume (Czech Republic, Districts)

Total volume, denoted Z, is estimated as

$$Z = \overline{zh} \cdot P \tag{8.3}$$

where $\overline{zh}$ is the estimate of average volume per hectare and P is area.

8.6.5 Volume per Hectare on Sub-plot

Volume per hectare on a sub-plot, denoted zh_i is estimated as,

$$zh_i = \frac{z_i}{p_i} \tag{8.4}$$

where z_i is the volume of trees on the sub-plot and p_i is the sub-plot area.

8.6.6 Error Estimation

A confidence interval is calculated for all assessed variables ($\alpha = 0.95$).

8.6.7 Estimation of Scatter and Standard Deviation of Total Volume per Hectare on Sub-plot

The standard deviation of total volume per hectare on a sub-plot, denoted s, is estimated as,

$$s = \sqrt{\frac{\sum_{i=1}^{n} p_i \left(zh_i - \overline{zh}\right)^2}{\sum_{i=1}^{n} p_i} \cdot \frac{n}{(n-1)}} \tag{8.5}$$

where zh_i is total volume per hectare on the sub-plot, $\overline{zh}$ is the average volume per hectare estimate and p_i is the sub-plot area.

8.6.8 Average Volume per Hectare – Error Estimation

The width, d, of an α-level confidence interval is calculated as,

$$d = \pm\, t_{1-\alpha;n-1} \cdot \frac{s}{\sqrt{n}} \tag{8.6}$$

where n is the number of sub-plots, s is the standard deviation of the total volume per hectare on the sub-plot and $t_{1-\alpha;n-1}$ is the student t-distribution value for level $\alpha = 0.95$.

8.6.9 Increment and Drain Statistics Estimation

Because only one inventory cycle has been conducted, evaluation of methods for increment and drain has not been finalized.

8.7 Harmonized Estimates

The possibilities to give the estimates on one hand on the basis of national definitions and on the other hand on the basis of COST Action E43 reference definitions are presented in Table 8.2.

8.8 Current Status and Future Prospects

The first cycle of the NFI was conducted during 2001–2004. No decision on a repeated NFI cycle has been made. Although the date for the initiation of NFI2 is not known, preparations for NFI2 are underway. The pilot project aimed at repeated inventories was realized in cooperation with IFER. Other projects aimed at methodological and technological processes should follow.

Table 8.2 The availability of estimates based on national definitions (ND) and reference definitions (RD)[a]

Estimate	ND	RD	Responsible	Remark
Forest Area	Yes	No	NFI	ND ≠ RD Different land cover criteria (area, width, crown cover, tree height) and land use criteria (legislative criteria in use)
Growing stock volume	Yes	No	NFI	ND ≠ RD Missing: trees below 7 cm *dbh*; stem top, Included: dead stems
Above-ground biomass	No	No	NFI	
Below-ground biomass	No	No	NFI	
Dead wood volume	Yes	Yes	NFI	Can be derived from NFI data
Dead wood volume by decay stage classes	Yes	Yes	NFI	Can be derived from NFI data
Afforestation Reforestation Deforestation (Kyoto 3.3)	No	Yes	Ministry of Environment	Applied in emission inventory
Forest type	No	Yes	NFI	Can be derived from NFI data

[a]RD is understood as either in use in the country, or easily derived from the national definition and activity data.

References

Forest Management Institute (FMI) (2007) National Forest Inventory in the Czech Republic 2001–2004. Introduction, Methods, Results. 224 p

Chapter 9
Denmark

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9.1 Development of the National Forest Inventory of Denmark

Since 1881, a Forest Census based on forest owner responses to questionnaires has been carried out approximately every 10 years (Larsen and Johannsen 2002). The first censuses acquired information on forest area and tree species distributions obtained from information on land area under agricultural cultivation. The information became more detailed with the 1951 census which included statistics on the number of forest estates, forest area, the distribution of tree species and forest owners at county level. Forest holdings larger than 50 ha were described according to age and site classes at regional level.

The Forest Act of 1989 established the census as the responsibility of the Forest and Nature Agency of the Danish Ministry of Environment and requested national forest statistics every 10 years. The two latest censuses were carried out in 1990 and 2000. The basic definition of forest included a criterion of a minimum area of 0.5 ha but no criteria for crown cover or tree height. Open woodland and open areas within forest areas were not included.

With the increased needs for new and more comprehensive information on forestry and forest-related issues, the first sample-based national forest inventory (NFI) was launched in 2002 (Johanssen 2003). During the first 5-year cycle, information on traditional forest resources such as growing stock, variations in stand structure, tree species mixtures, and indicators of biodiversity was collected. The definition of forest was also reformulated in accordance with the FAO definition (UNECE/FAO 2000).

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9.2 The Use and the Users of the Results

9.2.1 General Use

The Danish NFI completed its first 5-year cycle (2002–2006) and has started the second 5-year cycle (2007–2011). The NFI covers all forests for all ownership groups and is intended to be a major information source and tool for forestry and forest-related issues.

Data from the latest NFI (2002–2006) have not yet been used to their full extent. However, the data have been used for training and validation purposes in the development of the European Joint Research Centre (JRC) Forest Map 2000 and for development of a Danish land cover map under the Global Service Element on Forest Monitoring project (GSE-FM). This project aims to establish baseline projections of emissions caused by afforestation, reforestation and deforestation (ARD) activities. The data have been officially reported for the first time in 2008. The data will also be used for reporting to international processes such as the Ministerial Conference on Protection of Forests in Europe (MCPFE 2007), the United Nations Economic Commission for Europe (UNECE/FAO) and United Nations Food and Agriculture Organization (FAO) Forest Resources Assessment (FRA 2008).

The NFI also produces data on forest health status and changes using the same methods as in the UNECE – International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forest (UNECE-ICP Forests) monitoring of forest condition using the European systematic 16 × 16-km grid (Level I). The Danish NFI and ICP Forests networks are currently being compared with the aim of harmonising forest condition monitoring in Denmark. The NFI is currently developing methods for monitoring habitats inside and outside the designated Danish habitat sites. In future years, the information generated by the NFI will be used for forest management planning at national, regional, and local levels, and in decisions concerning sustainable forest management, forest resources, recreation and habitat monitoring.

9.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

NFI data are used to estimate carbon pools and carbon pool changes for reporting under the United Nations Framework Convention on Climate Change (UNFCCC 2007), Land Use, Land-Use Change and Forestry (LULUCF) sector, as well as for reporting emissions and removals under the Articles 3.3 and 3.4 of the Kyoto Protocol of UNFCCC. The NFI will be a major information source for greenhouse gas reporting for the LULUCF sector of UNFCCC and will replace the former forest censuses of 1990 and 2000 as sources of information. The NFI land use categories are consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC 2006).

For the Danish Forest Censuses of 1990 and 2000, estimates of standing volume and volume increment were based on forest owner responses to a questionnaire that included information on the distribution of forest area by species and age classes and information on site productivity. These data were used with standard yield table functions to estimate standing volume and rate of increment for each tree species category. Estimation using NFI data will replace this procedure for future reporting.

9.2.3 The Role of NFI in Assessing the Status of Biodiversity

Selection of NFI field variables is based on the national criteria of sustainable forestry, the pan-European criteria of the MCPFE and other main international processes. The NFI includes traditional variables such as tree species, diameter at breast height *dbh*, height, age, growth, regeneration and wood density/quality. Data for these variables are combined with data for site and stand variables such as tree species, stand structure, coverage, treatments and soil characteristics, forest health characteristics.

A forest biodiversity module has been developed as a component of the NFI to enable reporting on Criterion 4 of the MCPFE (MCPFE 2003) and to Natura 2000 (2009). A reduced version of this biodiversity module is being used in the current NFI and includes assessments of stand structure, deadwood, large trees, forest edge and ground vegetation. No ground vegetation assessments have been conducted yet.

A protocol for extensive monitoring of the Natura 2000 forest types outside the designed habitat sites has been developed for use in the 2008 field season. The new protocol will include data collection on species richness, continuity indicators such as large trees, cavities and bird holes, standing and lying deadwood, hydrology, and indicators of forest management. Ten key biotopes are defined for Denmark (Table 9.1).

Table 9.1 Danish forest key biotopes and habitat types

Habitat type	Biotope
9110	Luzulo-Fagetum beechforests
9120	Beechforests with Ilex and Taxus, rich in epiphytes (Ilici-Fagion)
9130	Asperulo-Fagetum beechforests
9150	Calcareous beechforest (Cephalanthero-Fagion)
9160	Stellario-Carpinetum oak-hornbeam forests
9170	Galio-Carpinetum oak-hornbeam forests
9180	Tilio-Acerion ravine forests
9190	Old acidophilous oak woods with Quercus robur on sandy plains
91D0	Bog woodland
91E0	Residual alluvial forests (Alnion glutinoso-incanae)

9.3 Current Estimates

Basic area estimates with the descriptions (definitions employed) are given in Table 9.2a and volume estimates in Table 9.2b.

9.4 Sampling Design

The NFI sampling design features single stage cluster sampling with partial replacement of entire clusters from one inventory to the next. This design produces good estimates of increment based on data from permanent clusters and current status based on data from both permanent and temporary clusters. In some cases, the sample variables describe actual values (e.g., are, growing stock), and in other cases ratios or percentages (e.g., proportion of area by species) (Table 9.2a).

Table 9.2a Basic forest resources estimates from the years 2002–2006

Quantity	Estimate (1,000 ha)	Share (%)	Description (since 2002)
Forest land	534.5	12.4	Area larger than 0.5 ha covered by trees with a minimum width of 20 m with trees at least 5 m at maturity in situ, and with a crown cover of at least 10%. Areas with agricultural production and urban land are not included.
Broadleaved trees	229.9	5.3	
Conifer trees	286.9	6.7	
Temporary unstocked	10.9	0.25	
Side areas (belt, roads, etc.)	7.9	0.18	
Other wooded land	41.1	0.95	Area larger than 0.5 ha covered by trees with a minimum width of 20 m with a crown cover of 5–10% of trees with a height of more than 5 m trees or trees which in situ potentially can reach these values, or areas with a crown cover larger than 10% made of tree and shrub species which cannot reach a height of 5 m at the site.
Other wooded land – broadleaved trees	23.3	0.54	
Other wooded land – conifer trees	9.0	0.21	
Total forest OWL	575.6	13.4	
Total land area	4,309.8	100	
NFI coverage			All forest land use classes excluding inland water and sea water including peat land and wetland
NFI provides area estimates for land classes			Forest, peat land and wetland in forests

Table 9.2b Basic volume estimates from the years 2002–2006

Quantity	Estimate
Growing stock volume (million cubic metre)	
Total forest	106.3
Broadleaved trees	56.2
Conifer trees	50.0
Average increment (million cubic metre year^{-1})	
All trees	5.4
Broadleaved trees	2.0
Conifer trees	3.4
Carbon sink (t/ha)	
Total forest	68
Broadleaved trees	81
Conifer trees	62

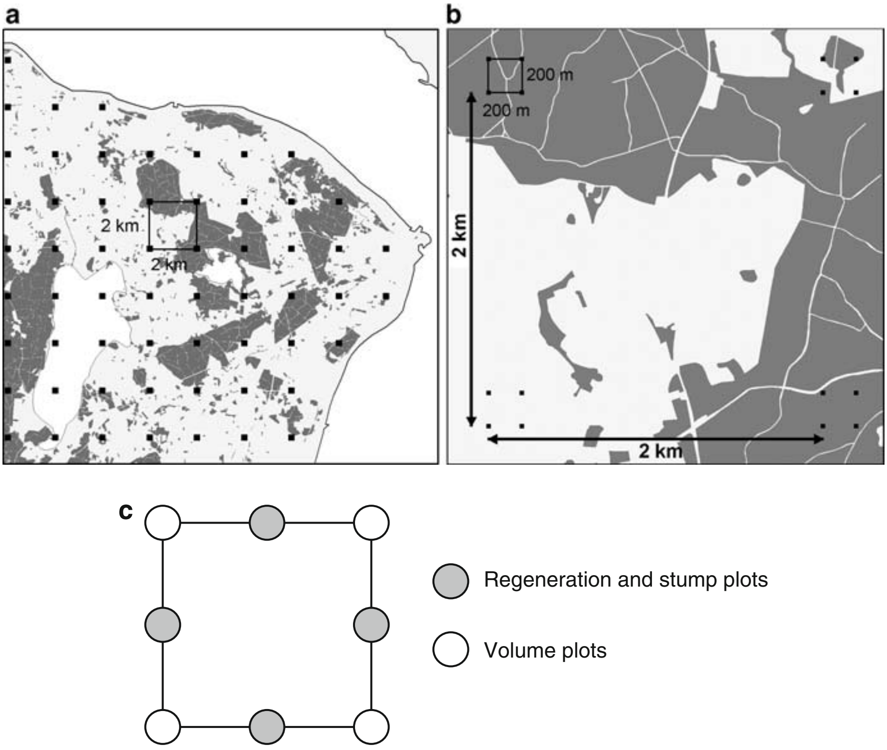

Fig. 9.1 (**a**) The locations of clusters. (**b**) The sampling grid. (**c**) Cluster of sample plots

The NFI sample design is based on a 2 × 2-km grid over the total land base of Denmark (Fig. 9.1a). At each grid intersection, a cluster (Fig. 9.1b) of four circular plots is systematically established as a square with side length of 200 m. The clusters are denoted Primary Sampling Units. Approximately 1/3 of the plots are permanent and are re-measured every 5 years; approximately 2/3 are temporary and are shifted to randomly selected new locations in the 2 × 2-km grid square (Fig. 9.1b) after completion of each 5-year inventory cycle. The plots have a radius of 15 m and are denoted Secondary Sampling Units.

Based on analysis of maps and aerial photos, each plot is assigned to one of three basic categories as defined by the FAO, reflecting the likelihood of forest or other wooded land (OWL) cover in the plot: (0) unlikely to contain forest or OWL cover, (1) likely to contain forest cover, and (2) likely to contain OWL cover. Heath and wetlands are viewed as likely to become forest and other wooded land, and included in the second category, likely to contain OWL cover. All plots in the last two categories are to be inventoried in the field. Plots are included for inventory regardless of the forest status of the other plots in the cluster.

9.4.1 The Sample Plot

Each plot is divided into three concentric circles with radii of 3.5, 10 and 15 m. A single calliper measurement of *dbh* is made for all trees in the 3.5 m circle, trees with *dbh* $\geq$ 10 cm are measured in the 10 m circle and only trees with *dbh* $\geq$ 40 cm are measured in the 15 m circle (Fig. 9.2). On a random sample of 2–6 trees, further measurements of tree height, crown height, age and diameter at stump height are made and tree health (defoliation and discoloration) and the presence of mast, mosses and lichens is recorded. The presence of regeneration on the plots is registered and the species, age and height of the regeneration is recorded. Stumps from trees harvested within a year from the measurement are measured for diameter (Fig. 9.1c).

Each plot is further subdivided into tertiary sampling units on the basis of different land use classes, counties, ownership, age classes (at least 20 years), tree species composition (at least 30% difference), and crown cover (at least 25% difference).

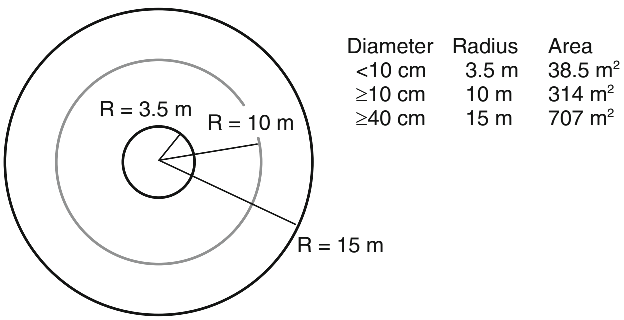

Fig. 9.2 The concentric circular volume plot. *dbh* thresholds vary with plot radius

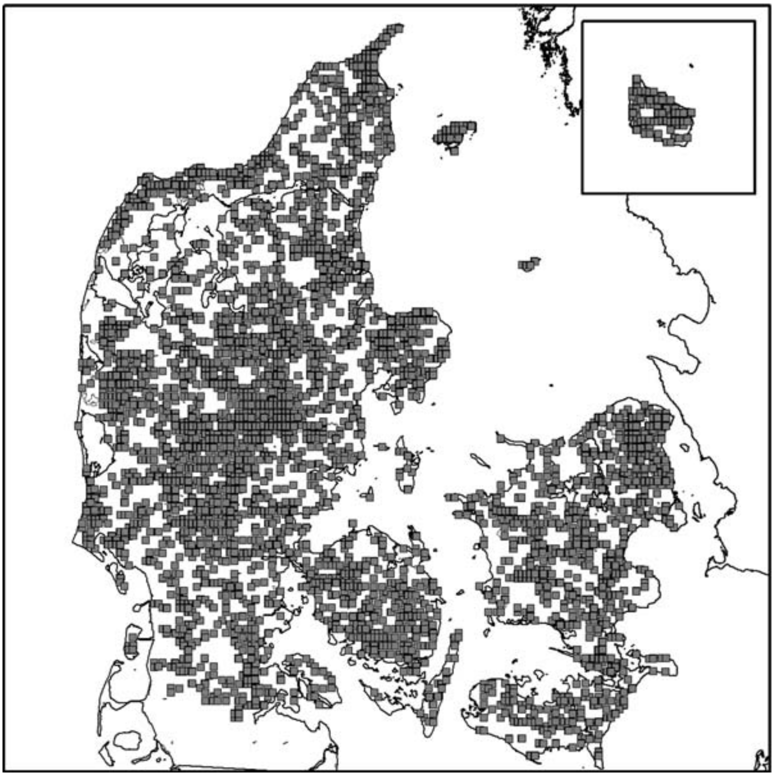

Fig. 9.3 NFI plots with forest and OWL in the first cycle (2002–2006)

The first 5-year cycle of NFI measurements entailed a total of 42,793 plots of which 7,610 were classified as likely to contain forest cover or likely to contain OWL cover. A total of 1,474 plots were not measured despite their classification in those two categories, which correspond to about 19.4% of the plots that should have been inventoried in the field or 3.4% of the total number of plots. The missing plots were mostly from the initial year, 2002, and are due to start-up difficulties. The measurements from 2002–2006 include 109,638 *dbh* measurements and 11,741 height measurements (Fig. 9.3).

9.5 Estimation Techniques

The collected data are used to estimate forest area, standing volume and volume increment of growing stock at different levels (e.g., national and sub-national levels). Uncertainty is expressed as variances of the estimates of means and confidence intervals, generally at the 95% level.

Table 9.3 Estimation of forest area

Variable	Estimator	Description
Percentage of forest area on the plot	$X_j = \frac{A_j}{A_{15,j}}$	The percent of forest cover on the plot $_j$. A_j is the forest area of the plot and $A_{15}, _j$ is the area of the circular plot with a radius of 15 m.
	$\hat{\mu}_z = \frac{1}{n_z} \sum_{j=1}^{n_z} X_j R_j$	The average forest cover on measured plots. $R_j = 1$ when the plot is measured; otherwise $R_j = 0$. $z = 1$ for areas with forest and $z = 2$ for areas with OWL. n_z is the number of measured plots where there is forest or OWL.
	$\hat{\mu} = \frac{1}{n} \left(\sum_{j=1}^{n} X_j R_j + N_{21} \hat{\mu}_1 + N_{22} \hat{\mu}_2 \right)$	Calculation of the total forest percentage of measured and not measured plots. N_{21} and N_{22} are the numbers of not measured plots with forest and OWL, respectively.
Total forest cover	$A_{forest} = \hat{\mu} \cdot A_{total}$	Calculation of the total forest area. A_{total} is the total land area, $\hat{\mu}$ is the estimated forest percentage and A_{forest} is the total forest area.

9.5.1 Forest Area

Forest area is estimated using proportion of area covered by forest observed on plots. An underlying assumption is that no forest land use exists for plots where no forest is observed on aerial photographs. Plots for which forest or OWL have been observed on the photographs but not in the field pose a problem because they contribute to underestimation of the estimate of total forest area. For estimating mean forest coverage, these plots are assumed to have the same mean forest cover as measured plots with forest and OWL. However, this assumption affects the estimator of the variance of the estimate of forest area. An estimator of the variance has been derived (Martinussen et al. 2008) (Table 9.3).

9.5.2 Volume Estimation

Volume estimates employ callipered *dbh*s and assessments of stand height. Height-diameter curves are used to estimate single tree heights using species, stand height, stand densities and other variables as predictor variables. These single-tree-height estimates permit more precise estimates of single tree volumes. The volume for each tree is then based on the *dbh* of the tree and the estimated single tree height and stand quadratic mean *dbh* (*Dg*) which are the input variables in the volume models developed for Danish forest tree species (Madsen 1987; Madsen and Heuser 1993). Estimates for the concentric plots are aggregated to per hectare values. If the plots are partitioned due to more than one stand being represented, both volume and area are estimated for each portion of the plot. The area of each portion is estimated using the polar coordinates of the line separating the portions and trigonometric relationships.

Volumes of trees removed by thinning between two inventories are estimated using the nearest height-diameter regression curve after the last measurement. This volume is added to the nearest main measurements. For individual callipering, the individual tree diameter and height estimated from curves are used. If the height is less than 3 m, regardless of species, the volume is estimated using a general model (Madsen 1987). If a volume model has not been chosen or if the form factor f (expression of the overall stem shape) is unrealistic then the volume of a coniferous tree volume is calculated using $f = 0.55$. The volume of a broadleaved tree is calculated with a form factor $f = 0.65$. For estimation of fellings, see Section 9.5.3.

More detailed measurements of individual trees are performed on two to six randomly selected trees for: tree height, age, crown height, fork height, stump diameter, seeds, tree health, moss and lichen absence or presence. Regeneration and harvest are assessed on the plots and non supplementary plots.

9.5.3 Estimation of Fellings

Diameters of stumps of trees felled within the past year are measured on a 10 m circular plot (same as 10 m radius volume plot). Species-specific models of the relationship between *dbh* and stump diameter are based on pair-wise measurements of *dbh* and stump diameter of standing trees. These models are used to estimate the *dbh* of the felled trees, and the estimated *dbh* is then used to estimate the height of the felled trees using the previously described height–diameter curves. Although the plot area for felled trees differs from that of standing trees, estimation of harvest volume follows the same procedures as for estimation of standing volume (Tables 9.4a, b and 9.5).

9.5.4 Increment Estimation

Site index is estimated for six tree species: beech, oak, Norway spruce, Douglas fir, sitka spruce and silver fir (*Abies alba* Miller) using dynamic fertility models (Nord-Larsen et al. 2008). Increment estimation begins with prediction of the production classes of individual tree species and plots based on a mathematical model of the tree species production overview. Production classes are predicted by interpolating between the tree species and production class height–age curves based on pair-wise

Table 9.4a Estimation of tree height, basal area and mean diameter of trees

Estimator	Description
$h_{ij} = 13 + (\bar{h}_j - 13)\exp\left(\alpha_1 \cdot \left(1 - \frac{\bar{d}_j}{d_{ij}}\right) + \alpha_2 \cdot \left(\frac{1}{\bar{d}_j} - \frac{1}{d_{ij}}\right)\right)$	Height–diameter regression model used to estimate heights of individual trees where *dbh* is measured. h_{ij} and d_{ij} are the height and the *dbh* of the *i*'th tree on the on the *j*'th plot. $\bar{h}_j$ and $\bar{d}_j$ are the mean height and *dbh* for the *j*'th plot, respectively.
$f_{d10} = \frac{A_{3.5}}{A_{15}}, f_{10 \le d40} = \frac{A_{10}}{A_{15}}, f_{d \ge 40} = \frac{A_{15}}{A_{15}}$	The relative plot area corresponds to the area of the concentric circle on which the individual tree is measured relative to the area of the entire plot (radius = 15 m).
$g_{ij} = \frac{\pi}{4} d_{ij}^2$	The basal area of the i'th tree on the *j*'th plot. Basal area is the cross-sectional area of the stem at breast height (1.3 m).
$G_j = \sum_{i=1}^{m} \frac{1}{A_{c,ij}} g_{ij}$	The basal area per hectare of the plot *j*. $A_{c,ij}$ is the area of the circular plot (with a radius of c = 3.5, 10, 15 m). g_{ij} is the basal area of the the *i*'th tree on the *j*'th plot.
$N_j = \sum_{i=1}^{m} \frac{1}{A_{c,ij}}$	The number of stems per hectare on the plot *j*. $A_{c,ij}$ is the area of the circular plot (with a radius of c = 3.5; 10; 15 m).
$D_{g,j} = \sqrt{\frac{4}{\pi}\frac{G_j}{N_j}}$	The basal area weighted mean *dbh* corresponds to the *dbh* of a tree with the mean basal area of the trees of the plot.

Table 9.4b Estimation of volume

Estimator	Description
$v_{ij} = F(d_{ij}, h_{ij}, D_{g,j})$	The volume of an individual tree v_{ij} is estimated using volume models based on the *dbh* and the height of the individual tree (height may be estimated) and the basal area weighted mean *dbh*
$\hat{V}_j = \sum_{i=1}^{n} \frac{1}{f_{ij}} v_{ij}$	The total volume of the plot. f_{ij} is the relative plot area for tree *i* on plot *j*
$\overline{V} = \frac{\sum_{j=1}^{N} A_{15,j}\hat{V}_j}{\sum_{j=1}^{N} A_{15,j}}$	Estimation of mean volume $\overline{V}$ per hectare
$\mathrm{var}(V) = \frac{1}{N-1}\sum_{j=1}^{N} A_{15,j}(\hat{V}_j - \overline{V})^2$	The variance of the volume per hectare estimate
$\overline{V} \pm t_{(1-\alpha/2;N-1)} \frac{s}{\sqrt{\sum A_{15,j}}}$	The confidence interval for the volume estimate. *t* is the *t*-value corresponding the two-sided significance level of α

measurements of height and age. The mean production class for each species and growth region is then predicted and then stand age is estimated using the production class height–age curves. Finally, the increment at each plot is estimated from the production class and the age of the stand, and the tree species models for the total production (Tables 9.6 and 9.7).

Table 9.5 Estimation of mean diameter of fellings

Estimator	Description
$d_{ij} = \alpha_1 + \alpha_2 d_{st,ij}$	For felled trees, *dbh* is estimated using a model based on stump diameter (d_{st}) α_1 and α_2 are model parameters

Table 9.6 Estimation of increment (Nord-Larsen et al. 2008)

Quantity	Estimator	Description
Site fertility	$H = H_0 \frac{t^{\beta 1}\left(t_0^{\beta 1} R + \beta_2\right)}{t_0^{\beta 1}\left(t^{\beta 1} R + \beta_2\right)}$ $R = Z_0 + \left[Z_0^2 + \frac{2\beta_2 H_0}{t_0^{\beta 1}}\right]^{0.5}$ $Z_0 = H_0 - \beta_3$	Estimation of height from tree species specific site fertility models. H_0 and t_0 are the observed height and age on the plot; t is the indexed age and H is the height at the indexed age (fertility). β_j, j=1,..3, are model parameters.
Height-age function	$H_{pt,j} = \frac{1}{\beta_{1,p} + \beta_{2,p} \cdot \exp\left(-\beta_{3,p} \cdot t_j\right)} + \beta_{4,p}$	Tree species specific and production class height-age function. $H_{pt,\,j}$ is the estimated height for the p'th production at the age t on the j'th plot. $\beta_{j,p}$, j=1,..4, are model parameters.
Total production	$P_{pt,j} = \frac{1}{\beta_{1,p} + \beta_{2,p} \cdot \exp\left(-\beta_{3,p} \cdot t_j\right)} + \beta_{4,p}$	Tree species specific and production class total production function.
Increment on the plot	$\Delta P_{pt,j} = P_{pt+1,j} - P_{pt,j}$	Calculation of the average increment on the j'th plot.
Average increment	$\overline{P} = \frac{\sum_{j=1}^{N} A_{15,j} \cdot \Delta P_{pt,j}}{\sum_{j=1}^{N} A_{15,j}}$	Average area-weighted increment in the forest. $A_{15,\,j}$ is the total area of the j'th plot within the 15 m circle.
Total increment	$P = \overline{P} \cdot A_{forest}$	P is the total increment in the forest. A_{forest} is the total forest area – see Table 9.3.

Table 9.7 Overview of trees species-specific production classes (Statens Forstlige Forsøgsvæsen 1990; Johannsen 2002)

Tree species	Growth region
Abies grandis	4
Abies grandis	1,2,3,5,6,7,8,9,10
Fraxinus excelsior	All
Pinus mugo	4
Pinus mugo	1,2,3,5,6,7,8,9,10
Fagus sylvatica	All
Pinus contorta	All
Pseudotsuga menziesii	All
Abies alba	All
Quercus spp.	All
Acer pseudoplatanus	All
Larix decidua	All
Abies procera	All
Picea abies	1,2,4,5,7,8,9,10
Picea abies	3
Picea abies	6
Picea sitchensis	1,2,3,5,6,7,8,9,10
Picea sitchensis	4
Pinus sylvestris	5
Pinus sylvestris	1,2,3,4,6,7,8,9,10

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Chapter 10
Estonia

Veiko Adermann

10.1 Development of Estonian National Forest Inventory

The total area of Estonia is 45,000 km^2, of which about 50% is forest. Large-area forest resource information, based on selective sampling, was conducted in Estonia in the 1990s.

Until the 1990s the national account of forest resources was based on stand-wise forest inventories. Regular inventories, every 10 years, were carried out on most of the forest land: state forest districts as well as the forests of collective and state farms. After independence was regained in Estonia in 1991, the ownership reform program was started. Part of it was land reform. Land, which had been unlawfully expropriated, was due to be returned to its initial owners or to their descendants. Borders of the state forests were restored accordingly to the year 1940, and the remaining land was left for privatisation. Changes were carried out in forest survey too: its administrative regularity disappeared, inventories of the forests within collective and state farms ended, and inventories of the first private forests were started. The planned economy, which had existed for 50 years, was replaced by a market economy resulting in intensive cutting of forests. As the land reform was not quick enough (and is still continuing today), a situation arose such that valid, current information was available only for one third of the Estonian forests.

Intensified forest management together with the land reform created a need for new inventory methods. The first tentative attempts to conduct regional forest inventories were carried out in 1992, 1996 and 1997 (Kohava 1999). The first National Forest Inventory (NFI) covering the whole country commenced in 1999. The basis of the present methodology is the Swedish Riksskogstaxering, although it has changed over time to accommodate local circumstances. With rather modest

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means the NFI is able to give a quite precise estimate of forest area and resources and cutting volume. The main objective of the NFI is to give a description of Estonia's forests, but the NFI also gives information about subjects such as the distribution of land by land use classes and the afforestation and growing stock of non-forest land etc.

The Estonian Forest Survey Centre conducted the NFI in 1999–2002. After its liquidation in 2003, the Department of NFI continues its work as a sub-unit of the administrative institution the Centre of Forest Protection and Silviculture (CFPS). It is responsible for the inventories, planning of the design and estimation methods, field assessments, as well as calculation and publication of the results. The law (Forest Act, §8) defines the tasks of CFPS (CFPS basic regulation, Regulation of the Minister of Environment no 43 from June 13, 2007) and accordingly the CFPS is responsible for NFI and forest resources.

The only possible alternative for a NFI in Estonia is the Forest Register (founded in 1999) of data from stand-wise forest inventories. Presently two thirds of the Estonian forests are covered with valid (less than 10 years old), forest management plans. Because management plans are not compulsory for forest owners in Estonia, the amount of actual information in the Forest Register will decline in the near future. At the same time, the Forest Register is limited to the data available in the management plans. Therefore, the Forest Register is not capable of giving an objective overview about the situation in Estonia's forests.

Methodologically, the NFI is designed as an annual research effort, which, using optimal methods must ensure continuous updating of information and the forest database. A grid of sample plots, covering the whole country, has been planned for 5 years with 20% or approximately 270–280 clusters assessed each year. Point estimates of quantities are calculated using data from the sample plots and form the basis for inferences to the entire population. Cluster sampling with partial replacement is used. Approximately 25% of the sample plots (and half of volume plots) are permanent. Because all permanent sample plots are re-measured every 5 years, the history of NFI can be divided into 5-year cycles (Table 10.1).

So far no significant changes have been made to the NFI methodology, although starting with NFI2, the design of the cluster grid has changed

Table 10.1 The national forest inventories in Estonia

Inventory	Years	Method	Number of clusters and plots per year
NFI1	1999–2003	Cluster sampling with permanent and temporary plots, entire country each year	Approximately 240 clusters, and approximately 4,400 plots, whence approximately 2,250 plots on forest land
NFI2	2004–2008	Cluster sampling with permanent and temporary plots, entire country each year	Approximately 275 clusters, and approximately 4,500 plots, whence approximately 2,300 plots on forest land
NFI3 (planned)	2009–2013	Cluster sampling with permanent and temporary plots	

(Adermann 2005). The aim is to achieve a uniform geographic distribution of sample plots and a constant spatial sampling intensity within the examined territory. The number of temporary tracts was increased and their sizes were decreased from 1,200 × 800-m to 800 × 800-m. In connection with the need for additional information the variables measured on sample plots have increased year-by-year. Because the Estonian territory is relatively small, systematic measures to cover the whole territory are encouraged. This enables the analysis of new variables and calculation of estimates based on the yearly assessments. Annual fieldwork leads to a more continuous work flow which permits the fixed field teams to functioning continuously rather than at multi-year intervals. The smallest unit for which NFI estimates are calculated is at county level (100,000–500,000 ha).

10.2 The Use and Users of the Results

10.2.1 General Use

Demand and use of the information generated by the NFI has increased considerably in Estonia, mainly because there is no alternative method for planning the sustainable management of forests, either on a State or international level.

After implementing the NFI in Estonia in 1999, the results were received with scepticism during the first couple of years. The NFI estimates of forest land, total volume, volume per hectare, and increment were all approximately 10% greater than for the earlier assessments based on stand level inventories (Adermann 2005). A significant difference appeared between the existing official statistics and the assessment carried out by the NFI, with respect to the cuttings – the difference was almost double. There may be several reasons: (1) the area of forest land increased by leaps and bounds in the 1990s because of conversion of previous agricultural lands; (2) the average growing stock had often been underestimated by stand level inventories because of visual assessments; and (3) the difference in cutting volume is due to the lack of official statistics on evaluation of cuttings on private property.

By 2001 the NFI assessments were used at the state level, as well as in compiling the strategic document "The Development Plan of Forestry until the Year 2010". From that period the NFI assumes an important role in taking decisions on effective management of forests and future prognosis – in large-area forest management planning such as planning of cutting at the national level. At present, the actual themes of the NFI monitoring system include global carbon cycles and observation of features related to the protection of biological diversity.

The Estonian NFI covers all land use classes, including all forests and other wooded lands in all ownership groups, including protected forests. Assessments of the forest resource by the NFI have become the basis for national and international statistics in Estonia, such as the Forest Resources Assessment (FRA) procedure of the Food and Agriculture Organization of the United Nations (FAO), the

Ministerial Conference on the Protection of Forests in Europe (MCPFE). The NFI also produces information on forest carbon pools and changes for the Land Use Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC 2008).

10.2.2 The Use of NFI Data in FRA 2005

NFI assessments of the Estonian forest resource were used first in 2004 for reporting to the Global Forest Resources Assessment (FRA 2005). Estimates in that report for the year 1990 are based on stand-wise inventory data, the quality of which is not often the best. Records for other wooded land are missing. Records for 2000 and 2005 are generated by the NFI. Noticeable, but inevitable, is the change of several assessments during the period 1990–2000, when the drastic change from stand-wise inventory statistics to the sample-based NFI took place. Therefore the changes during that period may seem to be larger than they were in reality. The extrapolation of NFI data to the year 1990 cannot be a solution in that case.

The basis of the assessment in the FRA 2005 report (FAO 2005) is the national forest definition. Starting from NFI2, FRA 2005 forest and OWL (FAO 2004) were used in parallel with the national forest definition (Forest Survey Instructions 2006). The aim was to present more precise and internationally comparable assessments in the future.

10.2.3 The Use of NFI Data in UNFCCC Including Kyoto Reporting

The Estonian NFI assessment is the primary source of information for greenhouse gas reporting on LULUCF sector to the UNFCCC. Also they are the primary assessments for reporting emissions and removals from afforestation, reforestation, deforestation (ARD) activities under the Kyoto Protocol. Area estimates of land use categories, corresponding to the Intergovernmental Panel on Climate Change (IPCC) Guidelines, are based on NFI data (excluding areas of cropland). The NFI also supplies information on soils, which is used to divide forest-land into mineral and organic soils as well as into undrained and drained lands. Most LULUCF related carbon pool change estimates are based on the NFI data. For details, see Greenhouse Gas Emissions in Estonia 1990–2006 (UNFCCC 2008).

10.2.4 The Role of NFI in Assessing the Status of Biodiversity

With the increased importance of natural biodiversity protection, the need to assess forests from that point of view has arisen. Therefore, to evaluate the state of forests and its changes over time, the need for a new type of monitoring resulted in biodiversity monitoring. Traditional NFI variables such as tree species composition, stand age and amount of deadwood enable researchers to evaluate several aspects of forest biodiversity. But the current NFI enables a lot more – it is a well-functioning monitoring system of the country, concerning overall aspects of biodiversity and based on the sampling grid covering the whole country.

Elaboration of the monitoring methodology of the biodiversity of forests was started in 2003 in Estonia. In cooperation with other specialists in that field many new items and indicators have been integrated into the NFI from the year 2005, including the registration of Natura 2000 habitat types. The aim is to better evaluate the condition of Estonian forests and OWL from the above mentioned aspect. Indicators in that context include structural variability, species or groups of species, outcomes of ecological processes or other features of biological process. The condition or existence values refer to the condition of the selected key elements and reflect the most important state of aspects of biological diversity. Variables and indicators are described in more detail in the Field Manual of the NFI (Estonian Centre of Forest Protection and Silviculture 2007).

The most important "traditional" indicators:

- Stand age and maturity class
- Tree species composition (all tree species are identified independently)
- Volume of dead wood by decay class and tree species
- Diameter distribution
- Management type of forests, including non-management

The most important variables and indicators added since 2005:

- Natura 2000 habitat type
- Correspondence to natural forest criteria
- The naturalness of forests (according to FRA 2005 definition)
- Presence of undergrowth, main species and coverage class
- Dominant adjacent land use category
- Forest appearance in 200 m radius
- Conjunction of stand compartments
- Amount of recent/old stumps
- Volume of decaying wood
- Existence of biologically old trees (by species)
- Human impact on ecosystem
- Set of species or species groups for which abundance is observed (e.g., the lichens Usnea spp., presence of Polyporus spp, hollows in trees, activity trails of woodpecker, holes in timber caused by Cerambycidae, etc.)

In 2007, European countries had an obligation to present an overview of the habitat types to the European Commission according to the Habitats Directive (Article 17(1), 92/43/EEC). Although reporting on the basis of expert opinions was permitted, the NFI reported the estimates about all Estonian forest habitat types based on statistical sampling.

10.3 Current Estimates

The area and volume estimates based on NFI 2006 (2002–2006) are given in Tables 10.2a and b. These quantities and their reference definitions were formulated in the Working Groups of COST Action E43.

Since 2005, the data measured and recorded by the NFI includes land that satisfies the UNECE/FAO and FRA 2005 definition for forest land, also that which does not necessarily qualify as forest land in Estonia due to the Forest Act. This dual forest area calculation using definitions simultaneously enables the submission of better estimates for international reports. The OWL definition was

Table 10.2a Basic area estimates from 2006

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Area of Lake Peipsi	152.9	3.4		–[b]
NFI coverage	All land classes including inland water (except Lake Peipsi)			
Forest land (reference definition, applied parallel with National definition since 2005)	2,391.1	52.9	Area min 0.5 ha and 10% crown cover with minimum height of trees of 5 m at maturity in situ (incl. temporary unstocked areas)	30.5
Other wooded land (reference definition, applied parallel with National definitions of land use classes since 2006)	173.8	3.8	Area min 0.5 ha and 5–10% crown cover with minimum height of trees of 5 m at maturity in situ or the combined cover of shrubs and trees >10%	13.1
Other land (reference definition)	1,957.8	43.3		22.3
Forest land in UNFCCC LULUCF reporting	2,251.9	49.8	Same as Forest land based on National definition	22.1
NFI provides LULUCF area estimates for the land use classes	Forest land, grassland (together with Estonian Agricultural Registers and Information Board), settlements, wetlands, other land			
Forest land (= productive forest land, National definition)	2,251.9	49.8	Area min 0.1 ha and 30% crown cover with average annual productivity more than 1 m^3/ha of stem wood (incl. temporary unstocked areas)	22.1
Forests (= Forest stands)	2,113.3	46.7	Area min 0.1 ha covered with trees with height more than 1.3 m and 30% crown cover with average annual productivity more than 1 m^3/ha of stem wood	22.1
Temporary unstocked forest land	138.7	3.1	Forest land, temporary unstocked areas	5.5
Total land area	4,522.7	100.0		–[b]

[a]Standard error.
[b]Assumed to be error free.

Table 10.2b Basic volume estimates on forest land from 2006

Quantity	Estimate	% Description	SE[a]
Growing stock volume on forest land			
million m^3	453.0		6.9
m^3/ha	201.2		2.3
Annual increment of growing stock on forest land			
million m^3	11.6		0.16
m^3/ha	5.5		0.05
Standing dead trees volume on forest land			
million m^3	15.0		0.58
m^3/ha	6.7		0.25
Dead wood volume (incl. standing dead trees)		Minimum length 1 m and minimum diameter 8 (15) cm	
million m^3	30.8		1.5
m^3/ha	13.7		0.61
Annual cutting average on forest land in 2001–2005			
million m^3	9.3		0.46
m^3/ha	4.1		0.15
NFI is main information source for the following carbon pool changes	Above-ground biomass Below-ground biomass Dead wood		

[a] Standard error.

also used, which includes fields that can be found in national land use classes such as bushes, natural grassland, swamps etc.

10.4 Sampling Design

The statistical design for the Estonian NFI is a systematic sample without pre-stratification. The grid of the sample plots covers the whole country and is planned as a 5-year cycle. The sampling grid is designed to meet the accuracy requirements at national level. The sampling intensity is the same throughout the whole country (Fig. 10.1). The sample (cluster) distribution is based on a national 5 × 5 km quadrangle grid, determined by the Lambert-EST co-ordinates system. The Estonian main map system is based on this density network.

Sample plots are organized into clusters to increase the efficiency of the survey (Fig. 10.2). The cluster co-ordinates give the location of the north-west (= permanent) or the north-east (= temporary) corner of the cluster. An observation unit is an individual field plot. The method of sampling with partial replacement is used. Plots are divided into permanent clusters and temporary clusters that form 800 × 800 m squares. All the permanent clusters (sample plots) are re-measured every 5 years.

No remote sensing is applied. Aerial photographs (in a scale of 1:10,000) are used only for orientation purposes in the field, for the identification of forests and change of land category in large non-forest areas (bogs, urban areas) and for defining “conjunction of forest compartments”.

Fig. 10.1 The sampling grid with the field plot clusters for NFI2

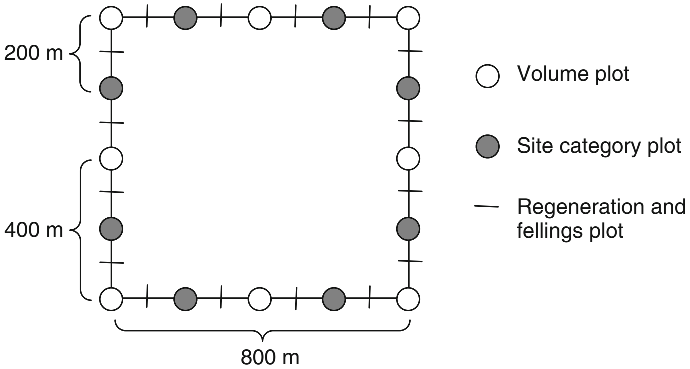

Fig. 10.2 Cluster and location of sample plots in NFI2

10.4.1 Sample Plots

Three types of circular fixed-radius sample plots are used (Table 10.3):

- Volume sample plots
- Site category sample plots
- Regeneration and fellings sample plots

The volume sample plots have more measurements including measurements of all trees using callipers. Volume sample plots are divided into permanent sample plots with a radius of 10 m and temporary sample plots (radius = 7 m) in a

Table 10.3 The sampling design in NFI2

Sample plot type	Area represented by one field plot (1,000 ha)	Mean distance of clusters in 5-year network (km)	Mean distance between clusters per year (km)	Distance between plots in a cluster (m)	Ratio permanent/ all plots
Volume plot	2.0	5.7	12.7	400	0.47
Site category plot	1.0			200	0
Regeneration, fellings plot	0.5			100	0

ratio of 1/1.13. In a cluster, the distance between volume sample plots is 400 m, between site category and the volume sample plots – 200 m, and between regeneration and felling and the volume sample plots – 100 m (Fig. 10.2). Site category plots and regeneration and felling plots are always temporary plots, with a radius of 7 m, although they may coincide with the 10 m radius permanent sample plots.

The sample plot radius depends on the assessed variables, as well as their values, for example, tree diameter. In addition to plots with the main radii of 10 and 7 m, where land use class is determined, plots of other radii are also used:

- All trees with *dbh* $\geq$ 80 mm are measured using callipers for volume sample plots with radii of either 10 or 7 m. Trees with *dbh* $<$ 80 mm are measured on temporary sample plots with radii of 3.5 m radius and in the first quarter section of permanent sample plots with radii of 5 m. Dead wood, including wood not usable for fuel wood, is measured on the sample plots with radii of 10 and 7 m.
- For assessments such as forest type, forest site type, drainage, damage, economic assessments, type of cutting, and several indicators of biodiversity, a sample plot is handled as a sector with a 20 m radius.
- Angle count plots are used in the selection of sub-sample trees.
- In regeneration sample plots of radius of 1 to 7(–10) m, trees with height less than 1.3 m are enumerated. The radius is chosen pursuant to the approximate number and homogeneity on sample plot so that the number of enumerated is sufficient.
- Plots of radii of 40 and 200 m are used for describing specific landscape patterns.

Plots with multiple land categories or stands of distinctly different growing stock or site variables are divided into sections according to detailed regulations. Part of the sample plot can remain ‘out’ where it is located directly on a coastline or on the border of the country.

10.4.2 Management

10.4.2.1 Personnel and Equipment

The Estonian NFI is given its task by the Centre of Forest Protection and Silviculture. The number of field staff is approximately eight people, including three team leaders. On temporary clusters, a field team of two persons is used and on permanent ones a working group of three is used. At present the whole territory is divided between three groups, carrying out cluster assessment. Fieldwork is carried out from June to November.

The field equipment is traditional – from callipers and tapes to Bitterlich-relascope and increment borers. Electronic devices are also used: GPS (Trimble GeoXT), height measurement instrument (Vertex®) and an ultrasonic distance measurer (Forester DME). A metal detector (Scout) is used to find a plot's hidden centre signpost. Handheld field devices (Trimble TSCe) were tested with the special programme of data capture in field conditions. Due to its small dimensions it has not been approved.

10.4.2.2 Quality Assurance

Before fieldwork, all the team leaders are annually trained on a course lasting 5 or 10 days. Methodological innovations are tested if needed. During the field season a proportion of sample plots are re-measured by a quality control crew. In practise, the need for check tests has been quite modest so far, because the group leaders have been very competent and have been involved with this kind of work for a long time. The data are checked manually in the field and daily as housework at the field crew lodging accommodation. The first computer-based data check takes place in data digitising. Final thorough data quality checking is done with the full database after the field season.

10.5 Estimation Techniques

All population units have equal probability of selection into the sample. Estimates are made as follows.

10.5.1 Area Estimation

Area estimation is based on the total land area and inland water, Lake Peipsi, which is known and assumed to be error-free. The number of plots (points) on land is a random variable. The estimate of the area, A_s, of land stratum, s, is estimated as the product of the known land area, A, of the administrative unit and the ratio, r_s, of the number of sample plots in the stratum and the total number of plots,

$$A_S = A.r_s, \qquad (10.1)$$

where

$$r_s = \frac{1}{n}\sum_{i=1}^{n} a_{si}, \tag{10.2}$$

a_{si} is the portion of the ith plot that is in stratum s, and n is the total number of plots.

10.5.2 Volume Estimation

National definitions in Estonia:

- The stem volume of a tree is defined as the volume of the stem over bark, from the ‘stump height’ to the top of a tree, excluding branches.
- The volume of growing stock of trees includes the stem volumes of all living trees, independent of species and with a minimum height more than 1.3 m.
- The standing volume of trees includes the volume of growing stock and the volume of standing dead trees which can be used at least for fuel wood; living and dead usable trees are measured for volume estimation in the same way.
- The volume of dead wood includes the stem volume of all dead trees with $dbh \geq$ 8 cm which can be used at least for fuel wood, and dead wood, not usable for fuel wood, with a length ≥1 m and diameter ≥15 cm.

The mean volume for a given stratum is the ratio of the sum of volumes for all trees on plots that belong to the stratum and the number of sample plots that belong to the stratum. The same regulation as in area calculation is valid for the divided sample plot. For total volumes, the mean volumes must be multiplied by the area estimate for the stratum in question.

Data models, such as the so-called ‘height curve’ (non-linear regression) for the estimation of height of callipered trees are based on measured data of sample trees as well as stand and site variables. Individual tree volumes are estimated using a model based on the tree species, measured *dbh* and predicted height. Separate models are used for trees with height <6 m.

10.5.3 Increment Estimation

For calculation of volume increment, the general models have been used so far. The model input variables are tree species, site quality class, age and relative density (Forest Survey Instructions 2006). Volume increment in the Estonian NFI means the increase in tree stem volume over bark, from above the stump to the top of the tree.

10.5.4 Drain Statistics Estimation

The total drain estimates in the Estonian forestry statistics are based partly on NFI data. Drain components such as cutting removals are reported by the NFI whereas the volume of natural losses is based on expert opinions. The use of permanent field sample plots should enable further precise assessments of drain estimates in the near future.

10.5.5 Actuality of Assessments

The Estonian NFI has so far published the inventory results annually. To prevent errors, inventory results of the last 5 years are combined during data processing. The possibility of alterations in time is taken into consideration. Earlier estimates are weighted less than current data with weights reduced per each passing year. For example, in the summary estimate for 2007, the weights W_y for year y were calculated as,

$$W_y = \frac{p_y}{\sum\limits_{y=2003}^{2007} p_y}, \tag{10.3}$$

where relative weight of the year

$$p_y = \frac{1}{2007 - y + 1} \tag{10.4}$$

This has been taken into consideration in the calculation of error estimates. Some assessments such as cuttings are based only on the data of the last year. Assessments in which time change is not considered, for example forest site types, drainage, are based on a 5-year average.

10.5.6 Error Estimation

Because all NFI estimates are based on sampling, they include sampling error. For estimating the relative errors in the area calculations Cochran's simple formula is used (Cochran 1977). In area error estimation spatial correlation among observations of variables is not considered. An error estimate of quantities depends not only on area but also on the variance of the components used to calculate the estimates. Relative error estimates are reported using a confidence level of 0.95. Because the reported results are the 5-year total assessments, the error assessments are calculated on the same principle. Results of every single year have been taken into consideration. For estimating the standard errors in the total volume calculations the random error of area assessments has been taken into consideration.

10.6 Options for Harmonized Reporting

Table 10.4 presents a brief summary of the status of harmonisation of the Estonian NFI.

10.7 Reporting and Prospects

The results of the Estonian NFI are provided for the whole country, separately for forests administrated by the Estonian State Forest Management Centre and for other forest owners. Some estimates for the 15 Estonian counties are also provided. The inventory results are available in the annual report "Estonian Forests. Statistics of forest resources and conditions by National Forest Inventory", and also on the Internet: http://www.metsad.ee.

The present period of NFI surveys (9 years) only allows for publishing mostly static forest parameters. For trend analyses a longer period is needed. The re-measuring of permanent sample plots started in 2004. Usage of permanent sample plots gives presumptions for several, so far not very precisely assessed, variables

Table 10.4 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Estimate	ND	RD	Remark
Forest area	Yes	Yes	Minimum 20 m width will be applied
Area of OWL	Yes	Yes	
Growing stock volume	Yes	Calculable	
Increment of growing stock volume	Yes	Calculable	
Standing dead wood	Yes	Calculable	
Dead wood	Yes	Calculable	
Above- and below-ground biomass	Yes	Calculable	IPCC default values are used
Litter	No, but potentially	No, but potentially	Default values (IPCC)
Soil	No	No	
Land use categories	Yes	Calculable	Excluding area of cropland
Afforestation Reforestation Deforestation	Calculable	Calculable	
Naturalness of forest	Yes	Calculable	
Forest type	Yes	Calculable	

(e.g., volume increment, drain statistics, ARD, biodiversity factors etc.) for getting better information.

The NFI will provide a baseline of where our forest resources are, and how they are changing over time.

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Chapter 11
Finland

Erkki Tomppo and Tarja Tuomainen

11.1 Development of Finland's National Forest Inventory

The National Forest Inventory (NFI) has been producing large-area forest resources information for Finland since the beginning of the 1920s. The first inventory was carried out in 1921–1924 (Ilvessalo 1927). The main reason behind the start of the inventories was the high interest in forest resources due to growth of forest industries since the late 1880s. Also, a need to establish a taxation system for forest incomes motivated inventories. So far (2009), ten inventories have been completed, the ninth one in 1996–2003 and the tenth one in 2004–2008 (Table 11.1). Field measurements for the eleventh inventory will be made in 2009–2013.

The sampling design in the first four NFIs was line sampling. The line interval in the first inventory was 16 km in most parts of the country. Plot measurements were carried out in line strips with a width of 10 m. The plot length was 50 m and the interval between plots on a line was 2 km. Similar sampling design with different sampling intensities were employed in the following three inventories up to 1963 (Table 11.1).

The lines were broken into detached tracts in the fifth inventory (1964–1970) and the plots on a tract were circular (Kuusela and Salminen 1969). This was a step towards a sampling design with clusters of plots. At the same time, the inventory became a continuous operation and proceeded by regions from south to north. The fixed-area rectangular sample plots were also changed to angle count plots (Bitterlich plots, called also angle count plots) (Bitterlich 1948). Trees are picked up using probability proportional to size sampling (PPS), the size being determined by the basal area of a tree at breast height. A new feature in the fifth, sixth and seventh inventories was the use of aerial photographs in Northern Finland (Poso 1972; Poso and Kujala 1971). A variation of two-phase stratified sampling

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Table 11.1 The forest inventories in Finland

Inventory	Years	Method	Number of plots or similar
NFI1	1921–1924	Line sampling with plots	13,347,610 m line on land, 93,290 stands, 4,919[a] plots on forest land
NFI2	1936–1938	Line sampling with plots	24,619,350 m line on land, 177,309 stands, 14,058[a] plots on forest land
NFI3	1951–1953	Line sampling with plots	22,507,000 m line on land, 30,809 (15,310 full plots, 15,499 rough tree plots) on forest land
NFI4	1960–1963	Line sampling with plots	10,546,000 m line on land 34,753 plots on
NFI5	1964–1970	Cluster sampling, detached lines, temporary plots on lines, photo interpretation in Lapland	~85,743[b] on land
NFI6	1971–1976	Cluster sampling, temporary plots, photo interpretation in Lapland	~85,743[b] on land
NFI7	1977–1984	Cluster sampling, temporary plots, Photo interpretation plots and ground plots in North Finland	141,053[c] on land 99,955 on forestry land
NFI8	1986–1994	Cluster sampling, temporary plots, satellite images for small areas	85,743 on land 70,955 on forestry land 60248 on forest land
NFI9	1996–2003	Cluster sampling with temporary and permanent plots, satellite images for small areas	81,249 on land 67,264 on forestry land 57,457 on forest land
NFI10	2004–2008	Cluster sampling with temporary and permanent plots, entire country each year (except regions 1 and 6, Fig. 11.1, each of them within one specific year), 5 years cycle, satellite images for small areas	69,388 on land 57,341 on forestry land 51,845 on forest land

[a]To calibrate the ocular stand assessments.
[b]Field plots.
[c]Field and photo plots.

(stratification based on aerial photographs) was employed in the fifth and sixth inventories and photo interpretation plots in the seventh inventory (Mattila 1985).

The field sampling intensity has been adapted to the variability in forests, taking into account the necessary budget constraints. The sampling intensity in Northern Finland has thus been less than that in Southern Finland.

Approximately one fifth of the sample plots have been made permanent since the 8th inventory in Northern Finland (1992–1994), and the establishment of such plots was completed for the entire country in the ninth inventory. The aim is to be able to obtain information of a kind that cannot be derived from temporary plots, e.g. the

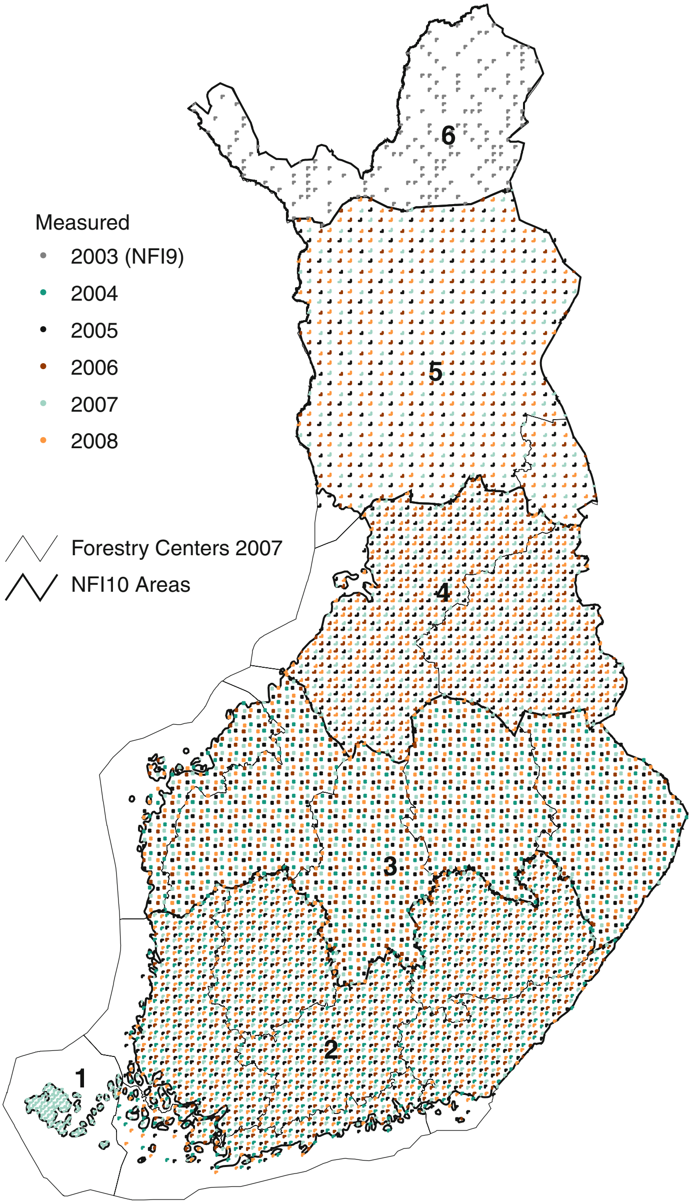

Fig. 11.1 The sampling intensity regions of NFI9 and NFI10 with the field plot clusters of NFI10 (**a**) Åland (region 1), (**b**) South Finland (region 2), (**c**) Central Finland (region 3), (**d**) North Finland (regions 4 and 5), (**e**) North Lapland (region 6) (for the clusters, see Fig. 11.2)

amount and structure of the drain, detailed changes in land use and other changes, and to reduce the standard errors of some estimates.

Forest statistics for small areas have been computed since 1990 using satellite images and digital map data, e.g. land use data, elevation data and soil data, in addition to field measurements. The role of this multi-source inventory (MS-NFI) is to be able to produce geographically localized information for areas smaller than is possible using field data only, e.g. for individual municipalities, which in Southern Finland typically have an area on the order of 10,000 ha.

Forest resource maps have been included among NFI products since the third NFI (1951–1953), first based on field data (Kriging smoothing in NFI9), and since the launch of MS-NFI, based, in addition to field data, on satellite images and digital maps.

The Finnish Forest Research Institute (Metla) has been responsible for the inventories: planning the design and estimation methods, field measurements, calculation of estimates and publication since the beginning of the inventories. The law and statutes concerning Metla define the responsibility to measure and monitor Finland's forest resources to Metla (law 1114/1999, statute 1140/1999).

11.2 The Use and Users of the Results

11.2.1 General Use

The information generated by the Finnish NFIs has traditionally been used for large-area forest management planning, e.g. for planning cutting, silviculture and forest improvement regimes at the regional and national levels, for decisions concerning forest industry investments and as a basis for forest income taxation. It has also provided forest resources information for national and international statistics such as the Forest Resources Assessment (FRA) procedure of the Food and Agriculture Organization of the United Nations (FAO) and the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2007). The NFI also produces information on forest health status and damage, biodiversity and carbon pools and changes in these for the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC 2007). NFI is main information source for the changes of the carbon pools above-ground biomass, below-ground biomass, dead wood, litter and soil organic matter (for litter and soil, NFI together with models and flux measurements). The NFI covers all forests in all ownership groups, protected forests and all land use classes, including inland water and sea water. It provides LULUCF area estimates for the land classes Forest, Grassland (together with Agrifood Research Finland), Wetlands (excluding peat extraction areas), Settlements, Other land. The NFI serves as a central information source and tool in forestry, the forest industry and forest environment decisions and policy making.

The municipality level estimates and maps obtained from the MS-NFI are employed by forestry authorities as an information source to assess municipality level forest resources, cutting possibilities, and to some extent, silvicultural regimes; by forest industries to assess cutting possibilities of forests by forest holdings; and by nature conservation agencies to assess landscape level biodiversity and the need and possibilities for forest protection; and by researchers for diverse research purposes.

11.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

The Finnish NFI has been the main information provider for greenhouse gas reporting for the LULUCF sector to the UNFCCC since the mid-1990s, and it will also play a central role in reporting LULUCF activities under Article 3.3 and 3.4 of the Kyoto Protocol.

The land use categories Finland reports are consistent with the IPCC Guidelines (IPCC 2003). Area estimates of land use categories are based on NFI estimates but excluding areas of cropland and peat production areas which are base on the statistical data. IPCC land use categories are formed on the basis of national land classes using other variables assessed in the NFI. The data from the four latest NFIs are applied in estimating time series of areas for land use categories from 1990 to the present.

Additionally, the NFI supplies information on soils, and it is used to divide forest land into mineral soil and organic soil forest land as well as into undrained and drained lands. New land use related variables and classifications are included in NFI10, because the data from previous inventories do not provide adequate information about land use transitions between IPCC land use categories. These additions are expected to give more accurate data for reporting emissions and removals from afforestation, reforestation and deforestation (ARD) activities under the Kyoto Protocol.

All forest related carbon pool change estimates are based either directly or indirectly on NFI data, except emissions per hectare from organic soils; similarly for the decomposition rate on mineral soils. However, all area information for both mineral and organic soils on forest land, wetlands (except peat production areas) and other land, comes from the NFI (Section 11.5.1). A comprehensive description of the system is given in the National Inventory reporting (Statistics Finland 2009).

11.2.3 The Role of NFI in Assessing the Status of Biodiversity

In addition to the conventional NFI variables, such as stand and tree age, tree species composition, diameter distribution of the volume of the growing stock and the number of trees, as well as soil and site variables, additional variable groups have been introduced to the NFI as a means of assessing the status of forest biodiversity. The most important additional variables are:

1. The abundance and the occurrence of ground vegetation species were assessed at the country level for the first time in the NFI3 (1951–1953), and then in 1985 and 1995.
2. The volume, decay class, roughness and appearance class of dead wood were introduced for the NFI9 (1996–2003) for all plots, and will stay in the succeeding inventories on the permanent plots, as well as the variables in groups 3 and 4.
3. Key biotopes (sometimes called key habitats) were introduced for the NFI9 (1996–2003). The key biotopes usually have rare vegetation composition, because they are located on distinctive sites. They maintain an important part of the biodiversity at local and landscape levels, because these sites often have diverse flora and fauna, which strongly differ from those of the surrounding areas. Many of the key biotopes are potential habitats for rare and threatened species. They are often small in area and are located within a regular stand or site figure. In the Finnish Forest Act, a part of key biotopes are considered. The land owner must leave those areas untouched, or only management regimes which support the naturalness of the site are allowed. Only natural and semi-natural key biotopes are considered in the Act. In NFI9 the aim was, nevertheless, to inventory all the biotopes regardless of their naturalness and separately evaluate the naturalness and ecological value of the biotope. The biotopes are described in more detail in the Field Instructions (Valtakunnan metsien 9. inventointi (1996–2003). The biotope variables are

   – Biotope class
   – State of naturalness
   – Management of the biotope compared to the management of the surrounding stand
   – Ecological value of the biotope
   – Biotope area that is within a circle of 30 m radius.

4. All tree species are identified independently of whether a tree belongs to the sample tree plot, i.e., to a plot with a radius of either 12.52 m in Southern Finland or 12.45 m in Northern Finland (Fig. 11.2), see Section 11.4, field plots, plot 3. This was introduced in the NFI9.
5. A plot for keystone individual trees, from the point of view of biodiversity, was a circle with radius the same as the maximum radius of the sample tree plot, i.e., either 12.52 or 12.45 m. These trees are of specified species and the minimum diameter depends on the species (Section 11.4.2). The trees were measured on centre point plots on forest land and poorly productive forest land. For calculation of results, the area of the centre point stand inside the circular plot was assessed (as tenth parts).

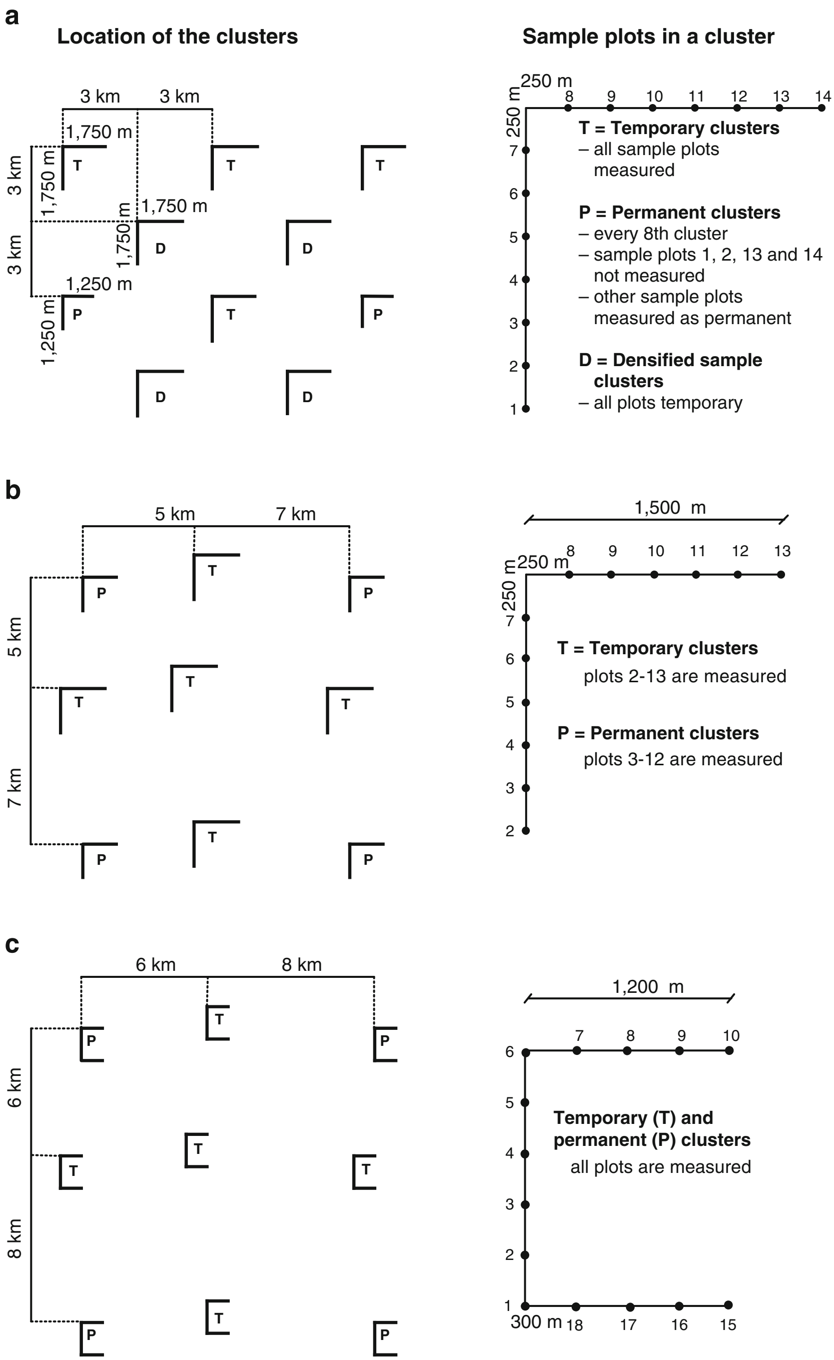

Fig. 11.2 Sampling designs of NFI10 (2004–2008) in different inventory regions: (**a**) region 1, (**b**) region 2, (**c**) region 3, (**d**) region 4 and 5 (in region 5, the design is same as in region 4 but the distances in NFI9 were 10 × 10 km, (**e**) region 6. Stratified sampling is used in region 6 (cf. Fig. 11.1)

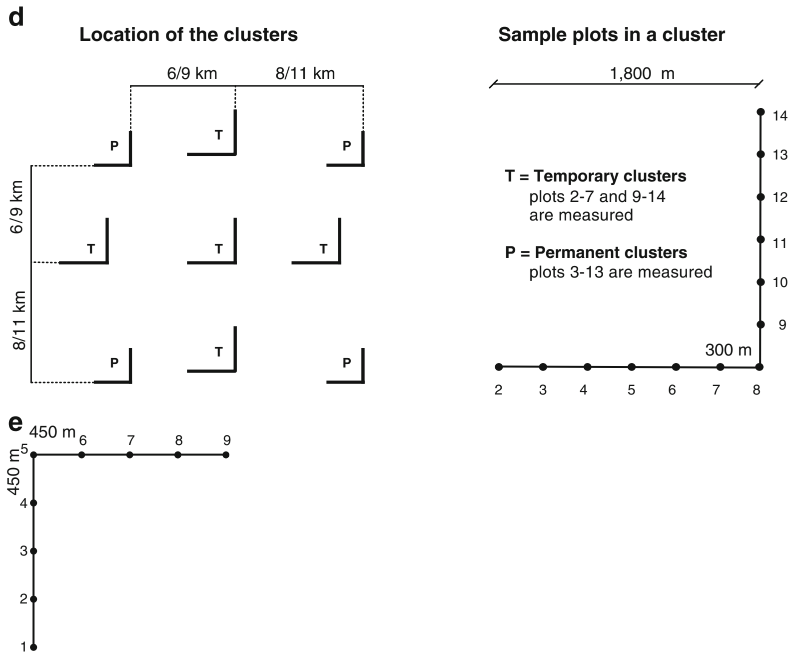

Fig. 11.2 (Continued)

6. The naturalness or the human impact on the ecosystem was introduced in NFI10 (2004–2008). It is assessed on the basis of the structure of the growing stock, dead wood, and accomplished silvicultural and cutting regimes. Five different categories are in use.

11.3 Current Estimates

The basic area estimates from NFI10 (2004–2008) are given in Tables 11.2a-1 and 11.2a-2 and volume estimates and volume estimates in Table 11.2b, together with the relevant definitions that were used. For Forest land, two parallel definitions are in use in field measurements, the definition used for international reporting, the TBFRA 2000 definition, adopted for the NFI in 1998 (UNECE/FAO 2007) (Table 11.2a-1) and the old national definition (Table 11.2a-2). The definition used for international reporting is same as COST Action E43 reference definition. Similarly, two parallel definitions are employed for other wooded land and poorly productive forest land (national).

Table 11.2a-1 Basic area estimates from years 2004–2008 (NFI10) based on the reference definition

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Forest land (reference definition, applied parallel with national definition since 1998)[b]	22,487	73.9	10% crown cover with minimum height of trees of 5 m at maturity in situ, minimum size 0.5 ha, minimum width for linear formation 20 m	81
Other wooded land (reference definition, applied parallel with national definition of poorly productive forest land since 1998)	826	2.7	5% crown cover with minimum height of trees of 5 m at maturity in situ, or combined crown cover of trees and shrubs 10%, minimum size 0.5 ha, minimum width for linear formation 20 m	31
Other land (reference definition)[c]	7,136	23.4	Land belonging neither to forest land nor other wooded land	80
Total land area	30,447	100.0		–[b]

[a]Standard error.
[b]Forest land in UNFCCC LULUCF reporting is the same as forest land based on the reference definition.
[c]The NFI provides LULUCF area estimates for the land classes forest, grassland (together with Agrifood Research Finland), wetlands (excluding peat extraction areas), settlements and other land.
[d]Assumed to be error free.

Table 11.2a-2 Basic area estimates from years 2004–2008 (NFI10) based on the national definition

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Productive forest land (national definition)	20,338	66.8	Average annual productivity ≥ 1 m^3/ha of stem wood over bark and over the rotation	83
Poorly productive forest land (national definition)	2,670	8.8	0.1 m^3/ha $\leq$ productivity <1 m^3/ha of stem wood over bark and over the rotation	58
Non-productive forest land (national definition)	3,156	10.4	productivity <0.1 m^3/ha over the rotation	61
Forestry roads (National definition)	154	0.5	Roads constructed for forestry use	8
Forest land (national definition)	26,317	86.4	Forest land plus poorly productive and non-productive forest land plus forestry roads	56
Other land (national definition)	4,130	13.6	Arable land, built-up land, roads, power lines	56
Total land area	30,447	100.0		–[b]

[a]Standard error.
[b]Assumed to be error free.

Table 11.2b Basic volume estimates from years 2004–2008 (NFI10)

Quantity	Estimate	Description	SE[a]
Growing stock volume on forest land and poorly productive forest land		Volume of stem wood of the living trees over bark, above stump until the top of the trees, breast height diameter (*dbh*) > 0 cm	
million m^3	2,201		11.1
m^3/ha	96.2		0.4
Annual increment of growing stock of trees on forest land and poorly productive forest land		Five years average of the increment of the volume of stem wood of the living trees over bark, above stump until the top of the trees, *dbh* > 0 cm	
million m^3 per year	99.2		0.7
m^3/ha	4.33		0.02
Annual drain on forest land and poorly productive forest land average 2004–2008		Includes the stem wood volume of the removals, cutting residues and natural loss	
million m^3 per year	68.99		n.a.[b]
m^3/ha per year	3.00		n.a.[b]
Dead wood volume		Minimum length, 1.3 m, minimum diameter, 10 cm	
million m^3	123.0		2.6

[a]Standard error.
[b]Not available (assumed to be small).

11.4 Sampling Design and Field Measurements

11.4.1 Sampling Design

Finland is divided into six regions, each with a different sampling intensity in NFI10 (2004–2008) (Fig. 11.1). The division is based on sampling simulation studies for NFI8 in North Finland (1991–1994), for NFI9 in South Finland (1996–2000) and for NFI10 in the entire country. The six sampling design regions represent different variability in land use classes and the values of forest variables (volume of growing stock by tree species). An observation unit is an individual field plot. For practical reasons and for increasing the efficiency of the field work, field plots are organized into clusters (Table 11.3, Fig. 11.2). Field plots cover all land use classes, including inland water and sea water. Total land area and water area estimates come from Land Survey Finland. For LULUCF reporting NFI provides areas for forest, grassland (together with Agrifood Research Finland), wetlands (excluding peat extraction areas), settlements and other land.

11.4.2 Sample Plots, Management, Personnel, Measurement Techniques, Quality Assurance

Multiple concentric plots were used in NFI9. On one hand, the radius of the plot depended on the variable in question and, on the other hand, on the value of the

Table 11.3 The sampling design in different regions

Region	Land area (1,000 ha)	Area represented by one field plot	Distance between clusters and distance between plots in a cluster in NFI9 and NFI10	Ratio permanent/ all plots	Remote sensing plots, type[a]
1. Åland	153	129.3	3 × 3 km, 250 m	0.12	
2. South	8,244	316.4	6 × 6 km 5 or 7 km × 5 or 7 km 250 m	0.22	
3. Central	7,062	343.4	7 × 7 km 6 or 8 km × 6 or 8 km 300 m	0.22	
4. Kainuu-Pohjanmaa	5,105	410.5	7 × 7 km 6 or 8 km × 6 or 8 km 300 m	0.23	
5. South Lapland	7,042	859.8	10 × 10 km 9 or 11 km × 9 or 11 km 300 m	0.24	
6. North Lapland	2,839	1996.5	Stratified sampling 450 m	0.23	
7. Total	30,447	437.7	–	0.23	

[a]Satellite images are employed together with field plots to calculate small area estimates.

variable, e.g. the radius of the tree plot, depends on the tree diameter. The plots used in NFI9 and NFI10 were:

1. The sample tree plot, measured on forest and poorly productive forest land, was an angle count plot. A tree with a diameter of d is thus measured on a circle with a radius of $r = 50d/\sqrt{q}$. The basal area factor q was 2 in Southern Finland (regions 1–3) and 1.5 in Northern Finland (regions 4–6). The maximum radius was 12.52 and 12.45 m, respectively and corresponded to breast height diametres of 34.5 and 30.5 cm, respectively. Where a relascope could not be used for judging inclusion reliably, the distance of the tree from plot centre and tree diameter at a height of 1.3 m were measured. Reducing the radius of a sample plot detracts very little from the reliability of the estimates, but it does noticeably reduce the fieldwork in some cases because the number of divided sample plots (i.e. sample plots belonging to two or more stands or strata) decreases. The use of maximum distance may also reduce errors caused by possible unobserved trees, usually located a long distance from the plot centre and behind other trees. Every seventh sample tree is measured as a sub-sample tree, see Fig. 11.3.
2. A plot for keystone individual trees from the point of view of biodiversity was a circle with a radius the same as the maximum radius of the sample tree plot, i.e., either 12.52 or 12.45 m (Section 11.2.3, Point 5).
3. All tree species, including those not on a sample tree plot, with a height of at least 1.3 m are identified from a circular plot with a radius of 12.52 m (regions 1–3) or 12.45 m (regions 4–6) but only on permanent plots (Section 11.2.3). These plots are measured on forest land, poorly productive forest land and waste

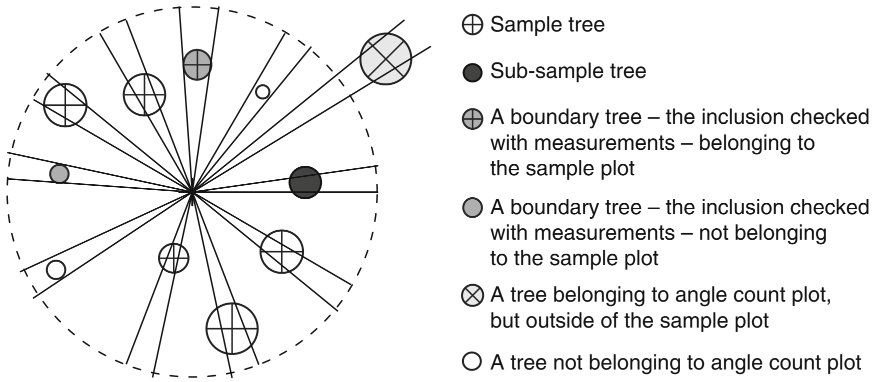

Fig. 11.3 A sample plot as used in NFI10. The maximum radius for trees to be counted was 12.52 m in Southern Finland (q = 2) (regions 1–3) and 12.45 m in Northern Finland (q = 1.5) (regions 4–6). Every seventh tree is measured as a sub-sample tree. The trees are counted by crews, starting at the beginning of the field season

land. For calculation of results, the area of forest land, poorly productive forest land and waste land inside the circular plot was assessed (as tenth parts).

4. Dead wood (also unusable even as fuel wood) is measured on centre point stands on forest land and poorly productive forest land with a circular plot with a radius of 7 m (Section 11.2.3). For calculation of results, the area of the centre point stand inside the circular plot was assessed (as tenth parts).
5. Key biotopes were recognized and classified on a circular plot with a radius of 30 m. The key biotopes were recognized on forest land, poorly productive forest land and waste land. For calculation of results, the area of forest land, poorly productive forest land and waste land inside the circular plot was assessed (as tenth parts) (Section 11.2.3).

The Finnish NFI is a task assigned to the Finnish Forest Research Institute, Metla, in Metla’s law and statute. When the Finnish NFI moved to a ‘rolling system’, i.e., the entire country is inventoried each year with a complete cycle length of five years, the number of field crews was increased from approximately 10–15 to 23–25 (of 1 + 2 or 1 + 1 persons). This meant a high increase in costs. A partial financial solution was to ‘lend’ some crew leaders from Forestry Centres from management inventories to the NFI. Also, co-operation with the forestry centres was further tightened, e.g., multi-source NFI data and 20 thematic maps with a spatial resolution of 25 × 25 m are be given to Forestry Centres use free of charge.

Field equipment is designed to measure only a few trees on each field plot. Electronic devices, in addition to global positioning system (GPS) and field computers, include only a height measurement instrument (Vertex). GPS is used also for orienteering to the plot.

An essential part of quality assurance is the annual training of the field crews. The training period is approximately 2 weeks. During field work, a proportion of field plots is re-measured and re-assessed by control crews. Five to six of the most experienced crews conduct control measurements part of their time during the field season. In practice, about 4% of the plots are re-measured for quality control.

The data are checked the first time in the field computers using logical checks. Further logical checks are done every day as in-house work by field crews using laptop computers at their places of lodging. The data are transmitted daily to Metla where further computer and manual checks are carried out during field season. A final, thorough quality check is done after the field season.

11.5 Estimation Techniques

11.5.1 Area Estimation

Area estimation is based on the total land area and inland water areas which are known or assumed to be error-free, and on the number of centre points of the plots. Briefly, the area estimate of a land stratum is the number of plot centres in the stratum divided by the total number of plot centres and multiplied by the known land area. Because the number of plot centres on land is a random variable (depending on the design), the area estimators are ratio estimators (e.g., Cochran 1977)

$$a_s = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} A = \frac{\bar{y}}{\bar{x}} A, \tag{11.1}$$

where a_s is the area estimate of the stratum s, A the land area on the basis of the official statistics of the Finnish Land Survey (Suomen pinta-ala kunnittain (The area of Finland by municipalities) 1.1.2008 2008), y_i is 1, when the centre point of the plot belongs to the stratum in question and 0 otherwise, x_i is 1 when the centre point is on land and 0 otherwise, and n is the number of centre points on land (Tomppo 2006). Examples of land strata are forest land, forest land categories on the basis of tree species dominance and tree species mixture, age classes, as well as forest land on the basis of accomplished and needed silvicultural and cutting regimes.

11.5.2 Volume Estimation

The stem volume of a tree in the Finnish NFI is defined as the volume of the stemwood over bark and above stump to the top of a tree. The volume of growing stock of trees includes the stem volumes of all living trees, independently of species, with minimum height of 1.3 m. The standing volume of trees includes the volume of growing stock of trees and the volume of dead trees that can be used at least for fuel wood. Living and dead usable trees are measured for volume estimation in the same way. Note that the volume of dead wood includes the stem volume of all dead trees with a minimum diameter of 10 cm and a minimum length of 1.3 m; these thresholds are used when measuring dead wood that is not usable for fuel wood. These measurements and estimates of dead wood are intended mainly for biodiversity assessment and LULUCF reporting. The non-living part of the standing volume is thus partly a subset of the dead wood volume and partly includes tree parts not belonging to the volume of dead wood (trees with $0 \leq dbh < 10$ cm).

The volume estimators are ratio estimators similar to the area estimators (Eq. 11.1). Briefly, to estimate the mean volume for a given stratum, the mean volumes of all trees belonging to that stratum are summed and divided by the number of field plot centre points in the stratum. The mean volume of a tree, means here, the volume per hectare represented by the tree. The indicator variable y_i in the nominator of Eq. 11.1 is replaced with the mean volume represented by a tree, or the mean volume of timber assortment class of interest represented by the tree, on field plot i when computing mean volume or total volume estimates. For total volumes, the mean volumes must be multiplied by the area estimate for the stratum in question.

Mean volumes (m^3/ha) and total volumes (m^3) are estimated as follows:

1. Volumes and volumes by timber assortment classes are predicted for sub-sample trees (every seventh sample tree) using volume and taper curve models (Laasasenaho 1982) and sub-sample tree measurements. The predictors are breast height diameter, $d_{1.3}$, diameter at the height of 6 m, d_6, (for trees with $h \geq 81$ dm) and h. Separate unpublished models for small trees are employed for trees shorter than a specified tree species-specific threshold, i.e. pine 4.5 m, spruce 3.5 m, birch 6.5 m, aspen 5.0 m and alder 4.0 m.
2. The volumes of sample trees are predicted by strata using the volume predictions for the sub-sample trees and measured and observed sample tree, stand and site variables, see below.
3. Mean volume estimates are tabulated by computation strata.
4. Area estimates are calculated for the volume strata.
5. Total volume estimates are tabulated by computation strata (Tomppo 2006).

The volumes of the sub-sample trees are predicted using the volume models of Laasasenaho (1976, 1982), the parameters of the models having been estimated for the following tree species or tree species groups: Scotch pine (*Pinus silvestris* L.), Norway spruce (*Picea abies* (L.) Karst.), birch (*Betula* spp.), aspen (*Populus tremula* L.), alder (*Alnus* spp.) and Siberian larch, (*Larix siberica*, Ledeb.). Models for pine or birch are used for other coniferous and broad-leaved tree species respectively. The explanatory variables of the models are (measured) diameter at breast height $d_{1.3}$, (measured) upper diameter $d_{6.0}$ (for trees of height at least 81 dm) and (measured) height h. The model is thus of the form:

$$\text{currentvolumeoverbark } v_{0b,0} = f(\textit{tree species}, d_{1.3}, d_{6.0}, h) \tag{11.2}$$

Separate unpublished models for small trees are employed for trees shorter than a specified tree species-specific threshold, i.e. pine 4.5 m, spruce 3.5 m, birch 6.5 m, aspen 5.0 m and alder 4.0 m.

When using angle count sampling (Bitterlich sampling), each tree represents the same basal area per hectare. It is thus convenient to work with quantities called form heights rather than single tree volumes when computing mean volumes or total volumes.

Form height is defined as

$$fh = \frac{v}{g}, \tag{11.3}$$

where v is the volume of a tree stem (or the volume of a timber assortment in a tree) and $g = \pi d_{1.3}^2/4$ is the basal area of the tree at breast height.

Form heights are predicted for sample trees by the non-parametric k-nearest neighbour (k-NN) estimation method. For each sample tree whose volume is to be predicted, the k nearest sub-sample trees are sought, the distance metric applied being Euclidean distance in the space of tree-level variables, tree species, $d_{1.3}$, and tree quality class, and stand-level variables, region code, cumulative day time temperature, site fertility class and stand establishment type.

The mean volume (m^3/ha) represented by a tree identified using angle-count sampling is

$$u = qfh. \tag{11.4a}$$

The maximum distance from the plot centre assigned to sample trees is 12.52 m in Southern Finland, where $q = 2$, and 12.45 m in Northern Finland, where $q = 1.5$. Trees greater in diameter than 34.5 or 30.5 cm, respectively, are counted in a fixed-radius plot of area $a = \pi R^2$, where R is the maximum distance. The mean volume represented by this type of tree is

$$u = \frac{g}{a} fh, \tag{11.4b}$$

where g is the basal area of the tree, $g = \pi d_{1.3}^2/4$.

The mean volume (m^3/ha) of a stratum is estimated using the formula

$$v_S = \frac{\sum_{i=1}^{n} \sum_{k=1}^{n_i} u_{i,k}}{\sum_{i=1}^{n} x_i}, \tag{11.5}$$

where v_S is the estimate for the mean volume of a stratum S, n is the number of centre points of plots on land in the region, $u_{i,k}$ is the mean volume represented by tree k in stratum S on plot i, n_i is the number of trees in stratum S on plot i and x_i is 1 if the centre of plot i belongs to stratum S and 0 otherwise.

The total volume estimate is

$$V_S = v_s a_s \tag{11.6}$$

where a_s is the estimate for the area of the stratum.

Note that the method takes into account plots shared between two or more calculation strata, so that trees belonging to the stratum in question in parts of a plot that do not include the centre are also included in the sum of volumes. It is assumed in volume estimation that the plot parts are distributed purely randomly between any two arbitrary strata s_1 and s_2. That is, for plots whose centre points belong to s_2, the expected area of the plot parts belonging to s_1 is the same as the area of the plot parts belonging to s_2 whose centre points belong to s_1.

11.5.3 Increment Estimation

Volume increment in the Finnish NFI means the increase in tree stem volume over bark, from above the stump to the top of the tree. The annual volume increment is calculated as an average over 5 years, based only on full growing seasons, assuming that tree growth has finished by August 1. Thus the increments for the 5 years preceding the inventory year are used for trees measured before August 1, and those in the inventory year and the four preceding years for trees measured on or after August 1. The phases in calculating the volume increment of a stratum are:

1. Prediction of the annual increments in sub-sample trees
2. Calculation of the average increments for sub-sample trees by diameter classes (at 1 cm intervals) and by strata, e.g. land use classes, site fertility classes and tree species groups
3. Calculation of the total increment for survivor trees in each stratum by diameter classes, by multiplying the average increment for trees in each diameter class by the number of sample trees in that class and summing the increments over the diameter classes
4. Calculation of the final increment adding the drain increment to that for the survivor trees. Drain includes cutting removals, cutting residues and natural loss. Note that only increments in trees that have survived until the inventory time can be measured. To calculate the total increment over the 5-year calculation period, the increments in the trees that have either been cut or have died naturally during the calculation period must be added to the increment of the survivor trees

The sub-sample tree variables employed in the volume increment calculation, in addition to those required in the volume calculation, are: bark thickness, diameter increment in 5 (full growth measured using borings on temporary plots) years at a height of 1.3 m (above ground) and height increment. The height increment is measured only for coniferous trees, while that for broad-leaved trees is predicted by means of models (Kujala 1980).

The change in bark thickness must be taken into account in volume calculations, and is done by introducing the ratio 'volume over bark divided by the basal area under bark (at a height of 1.3 m)'. The change in this ratio is assumed to be parallel to the average change calculated from a large set of sub-sample trees (Kujala 1980).

The details of the increment estimation are given in Tomppo (2006), see also (Kujala 1980).

11.5.4 Drain Statistics Estimation

The total drain estimates in the Finnish Forestry Statistics are based at the moment only partly on NFI data. Drain consists of the following components (Finnish Statistical Yearbook of Forestry 2008):

1. Cutting removals reported by forest industry companies
2. Non-commercial roundwood removals, e.g. contract sawing and fuel wood used in dwellings
3. Etimates of harvesting losses, including those arising from silvicultural measures, based on a special study by the Finnish Forest Research Institute
4. Volume of unrecovered natural losses (currently 4.9 million cubic metre)

When estimating the increment of the drain (the four groups above), the percentage increment in trees that have subsequently been cut or have died is assumed to be, on average, 70% of that in survivor trees. The fact that drain statistics are compiled by calendar years whereas inventory measurements in a region are carried out during the growing season, often partly before August 1 and partly on or after that date in the same region, must be considered when estimating the increment represented by the drain, which is done by dividing the inventory region into two sub-regions on an area basis.

11.5.5 Specific Estimation Questions Related to LULUCF Reporting

The method applied for area estimation differs from that applied for calculation of official forest resources results. Until the tenth NFI, field work proceeded by regions and the duration of inventory periods varied. A linear interpolation by regions is made to avoid abrupt changes in areas due to the NFI data used.

Finland applies the IPCC default method (increment and drain) to estimate carbon stock change in living biomass (IPCC 2006). The data applied to calculate carbon loss in tree biomass is based on annual statistics of the drain of growing stock. The increase in carbon stock is calculated on the basis of the increment of growing stock estimated from NFI data. The use of NFI data enables the calculation of the desired stratum's increment like the increment of mineral soils on forest land or organic soils on forest land. The problem due to the fact that statistics on drain are available for nationally defined combined forest land and poorly productive forest land, was solved by applying information on intermediate and regeneration fellings on different kinds of sites assessed in the NFI.

The carbon stock changes in litter, dead wood and soil organic matter are estimated with the Yasso model (Liski et al. 2005, 2006). Information about annual litter production from living tree biomass, natural losses of growing stock and harvesting residues are needed as input data for the model. Sub-sample tree level data measured in NFIs and the models by Repola et al. (2007) from 2009 onward, and before that the Marklund's biomass models (1988) for tree elements are applied to calculate the annual litter production from living trees. The natural mortality of trees is based on the NFI estimates of dead wood. NFI data is applied in the same way to divided harvesting residues into those on mineral and organic soils as in the case of the drain.

11.5.6 Error Estimation

The method used for estimating the standard errors of the area and volume estimates is based on the ideas presented by Matérn (1947, 1960) and is described and discussed in detail by Heikkinen (2006) and also presented in Tomppo et al. (2008). Matérn (1947, 1960) suggested the error variance, $E(m\text{-}M)^2$, as a measure of accuracy of the estimator m for the true value M of the unknown parameter. Matérn also proposed an estimator of the error variance.

Consider the cluster-wise residuals

$$Z_r = x_r - my_r, \tag{11.7}$$

where $x_r = \sum_{i \in r} x_i$ and $y_r = \sum_{i \in r} y_i$, with r a cluster of field plots i, and assume that the residuals form a realisation of a second order stationary (weakly stationary) stochastic process. Here m stands for a_s in Eq. 11.1. The variance of the process can be estimated by means of quadratic forms of the residuals. The method is applied by sample plot density regions as follows. Within each stratum, groups g of four field plot clusters

$$\begin{matrix} r_3 & r_4 \\ r_1 & r_2 \end{matrix}$$

are composed in such a way that each cluster belongs to four different groups; a cluster being in turn lower right, lower left, upper right and upper left member of a group of four clusters (with necessary boundary modifications).

An example of the quadratic forms, as employed in the Finnish NFI, is $T_g = (z_{r_1} - z_{r_2} - z_{r_3} + z_{r_4})^2/4$. This describes the within group variation. The standard error estimator (the square root of the error variance estimator) for each stratum is

$$s = \frac{\sqrt{k \sum_g T_g}}{\sum_i y_i}, \tag{11.8}$$

The method takes into account systematic sampling and spatial correlation of the variable in questions, and produces conservative error estimates in case of positive spatial correlation.

11.6 Options for Harmonized Reporting

Table 11.4 presents a brief summary of the status of harmonisation of the Finnish NFI. Note that forest is assessed in the field on the basis of both national and reference definitions. Tree level measurements for volume estimates and volumes correspond to the reference definitions. The national definition of forest type describes site fertility. The reference definition for forest type can be derived from other variables. The Finnish NFI is able to report forest area and the volume of growing stock on the basis of the reference definitions.

11.7 Current and Future Prospects

Only area information has been provided for land classes other than forestry land (forest land, poorly productive forest land, non-productive forest land, forestry roads) until NFI10. In NFI11, starting in 2009, trees are also measured on the

Table 11.4 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current Finnish NFI

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	ND ≠ RD, both are employed in the field
Growing stock volume	Yes	Yes	NFI	ND = RD
Above-ground biomass	Yes	Yes	NFI, models	ND = RD
Below-ground biomass	Yes	Yes	NFI, models	ND = RD
Dead wood volume	Yes	Yes	NFI	ND = RD
Dead wood volume by decay stage classes	Yes	Yes	NFI	ND = RD
Afforestation	Yes	Yes	NFI, statistics	ND = RD
Deforestation	Yes	Yes	NFI, statistics	ND = RD
Reforestation (Kyoto 3.3)	Yes	Yes	NFI, statistics	ND = RD
Forest type	No	No	NFI	Can be derived from NFI data

other land classes. This makes it possible to estimate above- and below-ground tree biomass and their changes for all LULUCF land categories in the future. The main principles for NFI11 sampling design are the same as for NFI10, except the number of field plots for a cluster will be slightly decreased and the number of the clusters increased respectively in such a way that the number of the plots will remain same as for NFI10.

The guidelines to assess the land use changes on the plots during past years have been revised and sharpened to NFI11 starting in 2009. The estimated reliability of the change assessments have been introduced for further in-house checks, using, e.g., aerial photographs. The time-span for the changes was extended 20 years.

The need possibilities for measuring additional field plots to decrease the errors of ARD estimates under Article 3.3 of the Kyoto Protocol during 2011–2012 will also be analyzed. Stratification will be considered both for the sampling design and estimation.

Methods will be develop to utilise the re-measurements of the field plots in the estimation, e.g., in the drain estimation.

The NFI research team has recently developed methods that use sparse pulse laser scanning data for management inventories. The potential of dense pulse laser scanner data in the NFI and the MS-NFI will be studied in the near future. The MS-NFI has so far used satellite images and digital map data in addition NFI field data (Tomppo and Halme 2004, Tomppo et al. 2008).

11.8 The Influence of COST Action E43 and Related Projects

The main definitions of the Finnish NFI for international reporting (related forest and volume of growing stock) correspond to the COST Action E43 reference definitions already in NFI9. However, the employed definitions have been checked in the course of COST Action E43. The importance of the minimum size of a forest patch (0.5 ha) and the minimum width for linear forest formations have been emphasized in the practical work, as well as a need to delineate the stand boundaries around a field plot separately for assessments based on national and international definitions if needed.

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Chapter 12
France

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12.1 Development of France's National Forest Inventory

The French National Forest Inventory (NFI) was created in 1958 as a department of the French ministry in charge of forests (until now, the Ministry of Agriculture). In 1994, the NFI was turned into a public institution supervised by the minister in charge of the forests.

Until 2004, the French NFI used a two-phase stratified sampling design (IFN 1985) covering one administrative division called 'départements' (NUTS 3 in the Nomenclature of Territorial Units for Statistics) at a time. Nearly 8 *départements* were inventoried each year. This methodology was developed in the late 1950s 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, although some dense forested départements had already been re-measured in 1976 (Table 12.1).

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). A field-verification was carried out on a part of the plots. The second-phase sample was a stratified sub-sample of the first-phase sample. The stratification variables were the ecological region, the ownership category and the type of vegetation. On the second-phase points, field measurements were conducted.

A mapping program using near-infrared aerial photographs was introduced in 1982 (Gard département), and the entire 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.

Data collected in the field since the beginning of the NFI concern forest resources (e.g. area of forests and other natural places, volume of growing stock, increment). In 1985, vegetation survey and soil description were introduced in a

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French National Forest Inventory, France

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Table 12.1 The forest inventories in France

Inventory	Years	Method	Number of plots
NFI1	1960–1980	Two phases stratified sampling	Average number of field plots: 1 for 130ha
NFI2	1976–1998	The stratification was based on	Total: 100,000 plots in
NFI3	1987–2006	forest region, ownership and	France surveyed in
NFI4 (only one part of France)	1998–2004	- on photo-interpretation before 1988 - on mapped forest categories since 1988	15 years
NFI5: new methodology	2004–2009	Systematic sampling scheme	Photo-interpretation: 55,000 plots/year Field observations: 10,000 plots/year (including 7,000 plots in forest)

part of the country, and these data have been collected all over France since 1992 (IFN 2005).

In 2004, in response to changes in the data needs and to enhance the possibilities of estimating the impact of major events like storms and droughts, the French NFI changed its methodology (IFN 2004). The sample, designed for 5 years, covers the entire French metropolitan territory. The annual sample is a systematic sub-sample of the 5-year sample also covering the entire country. Data are produced every year at the national level. The next 5-year sample will have the same characteristics. This system avoids observing the same plot twice within 5 years. All plots are temporary, but could be re-measured for purposes such as estimating the impact of major events such as important storms and drought.

For the annual sample (1 point for 10 km^2), land cover is interpreted using aerial photographs. Field observations are carried out on a sub-sample which is selected subject to the following considerations:

- Half the annual sample plots in forest (except in mountainous or low productive forests, where one fourth of the plots are visited in the field)
- One fourth of the photo-interpreted plots in heath areas (none 1,700 m above sea level in mountainous areas) and for hedges and tree rows.

The use of each year's results depends on the needs: a 1-year sample is sufficient to compute national results for a general overview. However, the comparison of two 1-year samples will be impossible in most cases because of statistically non-significant differences. Several years will be merged to obtain more precision at the national level and to produce results at the regional level. Depending on the need for statistical and temporal precision, merged data for 2–5 years will be used for national reporting. However, results can be updated every year using a moving average (Johnson and Williams 2004; McRoberts 2001; Roesch and Reams 1999).

The partition of the territory into nearly 50 ecological regions is under development. These regions will be used as a new scale of local reporting, independent of administrative divisions.

12.2 The Use and Users of the Results

12.2.1 General Use

The information produced by the French NFI is used by policy makers (Ministry of Agriculture and its local representatives) to elaborate the forest policy and to evaluate its consequences. The French authorities ask the NFI to compile the national results in a publication about the sustainable management of French forests (French Ministry of Agriculture and French NFI 2006), to fill in the tables for the international statistics such as Forest Resources Assessments of the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Commission for Europe (UNECE) and to provide data for the Ministerial Conference for the Protection of Forest in Europe (MCPFE). The NFI also produces data on carbon stocks and carbon pools in forests (Carbofor 2004) for the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC).

The national forestry board utilises the NFI results to define guidelines for the management of public forests. Researchers use NFI data for developing models for production, global change, biodiversity, carbon storage, and forest ecology. Industrial companies ask the NFI for information to evaluate the resources available in a specific area where they want to create a new production unit. Recently, many questions were asked by the Ministry of the Environment concerning biodiversity, ecology and available wood fuel.

12.2.2 The Use of NFI in UNFCCC Including Kyoto Reporting

The French NFI is one of the main providers of information on forests and other wooded land for the greenhouse gas reporting of LULUCF sector to the UNFCCC. It is the main information source for the carbon pools above-ground biomass, below-ground biomass and deadwood. It will also play a central role in reporting LULUCF activities under Articles 3.3 and 3.4 of the Kyoto Protocol by providing data on annual growing stock and growing stock increment for forests available for wood supply.

12.2.3 The Role of NFI in Assessing the Status of Biodiversity

The French NFI provides forest biodiversity indicators to the Ministry of Agriculture in the framework of the French forest sustainable management assessment. These biodiversity indicators are for example the number, the extent and the repartition of forest types, of tree and shrub species etc. The French NFI data are also used by forest researchers to study the impact of global change on forest biodiversity and on the spatial distribution of the main tree species.

12.3 Current Estimates

The forest resource estimates for France and their standard errors, as well as the associated descriptions are given in Tables 12.2a and b. The estimates are based on the 2005 forest inventory.

For Forest land, the definition changed in 2005 to comply with the definition proposed by Working Group 1 (WG1) of COST Action E43: the minimum width for windows and corridors changed from 25 to 20 m. The minimum area is 0.5 ha instead of 0.05 ha and poplar plantations are now included in forest.

A definition for Other Wooded Land (OWL) similar to the Temperate and Boreal Forest Resources Assessments (TBFRA) of 2000 and 2005 (UNECE/FAO 1997) or COST Action E43. However, some additional data are available for computing an estimate of other wooded lands:

- Tiny woods: stands wider than 20 m, with an area greater than 0.05 ha but less than 0.5 ha, and a crown cover by forest trees greater than 10%
- Heath: non-cultivated vegetation with width greater than 20 m, area greater than 0.05 ha, and crown cover by forest trees less than 10%

For FAO reporting on OWL, results are obtained using these categories.

Tree rows and hedges are also inventoried. The total length is estimated as well as dendrological and biodiversity variables. Tree rows are tree alignments whose width is less than 20 m and length is greater than 25 m and with regularity in tree diameter and spacing. Tree spacing is more than 1 m. Hedges are forest tree alignments whose widths are less than 20 m and lengths are greater than 25 m and with no interruption of more than 10 m and no regularity.

Table 12.2a Basic area estimates from 2005

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Production forests	14,980[b]	27.3	Forest available for wood production	65[b]
Other forests	728	1.3	Inaccessible forests due to relief or strong protection	n.a.[c]
Forest land	15,708[b]	28.6	Area greater than 0.5 ha, with a minimum crown cover of 10% with minimum height of trees of 5 m at maturity in situ	65[b]
Other land	39,165	71.4		n.a.[c]
Total land area	54,873	100.0		–[d]

[a]Standard error.
[b]Two years results; data collected in 2005 and 2006. The standard error will decrease with the inclusion of additional years.
[c]Not available.
[d]Assumed to be error free.

Table 12.2b Basic volume estimates from 2005

Quantity	Estimate	Description	SE[a]
Growing stock volume on forest land		Volume of trees with *dbh* > 7.5 cm including stump, bole up to 7 cm diameter and bark.	
- million cubic metre	2,400[b]		13
- m^3/ha	160[b]		n.a.[d]
Annual increment of growing stock of trees on forest land		Mean annual volume increment computed over the last 5 years. Includes the biological increment and the volume of trees that reached 7.5 *dbh* in the 5 last years. Annual increment is not measured in poplar plantations.	
- million cubic metre per year	103.1[b]		0.6
- m^3/ha per year	6.9[b]		n.a.[d]
Mortality million cubic metre per year	n.a.[d]	Volume of trees that died in the last 5 years.	n.a.[d]
Dead wood volume		Volume of standing and lying dead trees that died during the last 5 years. It includes only the trees with *dbh* > 7.5 cm.	
- million cubic metre	23[c]		n.a.[d]
- m^3/ha	1.7[c]		n.a.[d]

[a]Standard error.
[b]Two years results, data collected in 2005 and 2006.
[c]Result from year 2004.
[d]Not available.

12.4 Sampling Design

12.4.1 Samples

The French NFI uses a systematic nested sampling design based on a 1.41 × 1.41-km square grid (Cochran 1977; McRoberts 1999). It covers all land classes including inland water. The entire sample is composed of five identical systematic sub-samples with one sub-sample inventoried each year (Fig. 12.1).

The sample is divided into systematic sub-samples called levels. The level $n + 1$ can be obtained from level n taking systematically one plot out of two (Fig. 12.2). This is used to adjust the work intensity, depending on the type of work to be done and the quality of expected results.

The sampling is designed in such a way that annual samples have the same characteristics and sampling intensity (Fig. 12.3), and the workload stays similar every year.

12.4.2 Location of the Centre of the Point and Point Design

Every point consists of a main plot and a transect. The main plot centre is randomly selected in a 900 × 900-m square centred on the knot of the square grid. It is also the centre of the transect (Fig. 12.4).

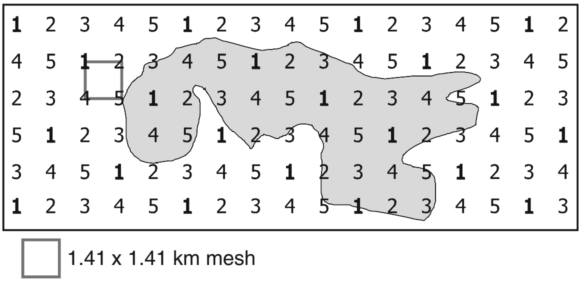

Fig. 12.1 Five-year sampling grid (numbers refer to the year of inventory)

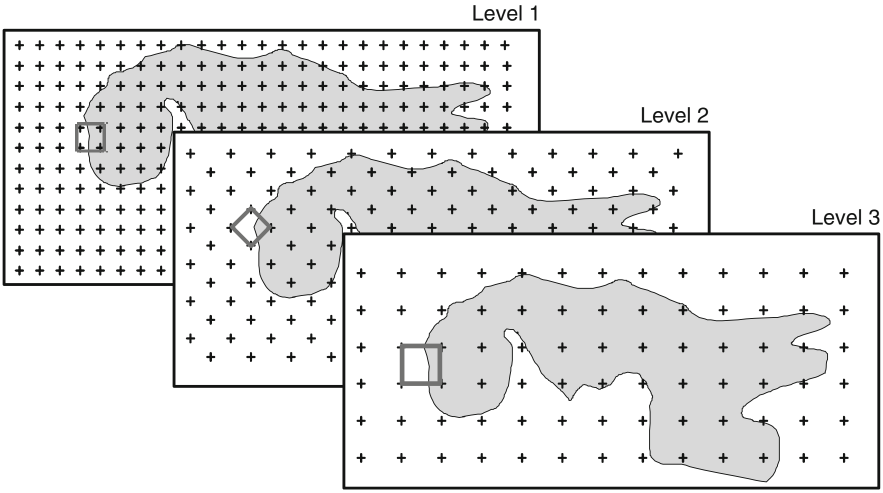

Fig. 12.2 Composition of the sample by sub-samples for the modulation of measurement intensity (levels). Sub-samples' intensity is divided by two at each level, but the grid remains square

In specific areas where many poplar stands are expected, three additional plots are added, creating a 450 m square cluster (Fig. 12.5). This enhancement gives more precision for poplar stands that are usually small and rarely detected using the normal sampling intensity.

In mountainous areas, data are collected on clusters of two plots located at the corners of a 450 m^2 (effective distance: 636 m).

12.4.3 *Use of the Modulation of the Intensity Using the Different Levels*

As presented previously, the definition of levels makes it possible to adapt the workload to the expected precision. In common cases, this modulation is used as follows:

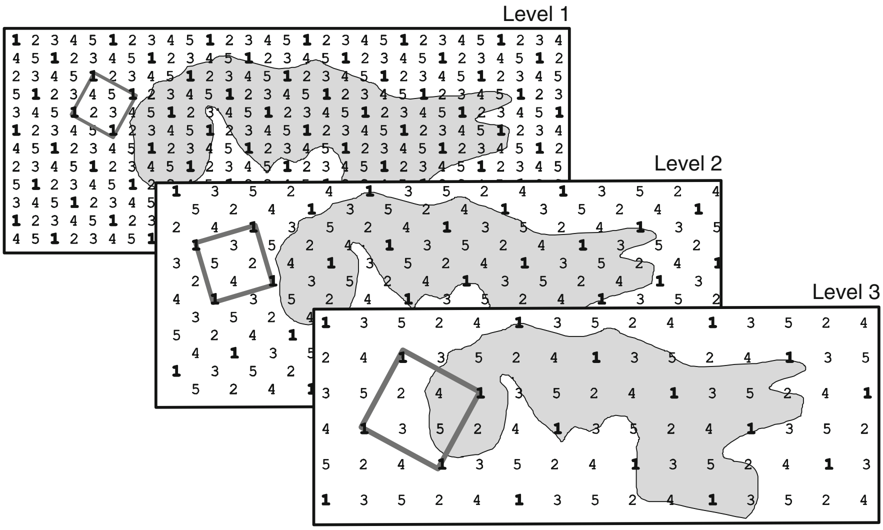

Fig. 12.3 Nested samples are comparable every year

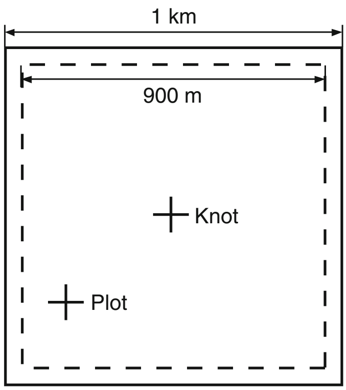

Fig. 12.4 Location of the plot in the 900 × 900 m^2 centred on the mesh knot

- Every plot of the level 1 sample (ground level, 1 plot for 2 km^2 in 5 years) is photo-interpreted: determination of the land cover (forest, heath, hedges, tree rows, agricultural land, other vegetation, inland water, artificial land without vegetation, natural land without vegetation).
- Plots from the level 2 sample (1 plot for 4 km^2 in 5 years) located in forest are visited in the field. If the type of land cover or use seen on the photograph is confirmed, normal measurement is done; if not, the real one is noted and field work is done according to the specifications for the corrected land use or cover category.
- Plots from the level 3 sample (1 plot for 8 km^2 in 5 years) located in heath or with hedges are inventoried.

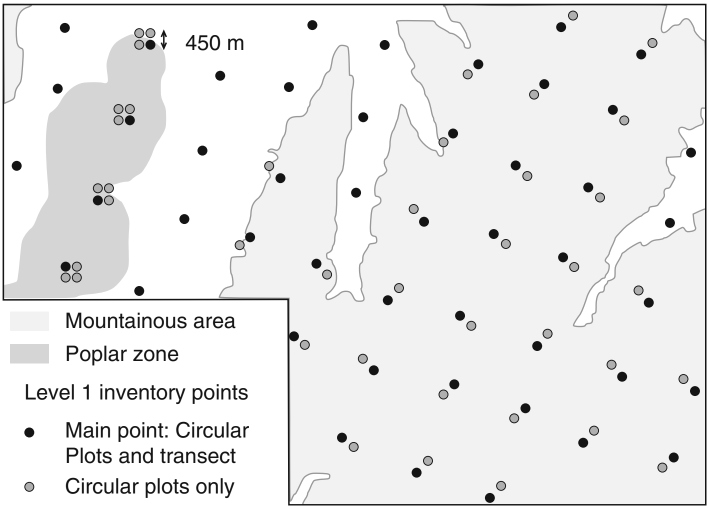

Fig. 12.5 Example of the entire sample with clusters in mountainous areas and in poplar zones

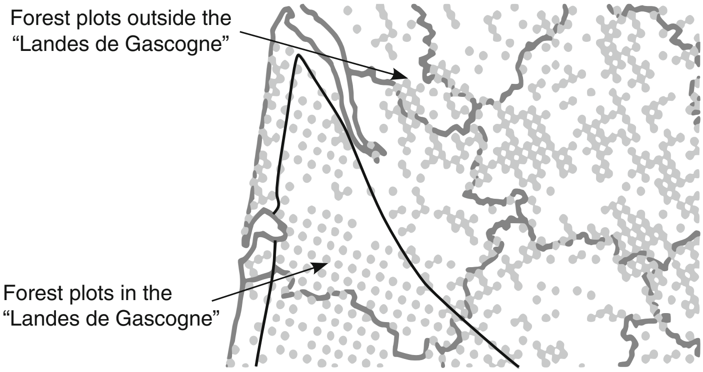

Fig. 12.6 Forest plot density is lower in the "Landes de Gascogne" forests than in other forests

To lighten the workload and reduce costs, some forest plots are visited only on the level 3 sub-sample (Fig. 12.6):

- Forests in homogenous regions (Landes de Gascogne: pine plantations in the south-west of France), because good precision can be achieved with less data.
- Forests in low productive areas (south-east poorly productive forests), because the expected precision of the inventory is limited.
- Forests in mountainous areas, because the assessment of plots is costly. The assessment on two-plot clusters compensates for the impact of the lower density.

Heath in places with altitude greater than 1,700 m a.s.l. are not visited in the field.

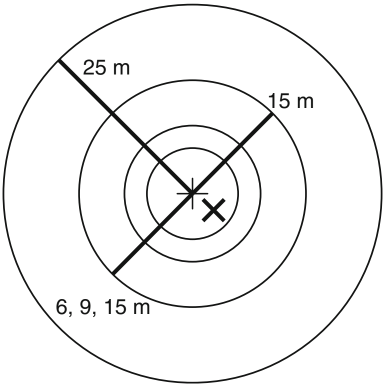

Fig. 12.7 Four concentric plots

12.4.4 Forest Field Plots

Information is collected in the field on four concentric circular plots with radii of 6, 9, 15, and 25 m (Fig. 12.7). Near the centre of the plot, the soil is described (humus, litter, horizons, depth, bedrock, structure, texture, etc.).

The following types of data are collected on the plots:

- 25 m radius: stand type, stand structure, stand composition, crown description and crown cover measurement, regeneration, topography
- 15 m radius: flora determination (species presence and cover), measurement of trees larger than 117.5 cm in circumference at 1.3 m
- 9 m radius: measurement of trees larger than 70.5 cm in circumference at 1.3 m
- 6 m radius: measurement of trees larger than 23.5 cm in circumference at 1.3 m

12.5 Estimation Techniques

12.5.1 Area Estimation

The total areas of the metropolitan territory and of the administrative divisions called ‘départements’ are known from the French National Institute of Geography and are assumed to be error-free. The usual area estimates are calculated using the field data (land use/cover) and the first-phase data (photo-interpretation), post-stratified by the forest map and the map of the départements. In some cases, a post-stratification using other variables can be envisaged (e.g. limits of protected areas). The estimation takes into account the use of different sampling intensities in specific areas (clusters/single plots; ground surveys at level 2 or level 3).

Forest area is estimated as the sum of wood, small wood and poplar plantations. If we use the term forest as defined in the reference definition of COST Action E43

Working Group 1, the definitions of the subcategories used in France are as follows:

- Wood is a forest (not composed of planted poplar) with an area greater than 4 ha
- Small wood is a forest (not composed of planted poplar) with an area between 0.5 and 4 ha
- Poplar plantations are forests composed of planted poplars covering more than 0.05 ha

In 2006, the size category of the poplar plantations changed in order to be recorded as forest, therefore only poplar plantations with area greater than 0.5 ha will be recorded.

Example of the usual estimate of the surface area of forest in a place '*A*':

S_A is the known total surface area of *A*. *A* is divided into strata using mapped information (forest types and the départements) as well as first-phase elements in *p* parts:

$$A = \bigcup_{k=1}^{p} A_k \tag{12.1}$$

The estimate of forest area in *A* is:

$$\hat{S}_A(forest) = \sum_{k=1}^{p} \hat{S}_{A_k} \cdot \hat{m}_{A_k}(I_{forest}) \tag{12.2}$$

where I_{forest} is the binary variable indicating forest or non-forest and $\hat{S}_{A_k}$ is the estimator of the surface area of the stratum A_k. This estimator is computed using the first-phase results. $\hat{m}_{A_k}(y)$ is the weighted mean value of the variable *y* in the stratum A_k and is obtained from

$$\hat{m}_{A_k}(y) = \frac{\sum_{i \in s(A_k)} w_i y_i}{\sum_{i \in s(A_k)} w_i} \tag{12.3}$$

where w_i is the weight of the point *i* and y_i is the value of *y* in *i*. The weight is inversely proportional to the local sampling intensity of the sample (it is higher when a lower intensity is applied, e.g. in the areas specified in 4.3).

The estimation of the surface area of the strata $\left(\hat{S}_{A_k}\right)$ follows the same principles but refers to the first-phase sample post-stratified using only mapped information. The surface areas of the first-phase strata are known.

12.5.2 Volume Estimation

The stem volume of a tree in the French NFI is defined as the volume of the bole over bark including stump above ground and to a cutting top diameter of 7 cm. The volume of growing stock of trees includes the stem volumes of all living trees, independently of species, with a minimum circumference of 23.5 cm at 1.3 m height above ground level along the main stem. The standing volume of trees includes the volume of growing stock of living trees and the volume of trees that have died in the last 5 years.

The volume estimate is calculated in a similar manner to the area estimate. The area of forest (or any specific category) in each stratum is estimated as indicated above. Then, on these areas, the weighted mean of the volume per hectare for the species of interest is computed using volume functions. The total volume by species in a category is the product of the sum of the area of the categories in the strata and the mean volume of the species of interest.

The volume of growing stock in forest is:

$$\hat{Total}_A(v,forest) = \sum_{k=1}^{p} \hat{S}_{A_k} \cdot \hat{m}_{A_k}(I_{forest}) \cdot \hat{m}_{forest\,\mathrm{in}\,A_k}(v) \qquad (12.4)$$

where $\hat{Total}_A(v,forest)$ is the estimator of the total volume of growing stock (function v) in the forest and $\hat{m}_{forest\,\mathrm{in}\,A_k}(v)$ is the weighted mean value of the variable volume per hectare in the forests included in the stratum A_k.

Volume functions are adjusted using data collected all over France using tree species, circumference at 1.3 m and total height as the main predictor variables.

12.5.3 Increment Estimation

Wood production in volume is evaluated over the last 5 years before the measurement. Two components are distinguished:

- Volume of recruitment that corresponds to the volume of trees that reach the threshold of 23.5 cm circumference at 1.3 m during the last 5 years.
- Volume increment of other trees above the threshold 5 years before. Each tree volume increment is estimated from the radial increment measured with a Pressler increment borer.

The estimate of the total volume increment (volume production) of the forest is obtained as the sum of the two components, with the same kind of estimator as the volume. The result is divided by 5 to provide an annual production rate.

12.5.4 Drain Statistics

The French NFI measures the circumference of stumps (results of thinnings and cuts) on plots when the trees have been cut less than 5 years ago. The volume of felled trees is derived from specific volume tables based on volume functions with stump circumference and species as inputs.

12.5.5 Error Estimation

Error estimation takes into account the two phases of the forest inventory, the post-stratification and the use of different sampling intensities presented in Section 12.4.3.

Post-stratification, especially when using the map (forest types and administrative zones), helps in reducing the statistical error without loss in the flexibility of the sampling design. For example, with the post-stratification, the standard error of the national forest area estimate is reduced by a factor of nearly 2.

12.5.6 Specific Estimation Questions Related to LULUCF Reporting

The method applied for area estimation under land use changes in inland France is based on the annual statistical survey of land use (Teruti-Lucas) conducted by the Ministry of Agriculture. This provides reliable sets of data by identifying the land use of several thousands of permanent plots at the regional level for periods 1981–1991, 1992–2004 and from 2004. Since NFI data are now annually refreshed, it will be possible to use these data in the future. In French Guyana, the NFI will provide data on land use modifications using remote sensing.

France applies the IPCC default method (IPCC 2003) to estimate carbon stocks change in living biomass. The data applied to calculate the increase in carbon stock is based on the NFI estimate of growing stock increment. Specific equations developed and published by Vallet et al. (2006) are applied at tree level and the result is then expanded to the whole growing stock resource. Losses of carbon stocks in living biomass are based on (1) the results of the annual survey on commercial drains conducted by the Ministry of Agriculture and (2) an estimate of the annual household fuel wood consumption. Until now, NFI data on drain has been partial because it only refers to the forests available for wood supply while a significant volume is felled in hedges and more generally in trees outside forests. The natural mortality of trees is based on the NFI estimate of dead wood.

The French NFI does not collect information on carbon stocks in litter and soils. Estimates of the amount of carbon stocks in litter and soil organic matter for several national forest types and for the other land use categories are based on data available in the national literature (Arrouays et al. 1999, 2001). Carbon stocks in litter and soil organic matter are assumed unchanged in forests remaining as forests.

Changes in carbon stocks of litter and soil organic matter are only due to changes in land use (A–B), from carbon stock of land use A to carbon stock of land use B within a 20-year period. Annual changes from land use A to land use B are derived from national research studies (Balesdent and Arrouays 1999).

12.5.7 Impact of Major Events

A new methodology was designed to be able to quickly produce information regarding the impact of major events like storms, drought, diseases etc. In case of such an event plots that were measured over the last years can be remeasured either in the field or using remote sensing. This new tool was used for the first time in January and February 2009 to estimate the impact of the storm Klaus (January 24, 2009) in the south-west of France. Results were produced nearly 1 month after the storm.

12.6 Options for Harmonized Reporting

The situation concerning harmonization of the French NFI is presented in Table 12.3. The forest definition is in accordance with the reference definition of COST Action E43.

12.7 Current and Future Prospects

A discussion is ongoing regarding development of a new methodology to assess drain with a greater level of accuracy.

Thanks to the flexibility of the new methodology introduced in 2004, drain will be now assessed using a field return approach. Field crews will be asked to return to plots that were assessed 5 years before to look for felled trees. Only plots that were in forest with a production function (primary or secondary function) and at least one measured tree are sampled for this operation. Nearly 3,000 plots per year will be reassessed.

The new inventory design implemented since November 2004 (annual field measurements at the national level) and a better accuracy in drain statistics could lead to a shift in the methodology to estimate carbon stocks change in living biomass for LULUCF reporting. The IPCC default method could be abandoned for the IPCC stock change method. Estimates of accuracy should be enhanced.

Table 12.3 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current French NFI

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	
Growing stock volume	Yes	No	NFI	The national definition does not include trees with $dbh \leq 7.5$ cm; the stem top is excluded whereas the stump is included Volume functions can easily be established to comply with the reference definition
Increment of growing stock volume	Yes	No	NFI	The increment definition is related to the national growing stock definition
Above- and below-ground biomass	Yes	Reference definition not available yet	NFI, models	
Dead wood	Yes	Reference definition not available yet	NFI	Only trees that have died during the last 5 years are part of dead wood
Litter	Yes	Reference definition not available yet	National literature, models	We assume that carbon flux in litter is neutral in forest remaining forest
Soil	Yes	Reference definition not available yet	National literature, models	We assume that carbon flux in mineral soils is neutral in forest remaining forest
Afforestation Deforestation Reforestation (Kyoto 3.3)	Yes	Reference definition not available yet	Inland France: statistical survey of the ministry of agriculture to assess land use changes of permanent plots spread all over the country French Guyana: NFI	Inland France, several datasets are available. 1982–1991: agriculture statistics; 1992–2004: Teruti survey; since 2005: Teruti-Lucas survey French Guyana: remote sensing and analysis of aerial pictures
Naturalness of forest	No	Reference definition not available yet		Can be derived from NFI data
Forest type	Yes	Reference definition not available yet		Can be derived from NFI data
Occurrence and abundance of vegetation species	Yes	Reference definition not available yet	NFI	All over France since 1992 All season survey

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Chapter 13
Germany

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13.1 Development of the German National Forest Inventory

13.1.1 Forest Surveys Before NFI

Since the beginning of the nineteenth century, forest statistics were recorded as part of agricultural statistical surveys. Their information content, however, was low, as the forest statistics were limited to forestry-holding based statistics, which chiefly included the number and area of holdings with forested properties.

In 1878, the first forest survey was conducted covering the entire German Empire as a combination of official statistics. On 7 July 1892, the Federal Council of the German Empire resolved to conduct a forest survey every 10 years. In the course of time, the forest survey became increasingly detailed. This considerably improved the informative character of the surveys. Nevertheless, these changes had negative effects on the comparability of the different forest statistics. The 1937 forest survey provided the most extensive information on the condition and the yield of the Länder of the German Empire.

In the first years following World War II, reliable data about the forests, particularly about timber stock, were very valuable. In 1946, the Allied Control Commission ordered a stand inventory in all four occupied zones to determine the timber stock. This inventory was inadequate, however, because of the lack of uniformity and incompleteness of the results.

Two years later, in 1948, a second forest survey was conducted in the American and British zones, which was extended to include the regions of the French

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occupied zone in 1950. This survey had methodological deficiencies as well, yet it was the first attempt to record the timber stock by tree species and age classes.

World War II and the post-war era in the German Democratic Republic (GDR) led to great shifts in forest ownership structures. The data from the forest survey of 1937 were outdated. Therefore, the German Economic Commission resolved to conduct a first extensive forest survey (begun on 1 April 1949) in the Soviet zone, in order to obtain information about the conditions of the forests for individual structural units and for the entire GDR and also to create a foundation for new forest management. All forest areas larger than 0.5 ha were recorded according to area size, type of ownership, tree species, yield class, soil type, timber quality grading and unstocked forest land. Based on work from 1956 to 1957, the GDR conducted random sample, large-scale forest inventories on the timber stock from 1961 until the early 1970s.

Between April 1961 and March 1962, the data for the first forest survey with reference date of 1 October 1960 were collected in the Federal Republic of Germany. The survey was based on holdings, i.e. all areas and parameters belonging to one economic unit (holding) were identified in the town in which the holding was headquartered. The results were evaluated and prepared by the statistical offices of the states (Länder) of Federal Rebublic. The Federal Statistical Office in Wiesbaden published them in four reports in 1964 and 1966.

Beginning in 1970, the GDR set up the Datenspeicher Waldfonds (DSWF), a nationwide forest management database. The forest cover data referred to partial areas (stands). The DSWF was centrally administered for all state managed areas in the GDR. It contained extensive data on the condition and the planned management of the forests. The status data were to be collected, on average, every 10 years. In the years between the data were updated with the aid of an increment model and based on notifications of changes by the forestry holdings. The DSWF was updated until 1 January 1993.

13.1.2 First German National Forest Inventory from 1986 to 1990

In the mid-1970s a debate commenced in the Federal Republic of Germany on how to best further develop the forest survey of the 1960s which resulted in the creation of a legal basis for the National Forest Inventory (NFI) in 1984. Questionnaires and estimates were finally replaced with a nationwide sample-based data survey according to mathematical and statistical methods. Hence, by the year 1990 – almost 30 years after the last survey – a comprehensive and reliable data base should be created for forest policy and trade policy decisions. It was a matter, in particular, of securing and strengthening the raw material function of the forest as well as preserving its protective and recreational functions. After many years of preparation the data of the first NFI (NFI1) were collected in the Federal Republic of

Germany (territory prior to 3 October 1990 including West Berlin) from 1986 to 1988. This large-scale inventory (reference date 1 October 1987) conducted on a random sampling basis according to mathematical-statistical methods was the first to provide information on extensive units, such as regional economic areas. It gave an overview of the extensive forest conditions and forest production potentials in the old federal states.

All of the sample ploots established for NFI1 were permanently, although not visibly, marked and the coordinates of all sample trees from 10 cm *dbh* were measured for distinct identification. This created the foundation for successive surveys of identical random sample objects and hence for the high reliability of future assessments of changes, increment and removals.

Even before the NFI1 had been evaluated, German reunification in 1990 led to the need for new information. However, the NFI1 could not be replicated in the new federal states, since too much time had already passed. Therefore, the initial inventory in the new federal states was linked with a subsequent survey in the old federal states. As an intermediate solution, the forest conditions in the new federal states were evaluated based on forest planning data (D*aten*s*peicher* W*ald*f*onds, DSWF)* as per 1 January 1993 analogously to the NFI1. Nevertheless, only limited comparability could be achieved since the evaluation was based on an entirely different kind of data situation. While NFI1 took relatively few random samples with great precision, the DSWF contained less precise data on approximately one million stands. In addition, the DSWF did not contain information on the assortment structure, damage caused by game, trunk damage and forest access. The precision of NFI1 could be appraised using its sampling errors, whereby in evaluation of the DSWF, collection errors and, in particular, entry and updating errors played major roles.

13.1.3 Second German National Forest Inventory (NFI2)

The federal government and federal states governments resolved to carry out a new German forest inventory in order to ascertain the extensive forest conditions and forest production potentials for the entire Federal Republic after German reunification. Due to the historical developments, in former West Germany it was a repeat survey and in former East Germany an initial inventory. The data of NFI2 were collected starting October 2000 until the end of 2002, then checked and evaluated until 2004.

In Germany, the federal states are responsible for forestry (under Art. 30 of the German Basic Law (*Grundgesetz*, abbreviated GG)). Only a few federal states conducted state forest inventories to plan forest policy tasks and timber market policy measures. There are too few state inventories and their survey methods are too inconsistent to reach a satisfactory, sufficiently corroborated national result. Because of the common forest policy intentions of the federal and federal states governments and the necessity to base these on a corroborated data basis, the federal and federal states governments resolved to carry out one German large-scale inventory.

To account for ecological and forestry developments and to meet the increased need for information, NFI2 covers new parameters that had not been taken into account in NFI1.

- Forest edges: As zones of transition from forest to open spaces, forest edges are important habitats for a wide variety of plant and animal species. The ratio between the length of forest edges and the forest area also serves as a measure of the size of forest areas and the diversity of the landscape.
- Deadwood is a special habitat and therefore an important component of the forest ecosystem. It contributes to the diversity of forest species. Surveying is limited to deadwood with a diameter over 20 cm at the thicker end or, for standing deadwood and stumps, a *dbh* of at least 50 or 60 cm diameter at felling height.
- The shrub layer and the ground vegetation allow conclusions about the silvicultural, hydrological and wildlife biological situation of a forest. During NFI2 the density of the ground cover was estimated in four stages for 14 different morphological plant groups (e.g. lichens, mosses, grasses, shrubs) as well as eight significant forest plant species (e.g. bracken fern, stinging nettles, blackberries).
- The comparison of the present composition of tree species at the sample plot with the composition of tree species of the natural forest community provides information on the naturalness of the tree species composition. The model of the present potential natural vegetation (PPNV) has been used as natural forest community for the NFI. It has been ascertained for each cluster by the experts of the federal states and has been described with regard to its main, secondary and pioneer tree species with regional and altitudinal zone differentiation. The PPNV is a proven comparative basis since it offers the safest evaluation basis through the acceptance of the site and flora changes that have occurred and the exclusion of possible future changes. Because it assumes the present site conditions, flora and tree species competitive relationships, in addition to indigenous tree species, permanently naturalised tree species also belong to the natural forest community. A wild plant species is considered an indigenous plant when it maintains itself as a population over a number of generations in the wild and without human assistance. The inventory crews examined the classification of the natural forest community on site and if necessary corrected it, in particular when azonale forest communities were found.

13.1.4 Other Forest-Related National Inventories

In addition to the NFI there are two other systematic sample-based inventories in German forests – the forest health inventory and the forest soil inventory. Their sampling grid was moved a few hundred metres away from the NFI. Since 1984 the forest health inventory has recorded crown condition and other data every year. The first forest soil inventory took place from 1987 to 1993 and the second from 2006 to 2008 (results are expected in 2013). Their basic grid is 8 × 8 km, but the sampling intensity for the forest health inventory varies form year to year and between the federal states. The 16 × 16 km sub-sample is part of the European level I system.

13.2 The Use and Users of the Results

Sustainable forest management and promotion of this management require knowledge of the state, structure, dynamics and productive capacity of the forests on individual holdings and at regional and national levels. This not only forms the basis for work and financial planning, but also influences many other areas, such as economic, traffic, environmental and structural policies. The NFI provides this important information on the extensive forest conditions and forest production potentials of the German forests. Furthermore, this information enables Germany to comply with its growing obligations in respect of international climate protection, to act for forest issues in the European Union and to provide international trade with up-to-date and comprehensive knowledge of its national resources.

The NFI must therefore meet the needs of various target groups: the political sphere, public administration, State forestry administrations or their legal successors as large forest owners, wood-based industries, forestry and timber associations and professional representations, research and training institutions, and the public.

The results assist in shaping policy: they provide justification and support for lines of argument regarding the development of funding principles (e.g. management of funds for renewable energies), funding projects (e.g. establishment of processing capacities) and research projects (development of products depending on the availability of raw materials, processing technologies).

The NFI is the public administration's source of information for national and international statistics on variables such as land use, land cover etc. The information is reported to, e.g., statistics for the Federal Statistical Office, the Food and Agriculture Organization of the United Nations (FAO) and EUROSTAT. These statistics are in turn used by the above target groups for their tasks. The statistics are of particular importance in connection with the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol: With regard to the subject of forests, the essential information comes from the NFI (forest area, volume of growing stocks and biomass and changes to these). Due to the Kyoto Protocol, an interim inventory was carried out on the NFI grid in 2008. Mention is also to be made of the nation-wide forest soil survey as another source regarding subterranean carbon stocks.

The NFI data are also used for assessing the requirements of biodiversity convention.

In research and training, the results are used as a foundation for information on forests and their development in general as well as for the purpose of clarifying specific questions on forests or surveying methodology. Fact sheets are frequently requested by schools.

Questions from the public as to methods and results are proof of the public's interest in forests and in the NFI.

The results have been published via various media: A brochure was published containing a succinct presentation of the essential results, methods and background information in a series of texts, tables and graphics. It is intended for the political sphere and for the public. The first edition of 10,000 copies was distributed in one year and was consequently reprinted (Schmitz 2004). Another brochure is intended for specialists and provides a deeper insight into the results via a section containing extensive and detailed tables. The methods are also explained in detail (Schmitz 2005a, 2006a, b).

The same pattern was used to draw up two brochures on the results of the future modelling of timber harvesting potential (Schmitz 2005b, c). They contain the results of a model on potential roundwood availability. The model takes into account the current usual rotation periods, target diameters and thinning procedures. Another volume of tables contains the parameters of the remaining stocks which have been estimated using the model (Schmitz 2005d). Explanations of NFI methods and background information, as well as a volume of tables with NFI results were printed in English for use in the international arena.

All results are available on the Internet in German and English (www.bundeswaldinventur.de). This enables the non-specialist to quickly become accustomed to the system, while also providing the specialist with the possibility of conducting a targeted search. It is, however, not possible to ascertain the uses to which the results are put. A DVD has been produced with the same content as that on the Internet site (Schmitz 2007a, b).

Large-scale consumers of wood have, subject to reimbursing the expenses, had their own timber stock models calculated by the Federal Research Centre for Forestry and Forest Products, which is responsible for technical execution of the NFI. This enables specific needs of the industry to be met.

Some federal states have issued their own publications, either in paper form or via the Internet, containing information for their territory, in some cases providing greater regional detail than the Federal Republic publications.

13.3 Current Estimates

The estimates of forest area and volume of growing stock for Germany with the associated definitions are given in Table 13.1.

Table 13.1 The estimates of forest area and growing stock volume

Quantity	Results for national definition	The national forest definition differs from the reference definition in that it…		Results for reference definition	
	Value	Includes…	Excludes…	Value (% of national value)	comment
Forest area (1,000 ha)	11,075.8	Areas from 0.1 to 0.5 ha Width from 10 to 20 m	Canopy cover <50%	Approx. 99.5%	Results from two federal states show no difference; canopy cover not considered Application of the reference definition is planned for the next NFI (2011–2012)
Volume of growing stock (million cubic metre)	3,380.6	Stump Newly dead trees	Trees <7 cm *dbh* Tree top (<7 cm diameter)	98.4%	All data available

13.4 Sampling Design

The NFI uses a systematic single-level cluster sample with regionally different sampling intensities. The reference grid of the random sample is designed to fulfil the precision requirements on the national level. In order to increase informative value, some federal states regionally have applied a denser sampling grid, so that in the end the sampling intensity over 21% of the area has been doubled and over another 26% quadrupled (Fig. 13.1 and Fig. 13.2).

The sampling grid (Fig. 13.1) is described by the NFI Administrative Regulation. The samples (clusters) lie on the intersection points of a national 4 × 4 km quadrangle grid. The north-south and east-west alignment of the quadrangle grid is aligned to the Gaus-Krüger coordinates system based on the Bessel ellipsoid. The sample grid is shifted relative to the grid of the crown condition assessment, because the latter is openly marked and therefore silvicultural influences on the grid of the crown condition assessment cannot be ruled out. The sampling grid of NFI1 has been expanded to the new federal states for NFI2.

Only plots in the forest are sampled (Table 13.2). The sample plots are given permanent concealed marks. In the old federal states, the sample plots measured for NFI1 are revisited and the forests thus reinventoriesd. The south-western corner of each cluster is allocated to this grid. It consists of a square with side lengths of 150 m. As a rule, each cluster has four plots (Fig. 13.3), fewer on border clusters. In every plot within the forest, data for different objects are surveyed in different survey units (e.g. sample plot circles).

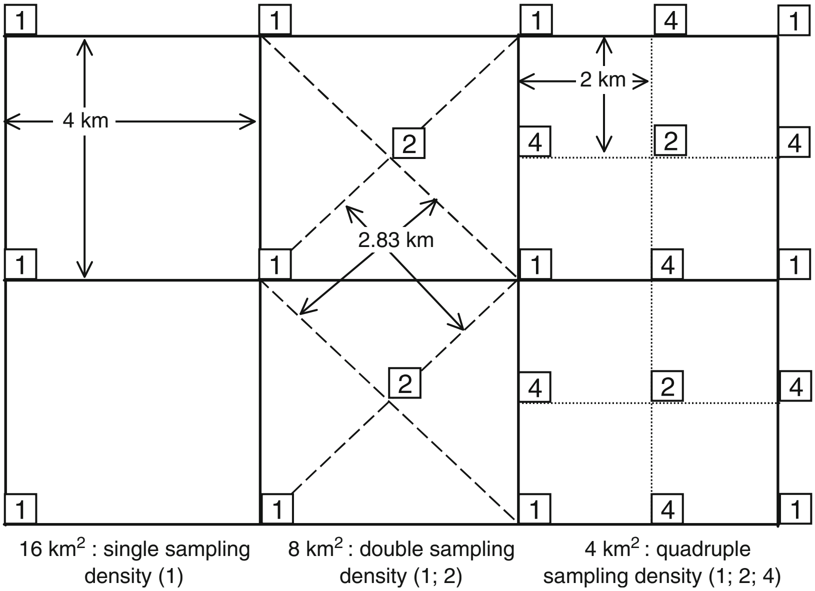

Fig. 13.1 Sampling scheme for different sampling densities

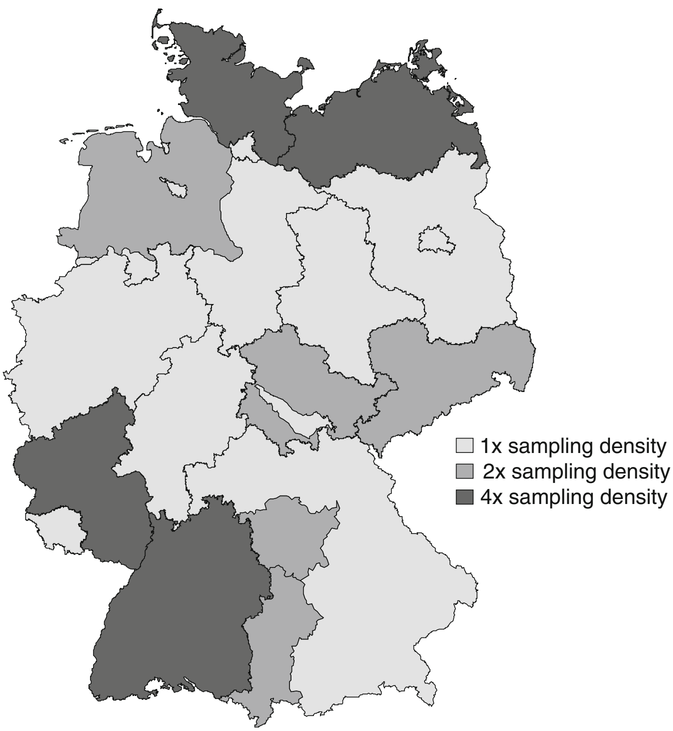

Fig. 13.2 Sampling density regions

Table 13.2 Sample size of the second German NFI

Federal states	Forest clusters	Forest plots	Newly measured sample trees of $dbh \geq 7$ cm	Remeasured sample trees of $dbh \geq 7$ cm	Total sample trees of $dbh \geq 7$ cm
Baden-Württemberg	4,598	13,619	39,534	57,184	96,718
Bavaria	2,711	7,747	24,640	37,840	62,480
Berlin	11	38	194	87	281
Brandenburg	809	2,676	17,908	0	17,908
Bremen	3	8	46	0	46
Hamburg	3	9	8	26	34
Hesse	694	2,202	5,852	8,626	14,478
Mecklenburg-Western Pomerania	1,911	5,351	36,035	0	36,035
Lower Saxony	1,495	3,794	12,223	11,225	23,448
North Rhine-Westphalia	841	2,228	6,267	8,885	15,152
Rheinland-Palatinate	2,811	8,391	48,989	7,720	56,709
Saarland	94	249	775	780	1,555
Saxony	900	2,565	16,400	0	16,400
Saxony-Anhalt	432	1,324	7,896	0	7,896
Schleswig-Holstein	734	1,632	4,507	5,854	10,361
Thuringia	749	2,266	16,130	0	16,130
Germany (all states)	18,796	54,009	237,404	138,227	375,631

13.5 Management

13.5.1 Organization

The composition and evaluation of NFI2 and the coordination tasks were undertaken by the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL). The Ministry assigned the national inventory administration to the Institute of Forest Ecology and Forest Assessment of the Federal Research Centre for Forestry and Forest Products (now Johann Heinrich von Thünen-Institut, Federal Research Institute for Rural Areas, Forestry and Fisheries) in Eberswalde. The national inventory administration worked directly with the federal state inventory administrations, chiefly to clarify specialised questions on the implementation and inventory controls and to check and evaluate the data.

The national inventory administration provided the federal state inventory administrations with all data from NFI1 needed for the repeat survey as well as with specially designed survey software. This contains programs for data management in the federal state inventory administrations, for data collection and validation by the inventory crews and for describing the tree species composition of the natural forest communities.

The data survey is the resposibility of the federal states. Each of the federal states established a federal state inventory administration, which was responsible at the federal states level for conducting NFI2. Their work encompassed duty planning

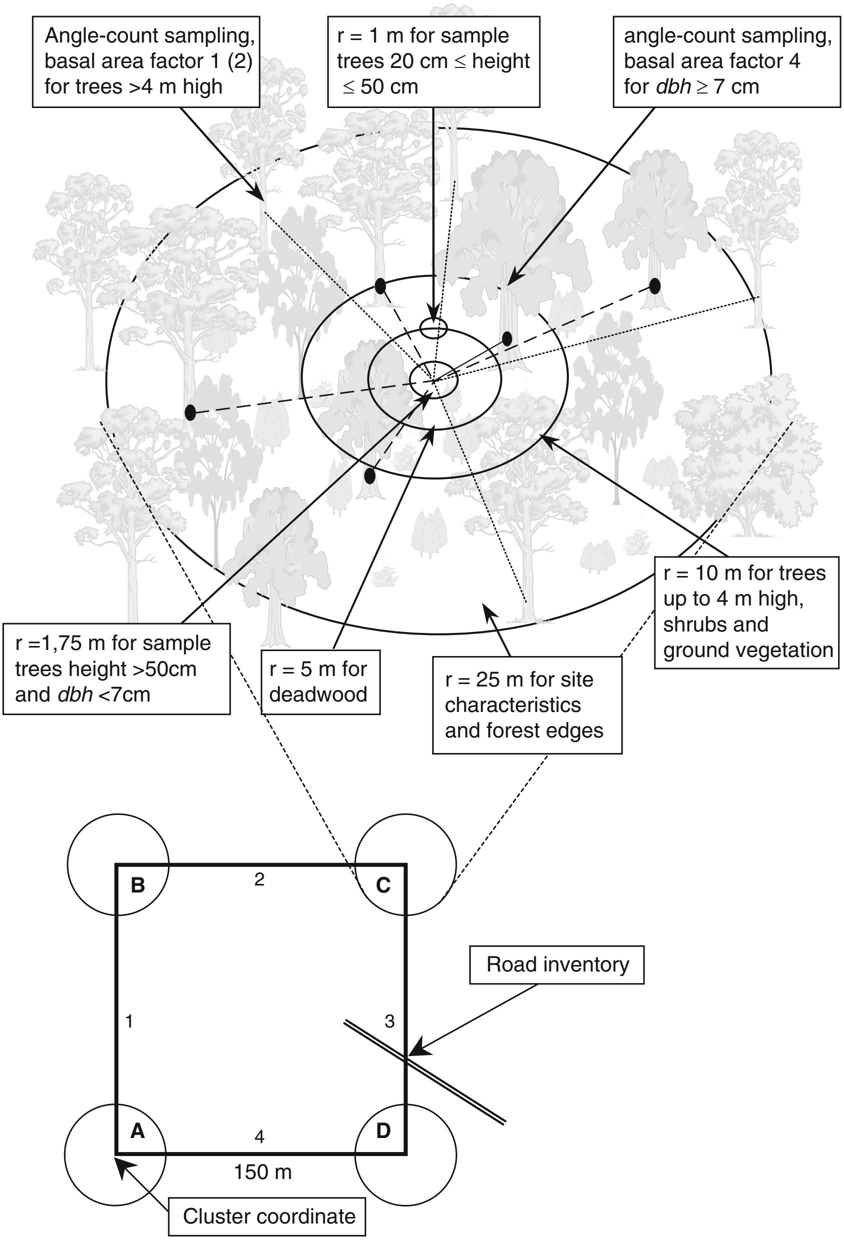

Fig. 13.3 Sample plots and clusters

and coordination of the inventory crews, the preliminary details of the cluster, controlling the survey work and data as well as sending the data to the national inventory administration.

The Federal Government and the federal states cooperated closely to develop the inventory procedure. A regular dialogue between the national and the federal state inventory administrations ensured that detail questions were uniformly clarified. Specific problems were solved by ad hoc working groups.

13.5.2 Inventory Crews

The federal state inventory administrations employed approximately 50 inventory crews to survey the clusters. Each team was composed of two forestry experts (at least one forest engineer or comparable qualification). The data was surveyed by private forest service firms in the following federal states: Brandenburg, Baden-Württemberg, Hesse, Lower Saxony (partially), North Rhine-Westfalia, Schleswig-Holstein, and Saxony-Anhalt. Forest personnel recorded the data in the remaining federal states.

Before fieldwork began, the BMVEL trained approximately 100 participants (staff of the federal state inventory administrations, leader of the inventory crews as well as their staff) in autumn 2000 and spring 2001. In addition, some federal states held their own training courses e.g. on recognising the natural forest community, plant species, etc.

The equipment of the inventory crews included: altimeter and distance metre, tape measure, diameter tape measure, relascope, compass (400 grade), upper diameter callipers for tree diameters to 30, 40, 60 cm as well as 7 m telescopic rod for upper diameter calliper. Mobile, robust field computers with built-in keyboards, active screens and with internal and external Flash RAM cards were employed for the data recording.

As a rule, the inventory crews entered the data on site in the survey database. Plausibility checks in the survey software pointed out data errors and contradictions on site and supported data controls. Program modules of the survey software supported the inventory crews in their search for the plots and sample trees on site.

13.5.3 Quality Assurance

A graduated control system in three steps ensured the quality of NFI2 data:

- Data control by the inventory crews: The survey software contained check routines for field data and for preliminary detail data. Data records were pre-initialised for all of the objects (clusters, plots, sample trees, stand edges) from the NFI1 that were known and clearly identifiable via coordinates. The tree species and *dbh* were displayed for each angle count sample tree from the NFI1. If these objects no longer existed, e.g. because a sample tree had been removed,

this was documented. Additionally, permanent attributes, such as coordinates, were preset in the repeat survey.
The plausibility checks were contained in the survey software and enabled the inventory crews to check and correct the recorded data on site after entry. Examples are renewed measurement of a value, surveying and replacing erroneous values, etc.

- Data control by the federal state inventory administration: The field database containing the recorded data of an inventory crew was transferred to the federal state database where it was checked again. The federal state inventory administration carried out the necessary corrections itself or passed on the erroneous data to the respective inventory crews for them to correct.
  The federal state inventory administration reviewed at least 5% of the clusters with quality control crews. Errors and deviations (particularly systematic ones) were clarified with the respective inventory crew. The federal state inventory administrations recorded the reviews with the ascertained deviations and had taken measures to assure the data quality.
- The national inventory administration checked the data from the federal states for plausibility and completeness using additional testing algorithms that were not contained in the software of the crews or the federal states. The data were transferred to a national database for the evaluation.

13.6 Estimation Techniques

13.6.1 Evaluation Steps

1. Predicting missing values, e.g.
   - Predicting tree height; tree height was measured only for a sub-sample of trees
   - Predicting upper diameter; the upper diameter was measured in West Germany only during the first NFI and in East Germany during the second NFI for a sub-sample of trees
   - Predicting *dbh* for trees which could not be measured at a height of 1.30 m
2. Calculation of derived attributes, e.g.
   - Calculation of individual basal area factors for sample trees near the stand boundary
   - Calculation of tree space, volume and increment for sample trees
   - Calculation of volume for pieces of deadwood
   - Calculation of attributes for plots, e.g. number of trees and volume per hectare
   - Virtual subdivision of the plots according to the area proportion of the tree species or age classes
   - Derivation of the naturalness of tree species mixture

3. Stepwise aggregation of data

– For plots and clusters
– For strata with uniform sample plot density
– For evaluation units

13.6.2 Angle Count Sampling (ACS)

This optical sampling method was first published in 1947 by Walter Bitterlich (1947, 1984). It uses sampling probabilities for trees proportional to their basal area. For the German NFI the sample trees are also measured. This considerably enhances the evaluation possibilities. Using this method, each tree trunk is focused on from the sample point with a prescribed horizontal angle α.

The constant $K = 10^4 \cdot \sin^2\left(\frac{\alpha}{2}\right)$
is called the basal area factor, often denoted by BAF. For the German NFI $K = 4$ m^2/ha, corresponding to a horizontal angle of $\alpha = 2.3°$. A tree is selected when its *dbh* is intersected by both sides of the angle α.

A sample tree z represents a basal area of K m^2/ha and a number of $N_z = \frac{K}{g_z}$ trees per hectare. where $g_z = \frac{\pi}{4} \cdot dbh_z^2$ is the basal area of the tree z.

The distance $R_z = \frac{dbh_z}{2 \cdot \sin\left(\frac{\alpha}{2}\right)}$ around the sample tree is called the marginal distance circle (Fig. 13.4). Every tree whose marginal distance circle includes the plot centre is a angle count sample tree. In other words: all trees not more than 25 times their *dbh* from the plot centre are sample trees. Only trees with *dbh* more than 7 cm and the marginal distance circle located inside plot centre stand are considered. Trees whose marginal distance circle is intersected by a stand boundary have a lower sampling probability. The part of the marginal distance circle area located within the stand is calculated for these trees. The coordinates of the stand boundaries have been accessed for that purpose.

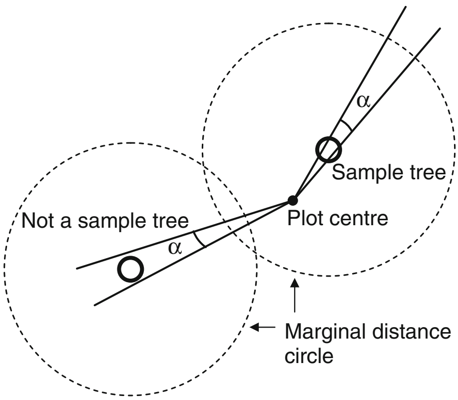

Fig. 13.4 Angle count method – selection of sample trees

The plot and tree-specific basal area factor K_z is

$$K_z = 4 \cdot \frac{Area\ of\ MDC}{Area\ of\ MDC\ inside\ the\ stand} \tag{13.1}$$

where *MDC* is the marginal distance circle.

These plot and tree-specific basal area factors give the basal area per hectare, represented by a tree at the stand boundary.

In the evaluation a value per hectare $\hat{X}_{ha}$ of an attribute x is estimated from the ACS as

$$\hat{X}_{ha} = \sum_{z=1}^{Z} \frac{K_z}{g_z} \cdot x_z = \sum_{z=1}^{Z} N_z \cdot x_z \tag{13.2}$$

where K_z is the tree specific basal area factor, g_z is the tree specific basal area, x_z is the value of the attribute x for tree z, Z is the number of ACS sample trees, and N_z is the number of trees per hectare represented by sample tree z. This formula is the basis for the calculation of all area-related stand attributes from the sample trees of the ACS.

13.6.3 Aggregation

The up-scaling is an aggregation of sample data for several levels and the calculation of sampling error. The systematic distribution of clusters with a random starting point results in a single stage cluster sampling. Because of the different sampling densities, post-stratified estimation is required. The strata h consist of areas with identical sampling intensities.

In principle all projections follow the same procedure:

1. Aggregation for plot and cluster level total value for plot j

$$x_{hij} = \sum\nolimits_{z=1}^{Z_{hij}} x_{hijz} \tag{13.3}$$

total value for cluster i

$$x_{hi} = \sum\nolimits_{j_{hi}}^{M_{hi}} x_{hij} \tag{13.4}$$

with x_{hij} value for plot j in cluster i in stratum h

M_{hi} : number of plots (forest and non-forest) for cluster i in stratum h.

2. Calculation of mean values per hectare total area (forest and non-forest) from the cluster values within stratum h.

Mean value per hectare total area

$$\bar{x}_h = \frac{\sum_{i=1}^{n} x_{hi}}{\sum_{i=1}^{n} M_{hi}} \tag{13.5}$$

variance

$$v(\bar{x}_h) = \frac{1}{\left(\sum_{i=1}^{n} M_{hi}\right)^2} \frac{n}{n-1} \sum_{i=1}^{n} \left(x_{hi} - \bar{x}_h \cdot M_{hi}\right)^2 \tag{13.6}$$

with n number of clusters (forest and non-forest). Most of the mean values per hectare total area are of low information value. Only the forest area per hectare total area has importance as a forest percentage. However, multiplication with the total area gives total final values for the stratum, e.g. forest area or timber volume.

The ratio of two mean values per hectare total area is called a ratio estimator. An often used ratio estimator has the forest percentage as denominator. This gives values per hectare of forest area, e.g. growing stock per hectare.

The up-scaling of mean values per hectare total area simplifies the calculation of sampling errors, because the denominator is not a random component. Note that the mean values per hectare forest area do have two random components.

3. Finally the results for the strata are aggregated to give results for the evaluation units. These are sums or area weighted means – according to the up-scaling projection type.

Many results are obtained in this manner, because up-scaling projections are not only made for the total inventory region but for multiple combinations of classification attributes.

13.6.4 Area Estimation

Forest area is estimated as the product of total area and the percentage of plots that are inside the forest (= mean value of forest area per hectare total area). Total area is preferably taken from official area statistics or from maps and is assumed to be error-free. Forest area is estimated for each stratum separately; the individual estimates are then added together.

Mixed stands are virtually subdivided into pure even-aged stands (equal age class and tree species group) for NFI estimation purposes. Most evaluations for tree-species groups or age classes refer to these virtual pure stands. The subdivision is carried out by calculating tree spaces for the main stand layer. Therefore tree-space functions of the form $F_z = \mathrm{a} + \mathrm{b} * g_z$ are used where g_z is the cross-sectional area = $\pi/4 * dbh_z^2$ and a and b are parameters specific to the tree species. Then the represented area of the plot is subdivided according to the area proportion of the tree species groups or age classes. Trees not belonging to the main stand layer are not considered because they do not cover additional area, but share their space with the main layer trees. Thus the estimates per hectare for tree species or age classes always refer to the main stand layer which is the layer with the main economic focus.

13.6.5 Volume Estimation

Volume estimation is based on sample trees with $dbh \geq 7$ cm selected by angle count sampling. For this purpose, taper curve (spline functions) that include the *dbh*, the diameter at 7 m height and the tree height are fitted and integrated for each specific tree. Because tree height and the upper diameter have been measured only for a sub-sample of trees, they are predicted with models for the others. Because bark thickness, top diameter, stem length and harvesting slash can be optionally included or excluded, predictions can be given for different growing-stock definitions. Furthermore it is possible to subdivide the tree volume into commercial assortments. This is especially important for the drain statistics estimation. The growing stock and the increment are always given as volume (m^3) of compact wood, i.e., above-ground stem volume with bark having a diameter of at least 7 cm. Stem tip is thus excluded.

13.6.6 Increment Estimation

In the old federal states, in which the NFI was being carried out for the second time, the increment for each sample tree was calculated as the difference in volume between the first and the second NFI. Account was taken of removed and ingrowth trees since the first inventory as well as trees assessed in both inventories. The respective missing data are predicted with models for trees which are documented in only one NFI. This relates in the case of the removed trees to their volume halfway between the successive inventories and in the case of trees newly grown into the sample to their volume at the first inventory. To predict these data, growth models have been developed using data from the sample trees assessed in both inventories. The projection of increment follows the same algorithms as shown in Section 13.6.3. The represented number of trees per hectare N_i for the trees measured in both inventories and for the trees newly grown into the sample is taken from the second NFI and for the removed trees from the first NFI.

Increment per hectare refers to the mean area of the evaluation region from both inventories. This avoids a bias and misinterpretation if the corresponding area – e.g. of the tree species – has changed. The mean annual increment refers to the time between the two assessments at the sample plot and is not calculated in calendar years but in vegetation periods. This is not identical to the time between the appointed dates of the inventories and is different for the evaluation units.

13.6.7 Drain Statistics Estimation

The volume of cut and dead trees is estimated from the removed trees. Their volume is predicted using models for the point in time half-way between the successive inventories. The number of trees represented per hectare N_i is taken from the first NFI. The volume is normally given in m^3 excluding bark, top and harvesting slash. The top diameter depends on *dbh* and tree species, e.g. 12–15 cm for a tree with a *dbh* of 30 cm.

Because the first NFI only assessed trees with $dbh \geq 10$ cm the drain estimates do not include trees which were smaller than 10 cm at this time. This gap between 7 (NFI2) and 10 cm (NFI1) is of low economic importance.

The volume of cut trees per hectare refers to the area of the evaluation unit at the time of the first NFI. As for increment, the mean annual results for cut volume refer to the time period between the two assessments at the sample plot, which is not identical to the time between the appointed dates of the inventories.

13.6.8 Estimation of Changes Between NFI1 and NFI2

Because the inventory methods have been modified between the first and second NFI, estimates of change are not simple differences. To obtain unbiased estimates for the changes between the first and the second NFI, data from the first NFI have been evaluated with the methods used for the second NFI. Furthermore only the intersection of the two samples was considered.

13.6.9 Software

Prior to actual up-scaling, the database from the survey has been completed by:

1. Predicting missing values, e.g.
   - Tree height (to decrease measurement effort it was only measured on a sub-sample of trees)
   - The diameter at 7 m height (to decrease effort, it was only measured in the old federal states during NFI1 and in the new federal states only at the south-western plot and only on a sub-sample of trees)
2. Calculating derived variables from the measured values, e.g.
   - The tree-specific basal area factors for sample trees at stand edges
   - The tree space, the stock and the increment for sample trees
3. Deriving parameter values on the plots, e.g.

– Virtual breakdown of the main stand according to the tree space percentage of the tree species
– Naturalness of the tree species composition

The steps are carried out once and the results are stored in a database to serve as the basis for the up-scaling.

Flexible evaluation software has been developed consisting of a modular system of three combinable parts. These parts carry out the tasks

(a) Providing data for a up-scaling
(b) Up-scaling data and storing the results in results databases
(c) Presenting the results from results databases (each with multiple results from one or more topics)

The evaluation stages are abstracted and modularised. The up-scaling projection program works with anonymous target parameters (x, y) and classification parametres (k1 to k7) and stores the results for areas anonymously. It remains anonymous until data presentation outputs the results as a table or graph with the specified target and classification parameters.

The task of providing data (a) encompasses both deriving parameters on the lowest level, such as the volume or the tree space of trees, as well as data selection and data transfer of pre-aggregated values for plots to up-scaling projection. This task depends on the concrete samples inventory and in most cases also on its data model. Therefore, special software modules have been developed for the NFI. In addition to the databases with the actual inventory data, a key database is set up, in which the nominal or ordinal scaled parameters (nominal: e.g. type of ownership, tree species; ordinal: e.g. age class, *dbh* class, elevation) and their classifications are defined. The results can be called up via control or meta data. Because of abstraction, the tasks of projection (b) and results presentation (c) are independent of any specific questions.

The results presentation module is available for public use on the Internet (www.bundeswaldinventur.de) or locally on DVD. The up-scaling module is reserved for selected users, since it requires specialised technical inventory and evaluation knowledge.

13.7 Options for Harmonized Reporting

13.7.1 Forest Area

Evaluations to compare forest area using national and COST Action E43 forest definition (see also Tables 13.1 and 13.3) were carried out for two test areas (federal states). The first test area (*Schleswig-Holstein*) is characterised by highly fragmented forests and the second test area (*Brandenburg*) has mostly compact forest areas.

Table 13.3 Differences in forest area definitions

Variable	German NFI definition	COST Action E43 reference definition
Minimum area	≥0.1 ha	≥0.5 ha
Minimum width	≥10 m	≥20 m
Minimum crown cover	≥50% currently	≥10% potential
Minimum tree height in situ	Not defined	≥5 m

Two different approaches have shown for the *Schleswig-Holstein* test area that the forest area estimate according to the COST Action E43 reference definition is 0.5% and 0.8%, respectively, less than the national estimate because of the lower minimum area and minimum width. No differences in estimates of forest area were detected for the *Brandenburg* test area. The influence of crown cover has not been evaluated. However, estimates of forest area, where the crown cover is potentially greater than 10% (reference definition) and less than 50% (national definition), are not expected to be significantly greater.

These results show that there is little difference in forest area estimates when using the national and the COST Action E43 reference definitions. Better results can be obtained when the COST Action E43 reference definition is employed in the next NFI (2011–2012).

13.7.2 Growing Stock

The German NFI contains all necessary data for calculating growing stock according to the COST Action E43 reference definition. A first evaluation has shown that the growing stock volume is 1.6% lower than the timber volume according to the national definition. This concerns mainly spruce, fir and larch, whose growing stock is about 3% lower compared with the national results. However the growing stock volume is higher for the aggregated group of "other broadleaved trees" because of a higher percentage of smaller trees.

Table 13.4. shows the difference in the volume definitions. On the one hand the COST Action E43 reference definition for the growing stock includes an additional volume of 1.0% (conifers 0.5%, broadleaved trees 1.8%) from trees smaller than 7 cm *dbh*. But on the other hand, the exclusion of volume from the stump is higher than the inclusion of volume from the stem top for trees with more than 20 cm *dbh*.

13.8 Options for Estimates Based on Reference Definitions

The status of harmonization of the German NFI is presented in Table 13.5.

Table 13.4 Differences in growing stock definitions

Variable	German NFI definition	COST Action E43 reference definition
dbh	≥7 cm	0 cm
Top diameter	7 cm	0 cm
Stump	Included	Excluded
Branches	Excluded	Excluded
Bark	Included	Included
Newly dead trees	Included	Excluded

Table 13.5 The availability of estimates based on national definitions (ND) and reference definitons (RD)

Quantity	ND	RD	Responsible	Remark
Forest area	Yes	No	NFI	Nearly no difference of Forest area between ND and RD
Growing stock volume	Yes	Yes	NFI	For RD special evaluations necessary
Above-ground biomass	Yes	No	NFI, models	ND only contains trees
Below-ground biomass	No	No		
Dead wood volume (=$DW_{10\ cm}$)	Yes	No	NFI	
Dead wood volume by decay stage classes	Yes	No	NFI	
Afforestation, deforestation, reforestation (Kyoto 3.3)	Yes	No	NFI	
Forest type	Yes	No	NFI	

13.9 Current and Future Prospects

The next NFI is planned for the years 2011 and 2012. This is the first repeat survey in reunited Germany and therefore the first NFI with estimations for increment and removals for the whole country. There are signs that indicate a strong increase in removals in recent years. We therefore await the results with great excitement. In 2008, was carried out an intermediate survey on a sub-sample of the NFI plots in order to get a quick idea of the situation and with a view to the opening balance for the first commitment period in of the Kyoto Protocol.

The future interaction between NFI and other forest monitoring activities is currently under discussion. Especially, it is examined how NFI data could extend the analyses of the forest soil survey which are carried out between 2006 and 2009 on another sampling grid than the NFI.

Methodological suggestions are currently being developed with regard to how the NFI could be used for reporting under the FFH Directive (Fauna, Flora and Habitats) of the EU. The NFI could take on the monitoring of large-scale forest habitat types. Furthermore the assessment of forest types and the reduction of minimum diameter for the asessment of deadwood to 10 cm is under discussion.

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Chapter 14
Great Britain

Mark Lawrence and Graham Bull

14.1 Development of the Great Britain's National Forest Inventory

The previous inventory, known as the first National Inventory of Woodland and Trees (NIWT1), was completed in 1999, with the woodland map updated in 2002 (Forestry Commission 2009). The current inventory, now known as the National Forest Inventory (NFI) of Great Britain (GB), commenced in 2007 starting with the creation of a new digital map of all woodland within GB. It should be noted that the inventories described in this report are for GB only (England, Scotland and Wales) and not for the United Kingdom (UK) as Northern Ireland has its own inventory of state owned/managed forests.

14.1.1 Background to the NFI

In prehistoric times, GB was largely covered with woodland. By the end of the first millennium, much had already been cleared to satisfy the needs of an increasing population. This trend continued, and by the end of the nineteenth century woodland cover had dropped to less than 5%. Since then GB's forest and woodland area has been expanding until, by the end of the twentieth century, there were more than 2.6 million hectare, just greater than 11%. This, however, still remains relatively low in international terms (Smith et al. 2009).

The British Board of Agriculture carried out woodland surveys between 1871 and 1913. The Forestry Commission (FC) was established in 1919 after World War I and has been carrying out national woodland inventories for GB on a regular basis since 1924. A new "Census" or "National Inventory" is carried out when it appears

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that the previous one is no longer able to supply the information that is required. This may follow significant events such as a World War (the impetus for the 1924 and 1947 Censuses) or the impact of Dutch elm disease (for the 1980 Census). The information from an inventory, however, grows increasingly out of date even with reasonable attempts at updating. (Smith et al. 2009)

Each subsequent inventory has involved the introduction of changes as developments in survey practice and technology occur. For the purposes of comparison it may be desirable for each inventory to change as little as possible from its predecessor but this has proved unrealistic in the past. Each new survey has introduced changes driven by information needs, technological opportunity and cost factors. The NFI has changed again by harmonizing a number of reference definitions in line with the COST Action E43. This new inventory is envisaged to be a continuous programme of continual updates however rather than an independent inventory (Smith et al. 2009). Table 14.1 summarizes the previous inventories carried out in GB.

14.2 The Use and Users of the Results

14.2.1 National Users

There are a wide variety of end users of the National Inventory results ranging from forestry professionals (Government and Private Sector) to academics and the general public.

The National Inventory provides data for the Private Sector Softwood Forecast of timber availability to estimate the potential timber production within the private sector, for a desired geographical location (from a specified radius from a grid reference point to all of GB). The information is used, in conjunction with the Production Forecast for the public sector, to advise the timber industry of what timber may be coming onto the market.

Policy makers utilise the data from the NFI's to formulate, and provide evidence for, the Forestry Strategies within each of the three countries (England, Scotland and Wales) for both Public and private forests.

14.2.2 International Reporting

NFI data is one of the main sources of information for international reporting on woodlands for GB and the United Kingdom. Data from Northern Ireland is added to the GB data to create UK data sets. The FC reports to a number of bodies and policies including the Food and Agricultural Organisation (FAO) (as part of the Forest Resource Assessment – FRA), the Kyoto Protocol and Land Use, Land-Use

Table 14.1 Previous woodland and tree surveys carried out by the FC. Note: prior to 1980 all areas were assessed in acres

Date	Scope	MSW[a]	Method	WLC[b] (%)
1924	FC (owned and/or managed by FC) and private woodlands	0.8 ha	Questionnaires to owners	5.3
1938	FC and private woodlands	2.0 ha	Inventory only partially completed due to outbreak of World War II	n.a.[c]
1947	FC and private woodlands	2.0 ha	Complete inventory	6.1
1951	Small woods (< 2.0 ha) hedgerows and park trees	0.4 ha	Sampling by strips	6.4
1965	Private woodlands	0.4 ha	Sampling by kilometre Ordnance Survey grid squares where woodland was depicted on the map	7.6
	Hedgerows, Parks, etc. (south of Humber/Mersey only)	–	Sample of one-third of the 1951 survey strips plus random selection of new strips	–
1980	Private woodlands (except Dedicated and Approved)	0.25 ha	Area – from 1:50,000 maps adjusted by sample check on aerial photography Crop – by sub-sample of the area sample	9.4
	Non-woodland trees	–	Sample strips interpreted from aerial photographs with ground checking. Additional parameters assessed on a sub-sample within each strip	–
1999	FC and private woodlands (main woodland survey)	2.0 ha	1% cluster sample of woodland area. Woodland mapped using Land Cover Map of Scotland (1988) (50% canopy cover) and paper 1:25,000 aerial photographs for England and Wales (20% canopy cover). 50 m minimum woodland width	11.1
	Small woodland survey	<2 ha	All individual trees, small woods (<2.0 ha) and linear features	–

[a]Minimum size of woodland.
[b]Woodland cover in percent.
[c]Not available.

Change in Forestry (LULUCF) reporting. Unlike the previous inventory the new NFI will also be able to report on the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2003) forest types and criteria.

14.2.3 The Role of NFI in Assessing the Status of Biodiversity

A number of biodiversity indicators were collected during the last National Inventory (Gilbert 2007). The data were used to provide evidence to policy makers regarding the impact of policies and strategies. Reports on the Habitat Action

Table 14.2 Data collected in the NFI plot

Tree	Stand	Woodland
Age class	Even/uneven aged	Ownership
Diameter at breast height	Horizontal diversity	Area by section
Basal area	Vertical diversity	Aspect
Top height	Deadwood – stumps, lying or standing	Ecological condition
Stocking		Management data (e.g. policy, characteristics)
Species	National Vegetation Classification (NVC)	
Timber quality		Social condition – indicators of use
Tree health		Veteran tree – presence and species
Damage		Soils

Table 14.3 Basic area information in Great Britain from years 1995–1999 (Forestry Commission 2009)

Quantity	Area (1,000 ha)	Share (%)
Total land area	22,933	100
Woodland >2.0 ha (from 1999 inventory)	2,544	11.09
Woodland 0.25 – <2.0 ha	107	0.47
Woodland 0.1 – <0.25 ha	13	0.06
Total woodland area	2,665	11.6

Plans (HAPs) for each country were generated for example. The current NFI plans to expand the data sets for biodiversity assessments from the last inventory reporting on a number of issues pertinent to the country forestry strategies.

Table 14.2 illustrates the indicators of biodiversity, amongst other measures, to be measured during the NFI (note: the final decision of what is to be assessed in the NFI is still to be made).

14.3 Current Estimates

The definition of woodland and forest area for the current NFI has changed from the NIWT1 (1995–1991) definition shown below following the COST Action E43 meetings: *Woodland/forest* is land with a minimum area of 2 ha, minimum width of 50 m, and minimum canopy cover of 20% in England and Wales and of 50% for Scotland. The basic area estimates are given in Table 14.3. The new NFI definitions can be seen in section 14.4.

Representatives from England, Scotland and Wales and from the FC’s International Reporting staff are evaluating the outputs and timings from the recent NFI pilot data collection to prioritise data collection requirements and assess the overall cost of the fieldwork. Once this is completed the data collection will start in earnest for 5 years beginning June 2009.

As data becomes available from the NFI it is envisaged that reports will be made available, via the FC's web site.

14.4 Sampling Design

The NFI is divided into two separate projects:

1. Main woodland inventory
2. Small woodland and trees survey

14.4.1 Main Woodland Inventory – Mapping

Prior to field sampling all woodland, regardless of ownership, within GB will be mapped from digital orthorectified aerial photographs, dated no earlier than 2003 where possible, using ESRI ArcGIS software. The definition of *NFI woodland* is:

- Area ≥0.5 ha (formerly 2.0 ha)
- Width of woodland ≥20 m (formerly 50 m)
- Crown/canopy cover ≥20% (or the potential to achieve 20%) – (formerly 50% in Scotland)

NB: The terms 'woodland' and 'forest' are interchangeable in the NFI and no distinction is made between them. Tarmac roads and normal gauge railways are not mapped as part of the woodland area regardless of size.

Within each woodland parcel the area is further defined into Interpreted Forest Types (IFTs). Table 14.4 summarises the IFT definitions.

NB: Orchards are not included in the woodland area for GB but are mapped for Carbon and Biomass reporting requirements.

Where a non-woodland area is found completely surrounded by woodland then an Interpreted Open Area (IOA) is mapped if the area is ≥0.5 ha (see Table 14.5).

14.4.2 Sampling 2009–2014

Approximately 15,000 to 20,000 1-ha Sample Squares (Fig. 14.1) are due to be assessed throughout GB using two sampling methodologies in order to create synergies between the NFI, European projects that the FC has participated in or is participating in (e.g. the Biosoils and FutMon projects) and the FC's Integrated Monitoring Framework:

- Systematic sampling – on an 8 × 8 km grid. This fits in with previous Biosoils sampling and the current FutMon project as well as the FCs Integrated

Table 14.4 List of IFTs

Code	Description	Comments
C	Conifer	Coniferous woodland. Some broadleaved trees may also be present but greater than 80% of the area consists of conifers
B	Broadleaved	Broadleaved woodland. Some coniferous trees may be present but greater than 80% of the area consists of broadleaved trees
Mc	Mixed woodland – predominantly conifer	The Conifer proportion of the area is between 50% and 80%
Mb	Mixed woodland – predominantly broadleaved	The Broadleaved proportion of the area is between 50% and 80%
O	Coppice	Coppice is always of broadleaved trees
P	Coppice with standards	Some areas of coppice also include larger broadleaved trees set in the coppice matrix
S	Shrub land	This category is intended to include areas that may possibly be woodland, where the growth is close to the ground and shows a rough character but no clear differentiation between. Areas being colonised by woody species may fall into this category. The cover is at least 20%
N	Young trees	Areas where planting is clearly visible but the trees cannot yet be allocated between Conifer and Broadleaved due to their immaturity
F	Felled woodland	Areas of woodland where the majority of trees have been harvested or felled so that the canopy cover is <20%
G	Ground prepared for new planting	Very difficult to differentiate from agriculture, but may show plough furrows, spaced earth mounds or weed killed patches or strips as part of a new woodland regime. Likely to be part of an approved grant scheme held on the Grants & Licenses databases
CS	Cloud or shadow	If cloud or shadow areas obscure woodland detail and it is difficult to allocate one of the above IFTs, then digitise a new boundary line feature around the area of uncertain forest type

Monitoring Framework. Approximately 400 sample squares will be assessed via this design.

- Simple random sampling – to be carried out within each region of GB. The regions are divided into: England: nine regions, Scotland: five regions and Wales, one region.

The intent is to allow specialist interest groups to add top-up sampling to the NFI's Squares to get greater precision in their areas of interest. These squares would be randomly allocated within an area (as specified by the interest group) and would assess the information they require. Should resources permit all the NFI information would be assessed at these extra sample locations. Already in South West England a group interested in softwood timber production has paid for extra data collection to add to the NFI data for that geographical location.

Table 14.5 List of interpreted open areas

Code	Description	Comments
W	Open water	Normally labelled within Ordnance Survey's MasterMap
Gs	Grass	A predominantly grassy area – may be agricultural or not
A	Agricultural land	May contain a cereal crop or pasture
U	Urban/Building	Buildings within woodland areas, may include gardens surrounding the building
Ro	Forest road, track	Linear feature, often fairly straight with gentle bends or turning circles
Ri	River	Linear feature, depending on location can be fairly straight or meander through woodland
L	Powerline	Linear feature, possible shadow evidence of poles, pylons or even the cable/lines
Q	Quarry	Show change in vegetation to geology, sand, slate, rock etc. Active quarries could have buildings, heavy plant tracks leading into the quarry
Ba	Bare	Bare ground/rock
Wf	Wind farm	Possible shadow evidence of turbines, normally in groups
V	Other vegetation	Not covered by the above, e.g. Gorse, Rhododendron, Bracken, Heather, etc

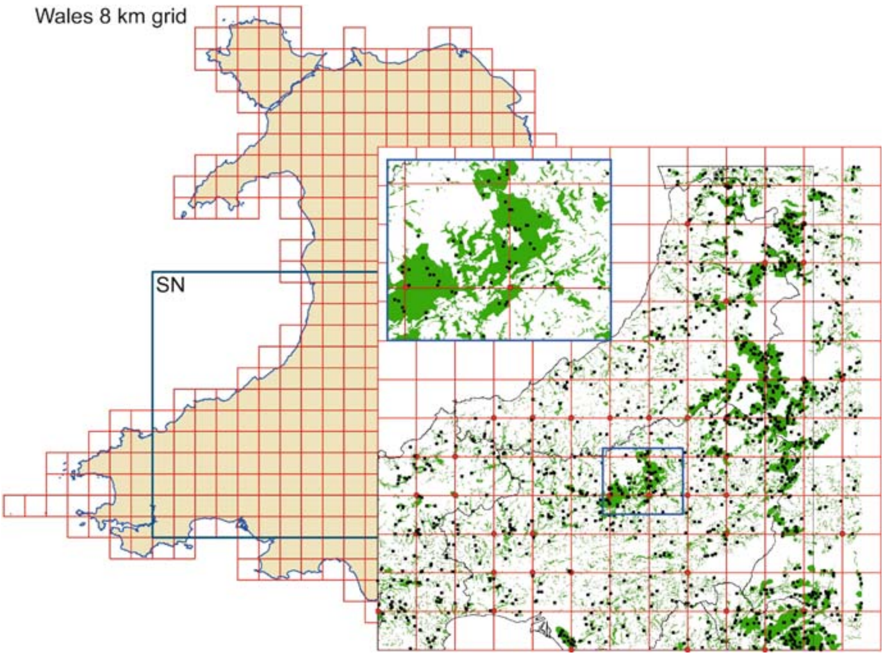

Fig. 14.1 Example of the sample designs in Wales, *red dots* show the 8 × 8 km sample squares with *black dots* illustrating those sample squares allocated using random sampling

Fig. 14.2 One-hectare sample square overlain onto an aerial photograph

Using data from the last inventory and from a recent pilot exercise the estimated number of sample squares required for a particular output and precision will be calculated at three scales: GB, country and region. The number of squares in a region will be allocated according to available resources and at a level of precision for those outputs deemed most important.

14.4.3 Sample Squares – Locating

Using the Woodland map, aerial photos and a geographic information system (GIS) the 1-ha sample squares can easily be located (Fig. 14.2).

All sample squares with a mapped area of woodland ≥0.1 ha may be visited. The probability of the square being visited is shown in Table 14.6.

Table 14.6 Filtering sample squares by area of woodland within the sample square

Area of woodland in 1-ha square	% of squares sampled
0.5–1.0 ha	100
0.2–0.5 ha	50
0.1–0.2 ha	20
<0.1 ha	none

Table 14.7 Small woodland and trees survey categories

Feature	Description
Small woodland	Areas of woodland (min. 20% cover or potential cover), with 0.1 ha $\leq$ area $<$ 0.5 ha
Linear tree feature	A narrow tree feature (could be single line of trees) <20 m wide with crowns touching and which is at least four times as long as broad. If connected to a Main woodland block it must be $\geq$25 m in length
Group	Area <0.1 ha, at least two trees with crowns touching i.e. two or more trees with an area <0.1 ha
Individual tree	A tree with a crown that has no contact with any other tree and which is estimated to be at least 2 m tall
	Boundary tree – an individual tree on a boundary
	Middle tree – an individual tree not on a boundary within a feature

The purpose of this filtering is to reduce the number of squares requiring assessment whilst not unduly reducing the total woodland area being assessed to the same degree allowing efficiencies to be gained. The mean woodland area of the 1-ha squares within the NFI is 0.63 ha. Section 14.4.5 describes the assessments within the sample squares.

14.4.4 Small Woodland and Trees Survey

Digital orthorectified aerial photographs will be used to map all trees, in 2,347 1 × 1 km squares covering 1% of the land area of GB that were originally assessed during the previous National Inventory, that have not already been mapped in the main survey. These trees will be divided into the categories shown in Table 14.7.

Figure 14.3 illustrates the distribution of sample 1 × 1 km squares across GB. A sub-sample of these squares will be visited for ground verification purposes.

14.4.5 Sample Squares – Field Assessments

Within the main woodland inventory sample squares will be located throughout GB as noted earlier. Within each 1 ha square the field surveyors will divide the

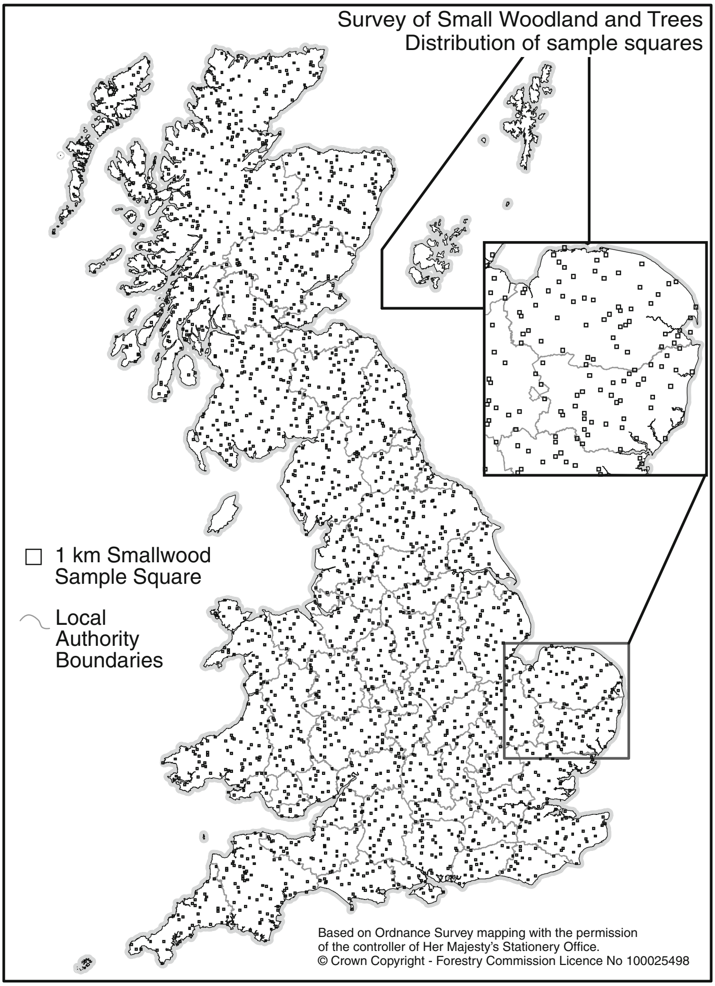

Fig. 14.3 Distribution of 1-km^2 sample squares across GB for the survey of small woodland and trees

woodland area into sections of at least 0.1 ha in size. Non-woodland areas at the edge of woodland blocks and internal open areas (≥0.1 ha) will also be described. Homogenous changes in forest type, silvicultural system, species, age, height, significant differences in growth rate, and mixture may be reasons for creating new sections (Fig. 14.4).

Within each section a number of assessments (Table 14.2) will be carried out at the section level (i.e. for the entire section). In addition in each section two, 0.01 ha circular plots, will be assessed for a variety of mensuration, deadwood and biodiversity measures (Fig. 14.4).

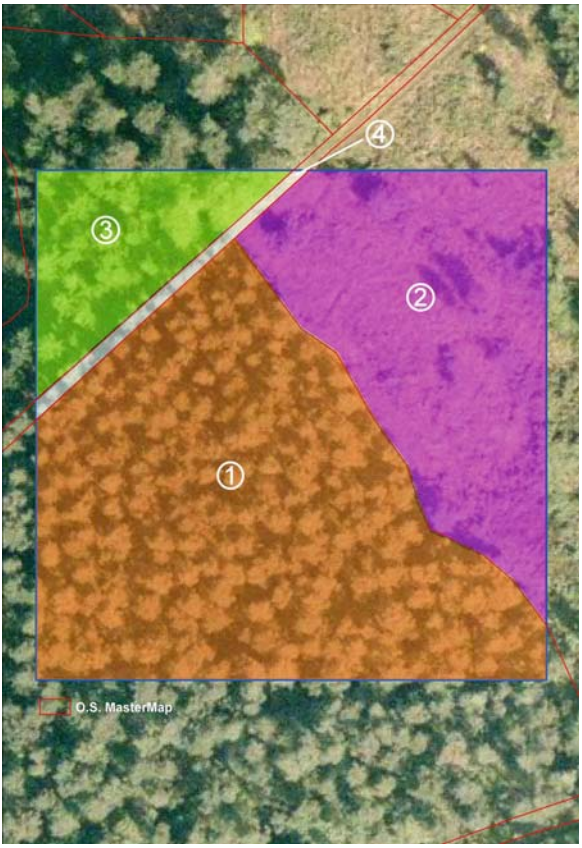

Fig. 14.4 The 1-ha square divided into sections: 1 – pure *Pinus sylvestris* stand, 2 – *Pinus sylvestris*, *Tsuga heterophylla* and mixed broadleaves mixture, 3 – young mixed broadleaves, 4 – track – in this case the small size of the track (<0.1 ha) means that it will be absorbed into section 1 – the largest adjacent section

The small woodland survey is planned as a desk exercise but some visits to the 1 × 1-km squares will be carried out for verification and quality assurance (QA) purposes.

14.5 Management

14.5.1 Personnel and Equipment

Approximately ten field staff, in single person teams, will carry out the fieldwork. Office based staff will co-ordinate the fieldwork, manage contracts and send information to field staff.

All field staff will be given Panasonic Toughbooks with ESRI GIS software. Data will be supplied for each Sample Square including aerial photos, the NFI woodland map plus other mapping datasets such as Ordnance Survey maps. Each surveyor will also be given a global positioning system (GPS) unit, Vertex® hypsometers and standard mensuration and soil sampling equipment. A digital camera is supplied to allow the surveyors to take photos to aid queries and record unusual features. A database will be created of the images to aid other surveyors answer similar queries easily.

14.5.2 Quality Assurance

Prior to commencing field data collection all staff will attend training courses to familiarise themselves with the hardware, software and assessment protocols. All assessments required for the NFI will have a Standard Operating Procedure (SOP) detailing the exact methodology to be used plus accompanying field sheets and aids. Experienced field staff will carry out field QA reassessments for approximately 5% of the sample squares.

The database software will have logical checks within it and also be programmed to show only those fields that require filling in for a particular type of section. For example there are differences in the mensuration assessments required whether the section is classed as thicket stage conifer or mature conifer.

14.6 Estimation Techniques

14.6.1 Area Estimation

Woodland area estimation will be taken directly from the woodland map (for woodland $\geq$0.5 ha). For woodland areas with canopy cover $<$20% (or the potential to achieve this) such as Other Wooded Land (OWL) the Small Woodland Survey mapping will be used to estimate this.

14.6.2 Other Estimations

The current NFI has departed from the last NFI in terms of volume estimation techniques and increment and drain statistics. The previous inventory used models to derive volume, increment, biomass and carbon estimations. New models are in development to take into account the mensuration data, which, previously, were not

Table 14.8 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current GB NFI

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	ND $\neq$ RD. Reference definition statistics will be derived from Main Woodland Inventory and Small Woodland Survey
Growing stock volume	Yes	No	NFI	Trees $\geq$ 4 cm *dbh* only measured. Volumes below this can be modelled to meet reference definition
Above-ground biomass[a]	Yes	–	NFI	–
Below-ground biomass	–[a]	–	NFI	–
Deadwood volume	Yes	No	NFI	Minimum length not required for national definition
Deadwood volume by decay classes	Yes	Yes	NFI	COST Action E43 has 4 classes and NFI 5 – can derive COST Action E43 definition from the 5 classes however
Afforestation, reforestation, deforestation (Kyoto 3.3)	Yes	–	NFI	–
Forest type	Yes	–	NFI	–

[a]Awaiting decision on what is to be assessed.

available in order to generate more precise estimates. These models are due to be finalised in the near future.

14.7 Options for Harmonized Reporting

The status of harmonization can be seen in Table 14.8. The NFI will be able to report statistics on both national definitions and the reference definitions of COST Action E43.

14.8 Current and Future Prospects

Unlike previous inventories, the current Inventory is planned to be a continuous inventory rather than an isolated inventory to be repeated every 10–15 years. The woodland map for the NFI is due to be completed in 2009. The map will then be subject to regular future updates from a variety of sources: planting grants, felling licenses, and remote sensing techniques.

Sample square data collection will be carried out for 5 years starting in 2009. These squares will be re-visited on a continuous 5-year programme.

The NFI has been greatly influenced by the COST Action E43 programme and a great deal of effort is currently going into harmonizing with European inventories whilst getting the outputs required for GB.

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Chapter 15
Greece

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15.1 Development of the Greek National Forest Inventory

Greece, a typical Mediterranean country, is located on the eastern edge of Europe. Greece occupies 128,900 km^2 (excluding water) and is a predominantly mountainous country with an elevation range from sea level to 3,000 m. In this area three floristic units are joined, the Mediterranean, the middle-European and the Iranokaspic.

An inventory was conducted in 1836, although it was not based on scientific or statistical planning. The 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 the total area today (Kontos 1921). Kontos (1929) published the results of a second inventory 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 (National Inventory of Greece 1992). Areas not covered 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). However, this forest inventory was conducted in ten inventory regions of unequal sizes (Fig. 15.1).

The inventory regions of the 1963 Greek NFI were:

1. Central Greece (or "Work 81")
2. Mornos
3. Evinos
4. Peloponnisos
5. Western Greece
6. Eastern Macedonia, Thraki

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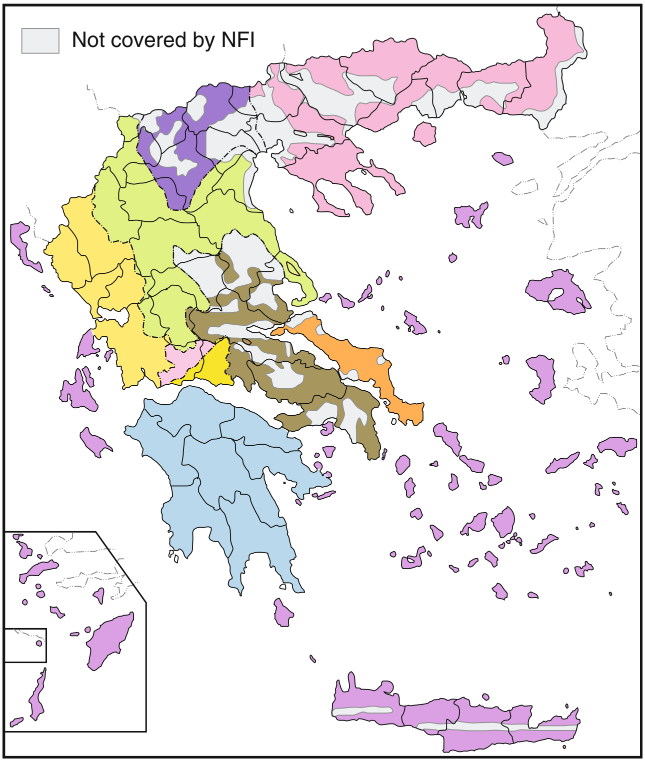

Fig. 15.1 The inventory regions and the areas not covered for the NFI

7. Western Macedonia
8. Eastern Central Greece
9. Euboea
10. Aegean, Ionian islands, Crete

The first region was inventoried in 1965, and the inventory subsequently expanded to the other regions. In 1985, the first phase of the inventory, consisting of interpretation of aerial photographs and the field measurements, was completed. In 1991, the entire NFI was completed, and the results were reported in a handbook titled, "Results of the First National Forest Inventory" (in Greek) (Table 15.1). The results of this inventory indicated that the area occupied by forests was approximately 19% of the country (Table 15.2) with approximately half of the country covered by forest and other wooded land. A characteristic feature of these forests is uneven-aged stands with trees belonging to all diameter classes.

The forest regions, or eco-regions according to the inventory, are shown in Fig. 15.2. Most forest land belongs to the state (Table 15.3), contrary to the situation today in most other European Union countries. The forest tree species composition is 38.4% conifers (mainly fir and pines) with the rest, 61.6%, broadleaved (mainly oak, beech and maquis). Coppice comprises 48% of the forests, 34.7% are high forests and

Table 15.1 A brief summary for the Greek NFI

Inventory	Year of publication	Citation	Language	Dissemination
First National Forest Inventory	1991	Ministry of Agriculture General Secretariat of Forests and Natural Environment (1992)	Greek	Printed

Table 15.2 Division of land by land use

Category	Acreage (1,000 ha)	Percent
Forest land	2,512	19.0
Partially forest land	3,242	24.6
Phryganic land	277	2.1
Alpine areas	440	3.3
Grasslands	1,756	13.3
Water (ponds, swamp)	273	2.1
Barren land	734	5.6
Agricultural land	3,964	30.0
Total	13,198	100.0

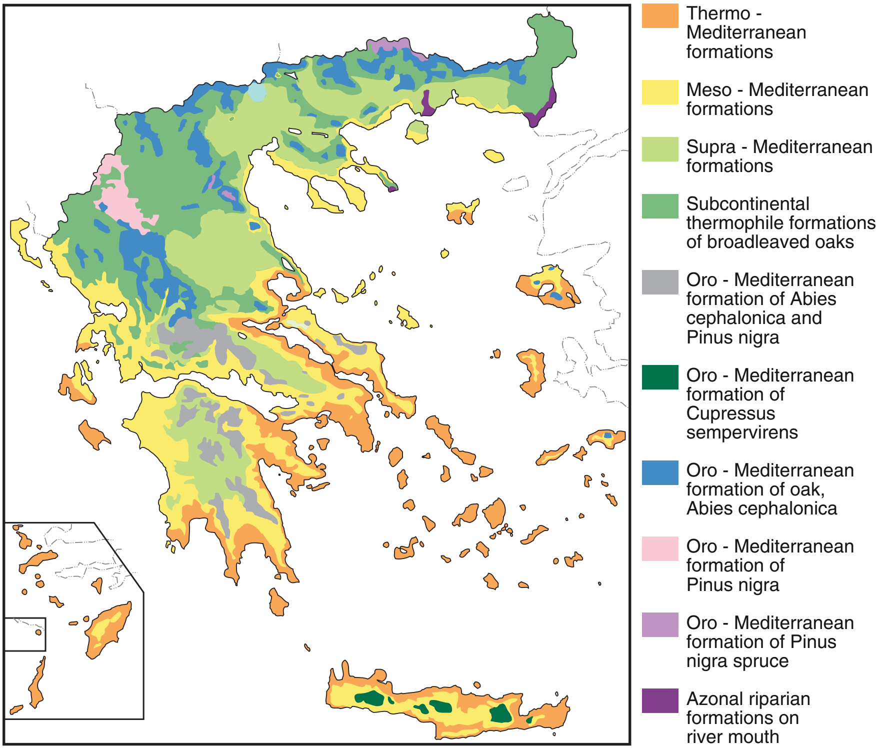

Fig. 15.2 Vegetation map of the forest regions in Greece

Table 15.3 Distribution of forests by ownership category

Ownership	Acreage (1,000 ha)	Percent
State	1,644	65.5
Community	302	12.0
Monastery	110	4.4
Charity institution	11	0.4
Co-operative	246	9.7
Private	200	8.0
Total	2,513	100.0

17.3% are composite. Annual production exceeds 4.0 million cubic metre of wood volume (1.85 m^3/ha per year) of which only a part, 2.7 million cubic metre, is cut. Total standing volume is approximately 158 million cubic metre. Two additional factors characterize Greek ecosystems. First, the ecosystems are heterogeneous, unstable, and vulnerable, as it is commonly the case in Mediterranean countries. Second, an authorized land registry is lacking.

15.2 General Use of the Results

The purpose of the NFI was to improve Greece's forests and soil resources. For each inventory region, data that were collected and recorded included:

1. Soil morphology and watershed network
2. Rocks – soil data
3. Climatic data
4. Vegetation data
5. Land use of the non-forested areas
6. Distribution of forests

The users of the results are the Hellenic Forest Service and the Hellenic Statistical Service. The usefulness of the results is uncertain because of the large gap between the time of assessment and the publications. Thus, the report can be used only as a general indication of forest conditions in Greece.

15.3 Current Estimates

The basic area and volume estimates are given in Tables 15.4a and b.

If we added to the forest growing stock, the volume of other wooded land of about 2.8 million cubic metre as well as the volume of about 2.7 million cubic metre of dead wood, the standing volume would be approximately 158 million cubic metre. The growing stock of Greek forests of approximately 45.2 m^3/ha is relatively low compared to the main growing stock of other European countries. However, there are many forest complexes that are well-organized, that have been managed for a long time, and that support stands with mean growing stock volume ranging from 350

Table 15.4a Basic area estimates based on the NFI

Quantity	Estimate (1,000 ha)	Share %	Description	SE[a] (1,000 ha)
Forest land	2,512	19	1. Ten percent 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. Reforestated areas 4. Maquis	
Other wooded land	3,960	30	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	
Other land uses	6,724	51.0	All other lands	
Total land area	12,890	100		–[b]
Area covered by NFI				
1. Forests				
1.1. Industrial forests	3,360	25.4		
1.2 Non-industrial forests	3,154	23.9		
2. Other lands	4,863	36.9		
3. Out of the Inventory	1,819	13.8		
According to the management type				
High forest	872	34.7		
Coppice forest	1,206	48.0		
Coppice forest with standards	434	17.3		

[a]Standard error.

[b]Assumed to be error free.

NFI coverage categories:

Industrial forests: areas characterized by high trees and produced merchantable wood. Another definition is the next one: areas which are capable to produce 1 m3 of wood per hectare every year. *Non-industrial forests*: areas with multibrushed dwarf trees and bushes, which for the time being cannot produce merchantable wood products but they have value for grazing and for protection. *Non-forest lands*: areas not classified as forest lands. *Range lands*: non-forest land used for grazing. *Crop lands*: non-forest lands which are used for crops. *Bare lands*: non-forest lands without any vegetation in more than 50%. *Urban, residential and industrial lands*: non-forest lands which are used for industry, residential areas, etc. *Water*: rivers, lakes, swamps.

NFI tree species:

Fir, Aleppo pine, Calabrian pine, Black pine, Scots pine, Spruce, Chestnut, Oak, Plane

Table 15.4b Basic volume estimates based on the NFI

Quantity	Estimate (million cubic metre)	Description
Volume of industrial forests	152	
Merchantable volume	138	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	139	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.
Stem top volume	14	Net volume of trees with *dbh* ≥ 5 cm between the top of the merchantable wood and the upper edge of the tree.
Desirable trees	60	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	59	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	21	Trees with less merchantable value; trees that do not adapt well to a forest environment; trees whose merchantable wood has been distorted more than 50%.
Rejected trees	12	Trees with no merchantable value.
Regeneration		Tree with *dbh* < 5 cm.
Net annual growth	3.8	The difference between gross annual growth and mean annual mortality.
Annual mortality	0.3	The annual loss of volume due to natural causes.
Annual increment of growing stock of trees per hectare on forest land	4.11	

Table 15.5 Growing stock increment for the main forest species

	Annual net increment over bark volume (1,000 m^3)	Percentage increment of growing stock (%)	Annual net increment/ha (m^3/ha)
Coniferous			
Fir	798	1.68	1.47
Spruce	29	3.08	10.35
Pine	1,090	3.10	1.24
Broadleaved			
Beech	931	3.06	2.77
Oak	695	2.62	0.47

to 400 m^3/ha. The main growing stock of the total forests has decreased significantly, because a high percentage of forests are coppice or have been over-thinned due mainly to human actions. Increment estimates are reported in Tables 15.5 and 15.6.

Table 15.6 Growing stock increment on forests

	Annual net increment overbark volume (1,000 m^3)	Percentage increment of growing stock (%)	Annual net increment/ha (m^3/ha)
Coniferous	1,918	2.26	1.34
Broadleaved	1,895	2.84	0.98
Total	3,813	2.51	1.14

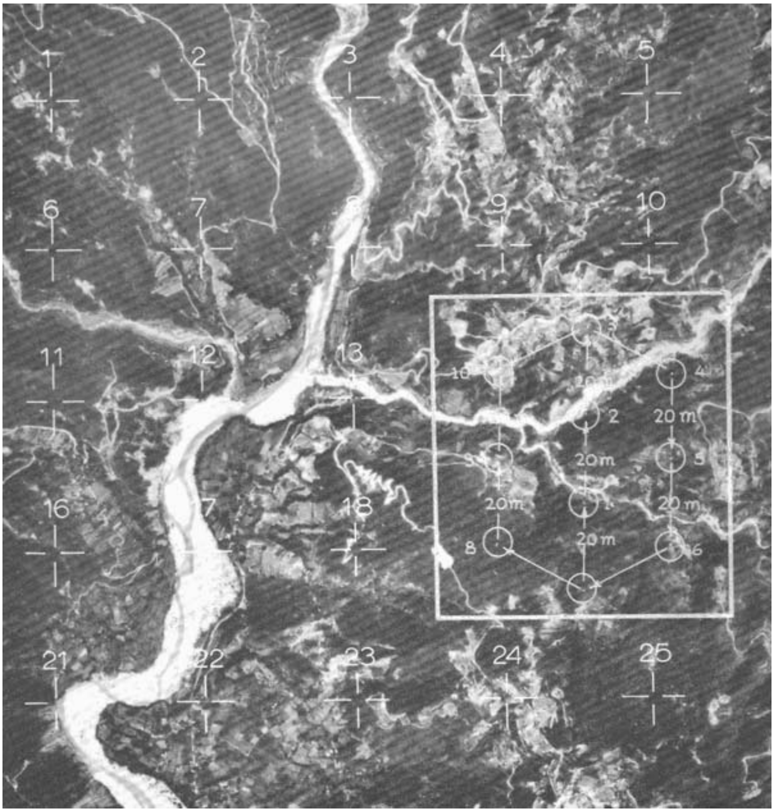

Fig. 15.3 Aerial photograph with 25 photo plots and an example of a field plot

15.4 Sampling Design

The source data for the inventory was panchromatic black and white aerial photographs 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 (Fig. 15.3), measured and classified according to their land use, forest types, closure density, tree height, slope, and degree of erosion. The field plots were located using the azimuth and the distance from characteristic points on the aerial photographs that were easy to recognize. Photo interpretation of 95,220 photo-plots was used as the basis for the stratification into non-forest, forest without volume, and forest with volume strata. A random process was used to select 2,744 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 (Fig. 15.3): 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 (Fig. 15.4). 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

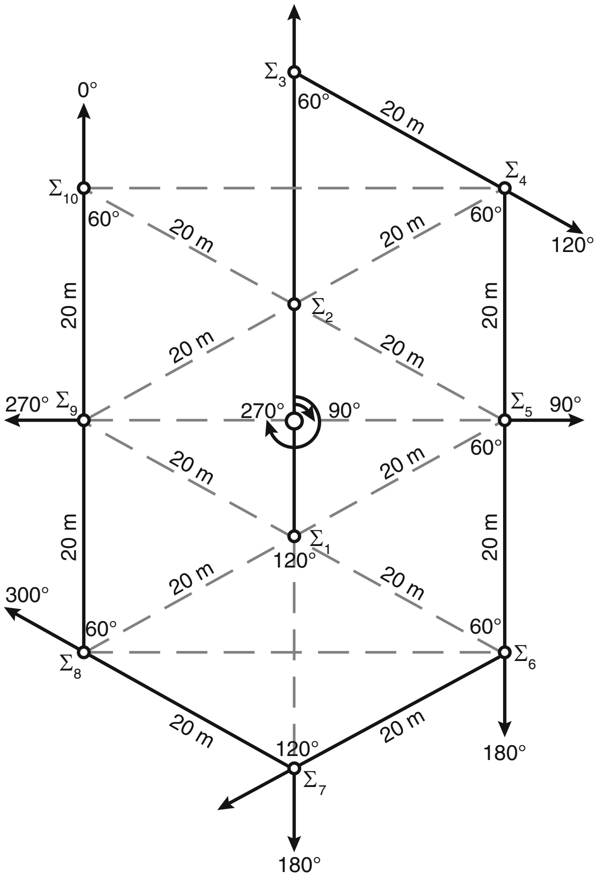

Fig. 15.4 The locations of ten sample points in NFI

thickness. Also, the tree species was identified, and the tree quality, degree of damage, and percentage of the healthy merchantable volume were estimated.

15.5 Estimation Techniques

15.5.1 Area Estimation

Areas were estimated by counting dots from a network of dots on 1:50,000 maps:

$$Area\,(ha) = A_i = A \sum \frac{M_i}{M} \tag{15.1}$$

where M_i is the number of photo-plots in the survey area by stratum (A_i), M is the number of photo-plots in the survey area and A the total land area.

15.5.2 Volume Estimation

Volumes were estimated using the general volume formula,

$$V = \sum \frac{U\,\pi\,(0.5\,dbh)^2\,H\,F\,A}{\pi\,R^2\,N} \tag{15.2}$$

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), and N is total number of field plots in the area surveyed. Based on the general formula, the following were estimated: net volume per hectare including limbs, net volume per hectare for the main stem inside bark, net volume per hectare for merchantable stem and net volume per hectare for saw timber volume.

15.5.3 Increment

Growth was estimated using the general growth formula,

$$G = \sum (H\,F\,A/N)\,P_V \tag{15.3}$$

where G is volume of annual growth for the survey area (m^3), and P_v is the annual growth.

15.5.4 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%

15.6 Current and Future Prospects

No new NFI is being planned and no NFI work is underway in Greece, because the people and the whole Service that conducted the existing inventory were recently transferred to another department.

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Chapter 16
Hungary

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16.1 Development of the Hungarian National Forest Inventory

The National Forest Inventory (NFI) has a long tradition in Hungary. The first order, to survey and map Hungary's forests, was decreed by Mária Terézia and came into force in 1769. The first forest act was issued in 1879. Treatment of the majority of forests had to be based on forest management plans. Sustainability was ensured based on existing age classes as it was ordered in 1920.

In 1935 the forest act meant that forest owners had to manage their forest using forest management plans. Development of forest management plans has been supported by computerised data processing since 1970. Forest management plans are prepared for districts and have been called District Forest Plans (DFP) since 1996.

16.1.1 District Forest Planning

Forest inventory and forest management planning are accomplished at the same time based upon stand-level surveys including site surveys and mapping. Considering that DFPs are made for a 10-year period, 10% of the total forest area is inventoried each year which amounts to approximately 180,000 ha per year. The inventory system principally is a full census. Sampling, aimed at volume, soil, species, sizes, etc. using very conventional methods, is always carried out at the sub-compartment level. There are more than 170 forest management planning districts and the size of districts ranges from approximately 3,000 to 24,000 ha.

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16.2 The Use and Users of the Results

16.2.1 General Use

About 25% of the arable soil of the country is used for forest management. The national economic importance of the sector is unquestionable, because forests are present in both the natural and man-made environment. Even though the sector has a moderate (0.3%) contribution to Gross Domestic Product, the size of the area, the large number of owners, managers and employees, the variety of natural conditions and the multiple, constantly renewed expectations of society regarding forests require a professionally founded administration system.

The information collected by the NFI is principally used to prepare DFPs and is stored in the National Forest Database. This database is used for reporting national and international annual statistics on Hungarian forests and serves as the essential basis for national forest policy. International obligations such as reporting to the Forest Resources Assessment of Food and Agriculture Organization of the United Nations (FAO 2006), to the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2007) and to the United Nations Framework Convention on Climate Change (UNFCCC) concerning the Land Use, Land-Use Change and Forestry (LULUCF) (IPCC 2003), are also based on this information. In addition, all forest related stakeholders (Fig. 16.1) are interested in and provide information on Hungary's forests.

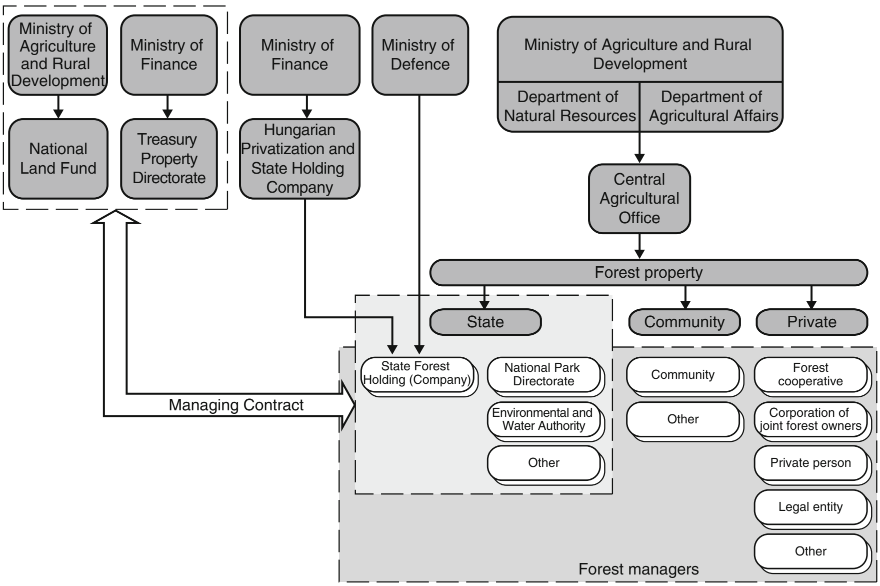

Fig. 16.1 Flow chart of forest stakeholders

The information used by forest authorities and other forest related authorities, (e.g. environmental authority, water management authority, etc.), political decision makers or potential investors are expected at both the sub-compartment level and also in more aggregated forms. The Hungarian NFI and the related database are the basis for supervision of all forest operations and contribute to the implementation and control of national and European Union subsidy systems.

16.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

The NFI supplies data for Kyoto Protocol reporting. Growing stock information is calculated for the forest management (FM), as well as afforestation, reforestation and deforestation (ARD) categories. The digital geographic information stored in the database is used to identify ARD areas.

16.2.3 The Role of the NFI in Assessing the Status of Biodiversity

Within the traditional NFI, tree species composition is assessed at the sub-compartment level. Additional descriptive data referring to the shrub and ground vegetation layers are also available in the NFI database.

The organization responsible for biodiversity monitoring in Hungary is the Ministry of Environmental Protection and Water. A special monitoring system was developed with more than 100 permanent 1-km^2 sample areas representing all the different habitats within Hungary, including forests. Recently, the two responsible ministries – Ministry of Environmental Protection and Water and Agriculture and Rural Development strengthen their cooperation to increase efficiency and improve the methods of biodiversity monitoring. A new approach is in development to use common sampling plots for forest inventory, forest condition monitoring and biodiversity monitoring. In the frame of this cooperation the National Forest Database will contain information on naturalness of sub-compartments in the near future.

In response to the European Union's new Life+ (the new Financial Instrument for the Environment in the EU) call for proposals, an international project proposal has been submitted aiming at the elaboration of methodologies and implementation of new methods for the assessment of forest biodiversity.

16.3 Current Estimates

Unlike most European countries, Hungary's NFI is based on stand-level inventories. Basic forest resources estimates are given in Table 16.1.

Table 16.1 Basic area and volume estimates with the definitions used in the Hungarian NFI

Quantity	Description	Estimate
Forest land (1,000 ha)	- With defined tree species - Minimum block size 0.5 ha - Crown cover min. 50% (30% if protection function)	1,869.3
Other forest related land (1,000 ha)	- Areas directly supporting forest management (e.g. glade, nursery, lane, etc.)	129.1
Primary forest function (1,000 ha)		
- Productive forests	- Primary aim is the tree production	1,188.9
- Protective forests	- Protective and protected forests	656.1
- Health-care, social and tourist forests	- Primary function is health-care, public welfare and tourism	18.7
- Educational and research forests	- Primary function is education and research including game park too	5.6
Tree mixture ratio	Trees with canopy cover greater than 5% of the area of sub-compartment were assessed during the field survey	
Growing stock (million cubic metre)	Growing stock of sub-compartments are assessed by sampling tree height and *dbh* for direct calculation or assessing crown cover and mixture rate for yield table calculation	341.4
Gross annual increment (million cubic metre per year)	Calculation uses yield tables based on assessed variables	13.7

16.4 Sampling Design

With Hungary's stand-level inventory system, each stand/sub-compartment is inventoried. In mature stands the sampling is mostly carried out using a strip sampling within the sub-compartment. The sampling method, and the reliability expected, is determined by the age and quality of the stands. In immature stands, the growing stock is estimated using yield tables; therefore a much less dense sampling density is required in these sub-compartments which range in size from 0.1 to 50 ha. This means that although the inventory covers the whole country, no systematic sampling is used. However, the sampling can be considered as a random from an inventory perspective, because the areas to be inventoried are determined by the management plans that have expired. Each year, approximately 180,000 ha are inventoried.

Aerial photos at scales of 1:10,000–1:30,000 have been used for multiple purposes: mapping, delineation of the borders of forested areas and sub-compartments, estimation of forest area, estimation of forest land use change, and supporting daily working plans. The number of photos is approximately 8,000–10,000 at the scale of 1:10,000. The last 2 years orthophotos have been available to support this work.

16.4.1 Sample Plots

Because of the stand-level inventory approach used by the NFI, data collection is carried out at a number of levels. The variables in the following subsections are discussed in the same order as they are found in the inventory records. There are four groups of variables the first group describes the sub-compartment as a land property, the second group describes the site, the third one describes the stand, while the last group of variables defines the management activities (CAO 2007a) which are suggested to be performed within the next 10 years. All data listed below are collected at sub-compartment level. Sub-compartment is the smallest economic/ land unit in the forest.

16.4.1.1 Sub-compartment Data

The following variables are recorded at sub-compartment level.

- Owner
- Municipality
- Sub-compartment ID
- Cadastral ID
- Responsible forest administration
- Actual forest area
- Primary forest function
- Restrictions (if any)
- Goal of wood production
- Game feeding potential
- Size of forest block
- Date of last management action

16.4.1.2 Site Data

Site data reveal habitat at sub-compartment level.

- Topography: elevation, exposition, slope declination
- Climate
- Hydrology
- Genetic soil type, soil texture and depth of fertile layer
- Potential/optimal stand type with its estimated mean increment
- Canopy class
- Shrub cover

16.4.1.3 Stand Data

All tree in the sub-compartment are grouped by tree species for stand data.

- Storey
- Tree-species, age, origin
- Species composition (by area), type of mixing
- Diameter at breast height *dbh*
- Height
- Stem quality
- Volume
- Basal area
- Current increment
- Method of volume measurement
- Dominant damage type, intensity

16.4.1.4 Management Data by Tree-Species

Management data by tree-species are used to describe wood utilization at sub-compartment level.

- Rotation age
- Drain/removal
- Intensity (m^3/ha to be harvested)
- Type of felling (cleaning, thinning, selective cutting, etc.)
- Reforestation
- Reforestation method
- Tree-species composition

16.4.2 Management

16.4.2.1 Personnel and Equipment

The Forestry Directorate of the Central Agriculture Office (CAO), the former State Forest Service, is responsible for carrying out the Hungarian NFI and DFP preparation. The cycle of the NFI is 10 years.

Inside the CAO there are ten regional forestry directorates and a headquarter responsible for forestry administration duties. About 110 persons are involved in the NFI and management planning, although they also work on other forestry related tasks (e.g. forest health monitoring, growth monitoring, mapping, etc.).

The field survey is supported with equipment such as global positioning system (GPS) receivers, rangefinders, and Bitterlich relascopes. Due to ongoing development subsidized by the EU more advanced technology will be introduced in the near future (CAO 2007b).

16.4.2.2 Quality Assurance

Quality assurance methodologies used by the Hungarian NFI include field manuals, training and control of field crews, spot-checks and tests, statistical checks of attribute qualities, and evaluation of changes on Hungarian NFI.

16.5 Estimation Techniques

16.5.1 Area Estimation

Forest area is defined by using aerial photos to delineate the border lines of sub-compartment boundaries. If there is a need for additional geodetic information, field surveys are undertaken.

16.5.2 Volume Estimation

Stand volume is calculated directly by evaluating the sampling data from the field survey using models and the parameters needed for yield table modelling.

16.6 Increment Estimation

Increment is always calculated at the sub-compartment level for the given tree species using yield tables.

16.7 Options for Harmonized Reporting

Reference definitions developed during the COST Action E43 project ensure a common basis for more exact, harmonized, understanding of forest inventory related definitions across Europe. Because Hungary has a very detailed data set, (not aggregated), establishing “bridge-building” processes from national levels estimates towards estimates based on reference definitions can be fulfilled in most cases.

16.8 Current and Future Prospects

To comply with the harmonization recommendations of COST Action E43, Hungary will initiate developmental work aiming at establishing a forest inventory based upon a statistical sampling design. Development of an appropriate methodology and initiation of a pilot project for a statistical forest inventory is a high priority task for the next two years. Experience with the existing growth monitoring system and the knowledge obtained from cooperation within the COST Action E43 project provide a good framework for preparing such a complex method within a short time frame.

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Chapter 17
Iceland

Arnór Snorrason

17.1 Development of Iceland's National Forest Inventory

The Icelandic Forest Inventory (IFI) was launched in 2001 as a project of the Icelandic Forest Research (Snorrason and Kjartansson 2004). Although the main goal of IFI is carbon accounting, the sample data will be used to produce information for other purposes as well.

Before launching the IFI, only woodlands of natural birch (*Betula pubescens* Ehrh.) had been surveyed in two country-wide surveys. In the first one, carried out in 1972–1975, all woodlands were mapped on aerial photographs and divided into homogenous units or polygons. For each unit measurements for a set of variables, including mean height and crown cover (Sigurdsson and Bjarnason 1977), were collected. The latter survey was carried out in 1987–1991 and was a more in-depth field inventory on sampled transects (Aradóttir et al. 2001). A new inventory of the area was not completed, but the area data from the first inventory were partially improved with new data from mapping of vegetation and field mapping. A map of the woodlands was digitised, projected in an official geographical coordinate system for Iceland known as ISNET93 and published as part of a vegetation map of Iceland at the scale 1:500,000 (Gudjonsson and Gislason 1998). A final report and publication for the latter inventory of the natural woodlands has not yet been completed, but rectification of the projection and formation of a geographical database of the data sampled was finished recently (Snorrason et al. 2007). According to the updated database, the combined area of natural birch shrub- and woodlands was estimated at 120,250 ha in the 1987–1991 survey.

Relatively good national statistics are available on the number of planted seedlings on an annual basis and the approximate location of plantations. These data have been used to estimate the area and age classes of plantations (Sigurdsson and

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Snorrason 2000). On the other hand, no national inventory, survey or aerial overview of the plantations existed before the IFI project.

In the first year of the IFI a database was compiled on the size (area), geographic location and contours of plantations, in order to build up a base for the target population of the sample-based inventory. Because most of the plantations are young, they cannot be evaluated using remote sensing and the IFI had to rely on information from forest managers. The main constituents of afforestation in Iceland are five independent regional afforestation projects, one national afforestation project, forestry associations (NGOs), the Icelandic Forest Service and the Soil Conservation Service of Iceland. In 2001 these institutions planted about 98% of the forest tree seedling production (Petursson 2002). The IFI has established a routine to compile such data on an annual basis. Information about new plantations is added to the geographical database annually.

For the natural birch woodlands, area results from previous inventories are used as the target population of the planned sample inventory.

A registration of permanent deforestation is completed with help of information from official institutions such as the Public Roads Administration and the Planning Agency which supervise, or are responsible for, processes that can lead to deforestation. These institutions have been informed about the importance of these data.

The next IFI step was to lay out systematic samples of permanent plots where carbon and wood stocks, among other valuable data, are collected. As mentioned earlier, the forests are split into two strata, one of plantation areas and the other of natural birch woodlands and shrubs. The sampling grid for plantations is denser (0.5×1.0 km) than the grid for natural woodlands (1.5×3.0 km). In the spring of 2005, the IFI started the first field measurements on plots and after 3 years has measured 383 plots in plantations and 126 plots in birch woodlands as seen in Table 17.1.

17.2 The Use and Users of the Results

17.2.1 General Use

The IFI is not only responsible for implementing the field inventory but also for providing historical, present and future prospective information for plantations based on model predictions of area and stock changes. This information, published or presented orally, is used by the government and other decision makers and affects forest policy in Iceland. The IFI also provides forest resources statistics and information for international organisations such as the Food and Agriculture Organization of the United Nations (FAO) and its Forest Resources Assessment as well as for the Ministerial Conference on the Protection of Forests in Europe (MCPFE). It also produces annual information on carbon pools and changes for the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United

Table 17.1 Forest inventories in Iceland

Inventory	Years	Method	Number of observation units
The first birch survey	1972–1975	Aerial survey with qualitative sampling of data	Number of described polygons = 738
The second birch survey	1987–1991	Aerial and line sampling with qualitative and quantitative of data	Total line length 418 km. Number of observations stops on line = 9,007
IFI sample-based inventory in plantations	2005–2009	Single plot systematic sampling with permanent plots, entire country each year, 5 years cycle	Number of plots measured = 383
IFI sample-based inventory in natural birch shrub- and woodlands	2005–2009	Single plot systematic sampling with permanent plots, entire country each year, 5 years rotation	Number of plots measured = 126 (first measurement cycle not yet finished)

Nations Framework Convention on Climate Change (UNFCCC). The IFI covers all forests in all ownership groups, including protected forests.

Mapping forest and woodland areas is essential because the IFI uses the maps as a population for the plot sampling. These maps are also used as general land use or coverage maps in Iceland. They have also been added with simple attributes to the CORINE 2006 land cover database of the European Environment Agency (Traustason and Snorrason 2008).

17.2.2 The Use of IFI Data in UNFCCC Including Kyoto Reporting

The IFI has been responsible for providing information for greenhouse gas reporting of the forest element of LULUCF to the UNFCCC from the start of the IFI project. One of the main reasons for the initiation of the National Forest Inventory in Iceland was the obligatory reporting connected to the Kyoto Protocol. The IFI reporting of forest activities under Article 3.3 of the Kyoto Protocol is considered an important part of the greenhouse gas reporting from Iceland.

Estimation for land use categories other than forest is done by the Icelandic Agricultural University. The Soil Conservation Service of Iceland provides data carbon stock and carbon stock changes on re-vegetated areas in accordance with the selection of re-vegetation as an activity under Article 3.4 of the Kyoto Protocol (Ministry of Environment 2006).

The data sampling in the IFI field inventory was tailored from the beginning to meet the reporting obligations of the UNFCCC and its Kyoto Protocol. The plan is that the IFI field inventory will give the answers to most of the reporting needs concerning forests and forestry. The IFI will aggregate the remaining information via other channels.

17.2.3 *The Role of IFI in Assessing the Status of Biodiversity*

Some variables are collected in the IFI field inventory only to describe biodiversity. The abundance and the occurrence of eight indicator species of ground vegetation and estimates of the coverage of eight ground plant classes are reported. The occurrence and coverage level of lichens growing on living trees is also reported. Other variables commonly used to analyse biodiversity are multifunctional and are also used to describe and measure common forest and carbon statistics.

17.3 Current Estimates

The basic area and volume estimates are given in Tables 17.2a and b. These variables were selected and their reference definitions were formulated in accordance with the

Table 17.2a Basic area estimates

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[c] (1,000 ha)
Forest land (reference definition)	38.7	0.38	10% crown cover with minimum height of trees of 5 m at maturity in situ	n.a.[d]
Plantations[a]	24.2	0.24		1.2
Natural birch[b]	14.5	0.14		n.a.[d]
Forest land (national definition)	80.5	0.78	10% crown cover with minimum height of trees of 2 m at maturity in situ	n.a.[d]
Plantations[a]	28.5	0.28		1.4
Natural birch[b]	52.0	0.50		n.a.[d]
Other wooded land[b] (reference definition)	105.5	1.02		n.a.[d]
Other wooded land[b] (national definition)	68.0	0.66		n.a.[d]
Other land (reference definition)	10,261.3	99.6		n.a.[d]
Forest land in UNFCCC LULUCF reporting	80.5	0.78	Same as forest land based on national definition	n.a.[d]
Total land area	10,300	100		–[e]
IFI coverage	Plantation forests and natural forests, natural woodlands and shrublands of birch. Total land area and water area estimates come from Land Survey Iceland			
IFI provides LULUCF area estimates for the land classes	Forest			

[a]Data from 2005–2007 of sample-based inventory.
[b]Data from survey of natural birch 1987–1991.
[c]Standard error.
[d]Not available.
[e]Assumed to be error free.

Table 17.2b Basic volume estimates

Quantity	Estimate	Share (%)	Description	SE[d]
Growing stock volume on forest land (million cubic metre)[a–c]	3.0		COST Action E43 Reference definition	n.a.[e]
Growing stock volume on other wooded land (million cubic metre)[b,c]	0.4		Reference definition	n.a.[e]
Annual increment of growing stock of trees on forest land and other wooded land (million cubic metre per year)[a–c]	0.067		Reference definition	n.a.[e]
Annual increment of growing stock of trees per hectare on forest land (m^3/ha per year)[a,b,d]	1.5		Reference definition	n.a.[e]
Annual drain on FOWL, average 2001–2005	n.a.[e]			
Annual drain per hectare on FOWL (m^3/ha)	n.a.[e]		Reference definition	
Dead wood volume (million cubic metre)	n.a.[e]			n.a.[e]
IFI is main information source for the following carbon pool changes	Above-ground biomass, below-ground biomass, dead wood, litter, soil organic matter (litter and soil, IFI together with models and flux measurements)			

[a]Data from 2005–2007 of sample-based inventory.
[b]Data from survey of natural birch 1987–1991.
[c]FAO (2005), MCPFE (2007).
[d]Standard error.
[e]Not available.

work of COST Action E43. Estimates based on observations and measurements of these variables are also given, as well as standard errors where they are known. The estimates are based on the IFI field inventory (2005–2009), model predictions for afforestation and updated data from the second natural birch inventory.

17.3.1 Notes on the Definitions

The national definition of forest in Iceland has recently been set to meet the obligations of the Kyoto Protocol (Ministry for the Environment 2006). It differs only for minimum height at maturity from the reference definition of COST Action E43 where the chosen value is 2 m instead of 5 m. Other definitions are equivalent.

17.4 Sampling Design

A systematic sampling design with a single plot at each grid intersection is used for the IFI field inventory. Annual measurements are countrywide, and each inventory cycle takes 5 years. All plots are permanent and will be re-measured at 5 years

Table 17.3 The sampling design in different forest populations

Population	Land area (1,000 ha)	Area represented by one field plot (ha)	Distance between plots	Ratio permanent/ all plots	Estimated number of plots in one cycle
Plantations forest	24.2	50	0.5 × 1.0 km	1	663
Natural birch woodlands	120	450	1.5 × 3.0 km	1	203

interval. The sampling density varies between the forest plantation population and the natural birch woodlands population as given in Table 17.3 and Figs. 17.1 and 17.2.

17.4.1 Sample Plots

Sample plots of natural birch inventory and plantation inventory differ to some extent (Figs. 17.3 and 17.4). The birch inventory plots are concentric circles of fixed size (Fig. 17.3). In the inner circle (50 m^2), all stems taller than 2 m are mapped and measured for diameter at 0.5 m height. Trees taller than 2 m are mapped and measured inside a 50 m^2 inner circle. Trees larger than 10 cm in diameter at 0.5

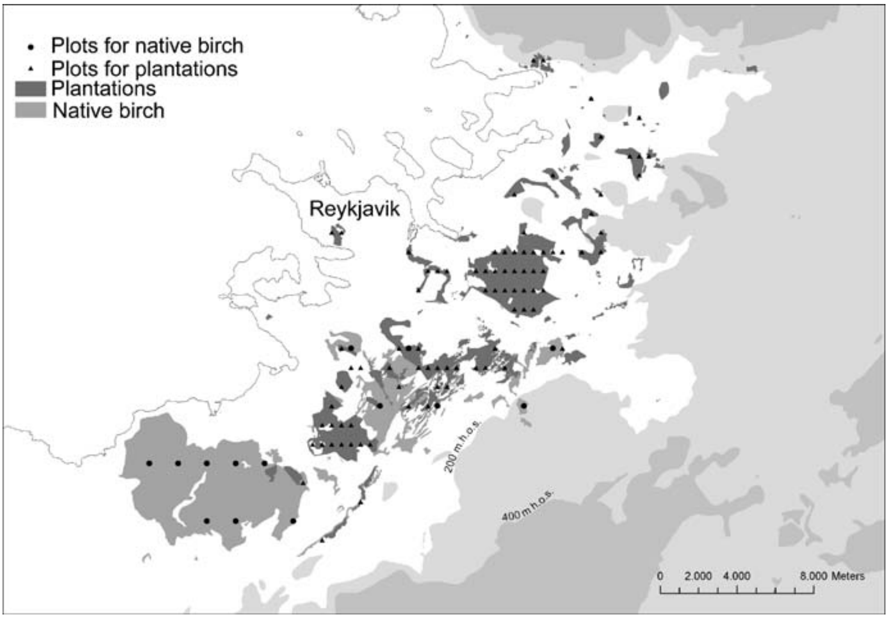

Fig. 17.1 Map showing the sampling density of field plots of the IFI (2005–2009) in the two sample populations around Reykjavík, the capital of Iceland

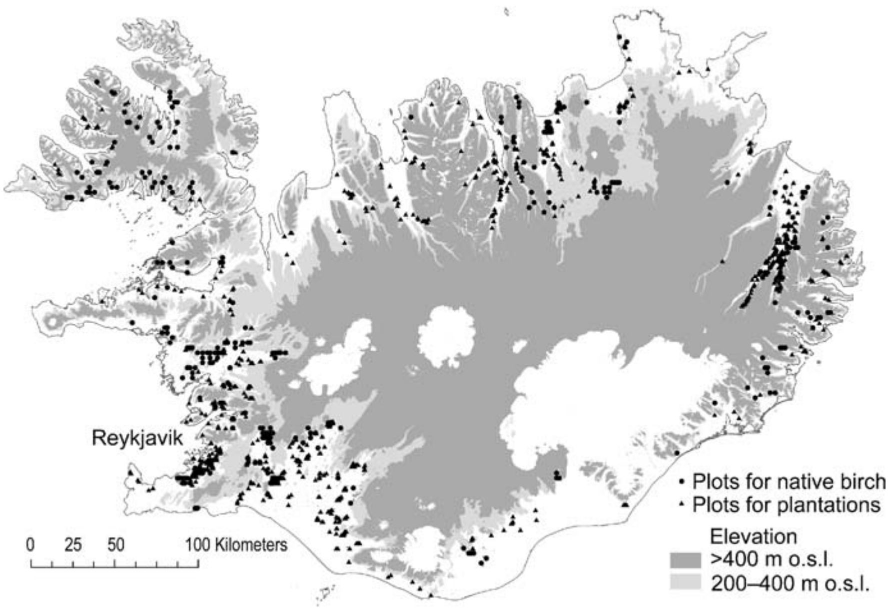

Fig. 17.2 The distribution of field plots of IFI (2005–2009) in the two forest populations in Iceland

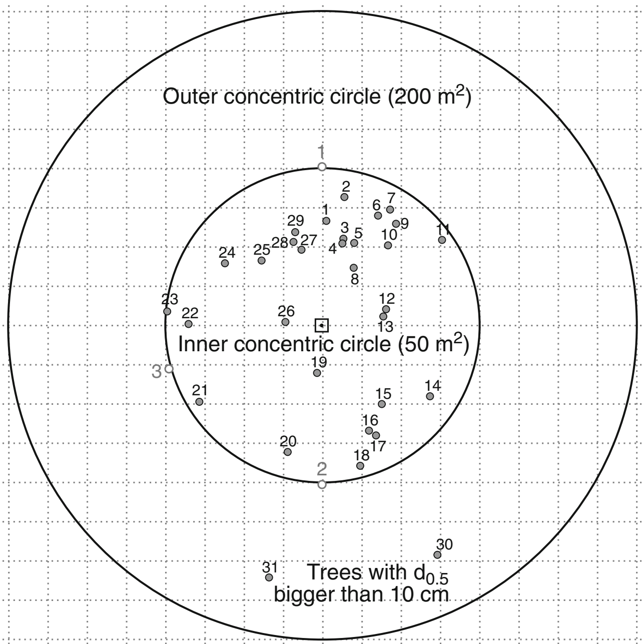

Fig. 17.3 A sample plot of the natural birch population. The picture of the plot is from the screen view of the software (Field-Map) used in IFI field data sampling. The grid in the picture is 1 × 1 m

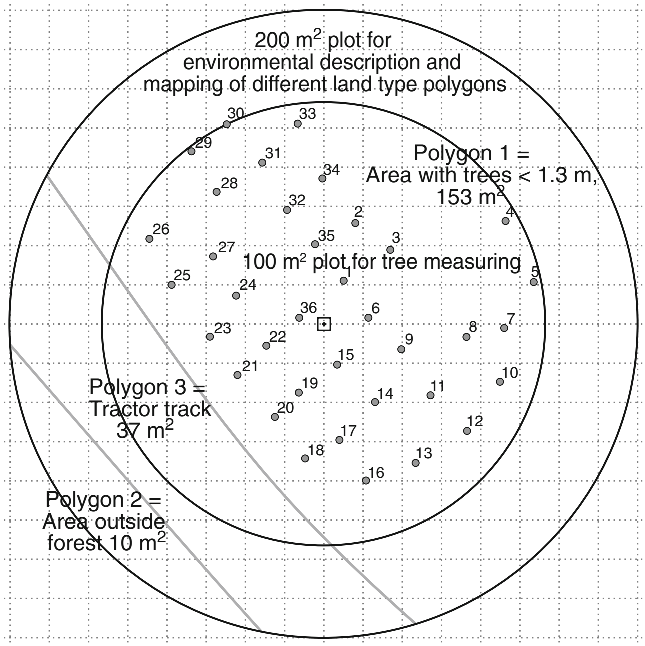

Fig. 17.4 A sample plot of the plantation population. In the case shown the 100 m^2 plot has been chosen as a plot for measuring trees. The plot to describe the environment and to map different land-types is always 200 m^2. The picture of the plot is from the screen view of the software (Field-Map) used in IFI field data sampling. The grid in the picture is 1 × 1 m

m height ($d_{0.5}$) are mapped and measured inside a 200 m^2 outer circle. Trees shorter than 2 m are measured on three 4 m^2 circle-sub-plots. At the centres of the same sub-plots, vegetation assessments are conducted. Soil, litter and ground vegetation samples are taken for carbon measurements in the centre of one of the sub-plots. Dead wood and stumps are also mapped and measured if they occur. The size of the plantation inventory plots is chosen according to the density of the plantation and can be 50, 100 or 200 m^2. If the number of trees or/and seedlings is less than or equal to 20 in 50 m^2 or 100 m^2 plots, then a larger size is chosen. In both inventories, a 200 m^2 plot is used to describe the environment and map different land types (see Figs. 17.3 and 17.4). Each land-type is represented with a polygon and further described with respect to trees, vegetation, soil, and other variables.

17.4.2 Management

17.4.2.1 Personnel and Equipment

The IFI is conducted by the Icelandic Forest Research. Two specialists at the institute are mostly occupied with IFI on an annual basis. Three specialists rotate in leading one or two field groups of two or occasionally three people. The field assistant is normally a foreign student on an internship or a staff member from the institute. Field measurements are carried out between late May and late September.

The field equipment includes a range/height metre, a digital compass and a global positioning system (GPS) connected to a field computer. This equipment package and the software were developed by the Institute of Forest Ecosystem Research in the Czech Republic (IFER 2009).

The field crew vehicle is equipped with a laptop computer with geographic information system (GIS) software installed. All modifications of forest maps and registration of measured or left-out plots are done using the vehicle computer. The vehicle computer is connected to the GPS so that the shortest road or track is chosen when heading to the next plot to be measured.

17.4.2.2 Quality Assurance

Training and calibration of assessments are done by joint field measurements of the group leaders. When group leaders change, they work together for at least 1 week before one of them assumes leadership. Training of assistants is done by the group leaders in the field.

The data are checked the first time in the field computers using logical checks. Each day data from the field computer and the laptop is backed up on a separate hard disk. After each field trip another backup is done to digital facilities at the institute. The final thorough quality check is done after the field season.

17.5 Estimation Techniques

17.5.1 Area Estimation

Area estimation is based on available forest maps. These digital maps are used as a population for the systematic plot sampling (see Fig. 17.1). When the sample is drawn, the maps are buffered by 16 m to decrease the probability of having some forest areas outside the population. For this reason, the number of visited plots is greater than the number of plots in forests. Some plots are split between strata (see Fig. 17.4). For plantation forests the ratio of measured to visited plots is approximately 0.7, which highlights the fragmentation of the plantation forests in Iceland. The area estimate of a land stratum is shown in Eq. 17.1:

$$a_s = \frac{\sum_{i=1}^{n} y_i r_i}{\sum_{i=1}^{n} x_i} A \tag{17.1}$$

where a_s is the area estimate of the stratum s, A is the population area, y_i is 1 when a fraction of the plot overlaps' the stratum in question and 0 when not, r_i is the ratio between the area of the plot overlapping the stratum and the total area of the plot. x_i for all sampled plots in the population is always 1. Examples of land strata are forest land, forest land-types etc.

17.5.2 Volume Estimation

In 2009 direct volume estimation using data acquired from the IFI field sampling has not yet been carried out. On the other hand, the methodology is rather clear. In the birch inventory all trees reaching the minimum size threshold are measured for diameter and defined as an object for growing stock estimation. A new single-tree volume model for birch will be used to predict the stem volume (Snorrason and Einarsson 2006). In a similar manner, all trees that reach diameter at breast height (*dbh*) more than zero will be objects for growing stock estimation in the plantation inventory. New single-tree models for eleven tree species grown in Iceland will be used to predict stem volume (Snorrason and Einarsson 2006). These single tree models predict stem volume which is defined as the volume of the stem over bark and above stump to the top of the tree. The volume estimators are weighted ratio estimators similar to the area estimators (Eq. 17.1).

Mean volumes (m^3/ha) and total volumes (m^3) are estimated as follows:

1. Heights of trees for which diameter is measured are predicted with height/diameter curves based on measurements of sub-samples of trees (candidates) that also have height measurements. The stem volume of each tree is then predicted using single-tree models.
2. Growing stock can then be calculated on each plot as a sum of all tree volumes. Mean volume (m^3/ha) and total volumes (m^3) are then calculated as an area-weighted average and area-weighted sum in each stratum that is defined.
3. Other sampling units are used if stratification is not on plot level (stratification on tree-species, diameter-class, land-types, etc.) (Albers 2007).

Growing stock estimates for Iceland published both in FAO 2005 and MCPFE 2007 are based on predictions using models constructed with annual plantation rates as inputs and growth curves for different groups of species (Snorrason 2006).

17.5.3 Stock Change Estimation

The stock change estimates for both growing stock and carbon stock in trees will initially be based on the difference between increment and drain estimates (IPCC

2003). Increment will be estimated with tree growth during the 5 years preceding the inventory year (forecasting), and the drain with stump and dead wood measurements. When re-measurement starts in the year 2010, differences between estimates of past and present stocks will be used to estimate the stock change (IPCC 2003).

17.5.4 Specific Estimation Questions Related to LULUCF Reporting

All forests are by national definition defined as managed (see Table 17.2a). Stock change estimation is described in a previous section. When estimating carbon stocks for single trees, the above-ground biomass is predicted with new single-tree biomass models (Snorrason and Einarsson 2006). A country specific biomass expansion factor is used to add the below-ground fraction of the tree (root stock and coarse roots >5 mm in diameter) (Snorrason et al. 2002).

For each plot measured, the ground vegetation, litter and humus layer are sampled together at a single location. At the same location, a soil sample, at 0–30 cm depth, is acquired. These samples will be analysed for carbon content and the mean carbon stock of each stratum can then be estimated. When the same plots are re-measured, new samples will be taken and new carbon stocks estimated. The difference between the two estimates will be used to estimate carbon stock change in carbon pools other than trees. Meanwhile, it is difficult to present country specific estimates based on direct measurement on plots for stock changes of carbon pools other than trees although new research results show high carbon sequestration rates (727 g CO_2 per m^2 per year) 14 years after afforestation on former heathland pasture with only 8% of the C-uptake in above-ground trees (Bjarnadóttir et al. 2007). Estimation and reporting of carbon change in soils will therefore, in near future, be for only tier 1 approach for afforestation (land converted to forest land). That is the difference between average C-stock in soils outside forest and average C-stock in soils inside forest on similar soil divided by the average age of the forest (IPCC 2003).

17.5.5 Error Estimation

The method used for estimating the standard errors for area and volume estimates is based on statistical methods for forest inventory described in Akça (2000) and Husch et al. (1972). The basic theory is that systematic sampling, as practiced by the IFI, will not produce larger standard errors than random sampling. Using standard errors based on random sampling to estimate standard errors based on systematic sampling will only overestimate the error and not underestimate it.

Table 17.4 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current IFI

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	IFI	ND ≠ RD. Minimum height is 2 m instead of 5 m
Growing stock volume	Yes	Yes	IFI	ND = RD
Above-ground biomass	Yes	Yes	IFI	ND ≠ RD. Deciduous foliage is included. Stump is excluded
Below-ground biomass	Yes	Yes	IFI	ND ≠ RD. Stump is included
Dead wood volume	Yes	Yes	IFI	ND = RD
Dead wood volume by decay stage classes	Yes	Yes	IFI	ND = RD
Afforestation deforestation reforestation (Kyoto 3.3)	Yes	Yes	IFI	ND = RD
Forest type	Yes	No	IFI	Can be derived from NFI data

17.6 Options for Harmonized Reporting

The methodology of the IFI has been evolving at the same time as the work of COST Action E43 has been going on. The IFI has tried to follow the reference definitions described by the various working groups of COST Action E43. National definitions do follow reference definition with a few exceptions (see Table 17.4).

17.7 Future Prospects

In the near future there is a desire to get better information on the expansion of the natural birch woodlands. With climate change and decreasing grazing pressure at least some of the remains of the natural birch woodlands show rapid expansion. The design of the sample-based inventory with maps from old surveys as a target population does not capture this expansion so other measures have to be taken into account. One possibility is to remap randomly chosen parts of the natural birch forest and compare the new maps to the old one to asses the increase (or decrease) of the area of the woodlands.

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Chapter 18
Ireland

Christy O'Donovan and John Redmond

18.1 Development of the Irish National Forest Inventory

18.1.1 Background

At the end of the nineteenth century, the area of forest cover in Ireland was estimated to be approximately 69,000 hectares (ha), or circa 1% of the national land area. During the first 75 years of the twentieth 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. As a result, the area of the national forest estate in Ireland has now increased to approximately 700,000 ha. Of these, approximately 57% are in public ownership and 43% in private ownership.

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) own 56% of the forest estate and maintain 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 resources.

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18.1.2 The National Forest Inventory

In 2007 the Forest Service of the Department of Agriculture, Fisheries and Food completed the first statistical National Forest Inventory (NFI) in Ireland. The purpose of the NFI was to record and assess the current extent, state and composition of Ireland's forest resources, both public and private, in a timely, accurate and reproducible manner.

This inventory involved a detailed field survey of Ireland's forests. Ireland's NFI is based on a randomised systematic grid sample design. As a result of a pilot study in Co. Wexford, a grid density of 2×2 km was estimated to provide the frequency of plots needed to achieve a national estimate of volume with a precision of $\pm 5\%$, at the 95% confidence level. This grid density equated to 17,423 points nationally, each representing approximately 400 ha. Each circular NFI permanent sample plot measures 25.24 m in diameter, equating to 500 m^2.

The underlying technology used in the NFI consisted of an integrated system of hardware and software developed by the Institute of Forest Ecosystem Research Ltd. (IFER), Czech Republic. It allowed for the preparation of a NFI database, background maps, and plot generation. This in turn allowed for the creation of projects for field teams, which facilitated the field data collection process.

To carry out the data collection work, the Forest Service recruited professional foresters, with six foresters working in the field at any one time. Due to staff turnover, twelve field staff were employed during the course of the project. The field data collection began in November 2004 and was completed in November 2006. In total, 1,742 forest plots have been established throughout the country, with the number of plots in each county relative to the size of the county and the level of forest cover. Training, field team support, validation and other quality control procedures were undertaken by two staff to ensure data quality and the smooth running of field operations.

Following the completion of field data collection work, primary data preprocessing and data analysis were completed. During data pre-processing the validity of the data was checked and data values were amended where necessary. Secondary variables, such as volume, were also calculated. Data analysis involved the production of statistics which describe components of the national forest estate, e.g. volume of standing deadwood per hectare. Data analysis and results generation were undertaken by the Forest Service, in close collaboration with the IFER, and completed in June 2007. Publication of three NFI documents: NFI Methodology (Forest Service, 2007a), NFI Results (Forest Service, 2007b) and Proceedings of NFI Conference (Forest Service, 2007c), occurred in November 2007.

18.1.3 Previous Inventories

In tandem with the growth and development of the forest resources a number of forest inventories have been carried out over the years. The earlier inventories were all carried out by the State Forest Service and they examined specific parts of the forest resource. They varied in their extent, consistent with the economic and personnel resources that were available at the time.

The outbreak of the Second World War in 1939 hastened the first general survey of forests, both public and private (O'Muirgheasa 1967). The purpose of this survey was to secure an estimate of timber resources, and it being war-time, the results were never published. From 1945 through to 1948 an ongoing survey of state forests was undertaken but this was abandoned after 1948. At that time the total area surveyed extended to 38,000 ha. In 1957 a stand level inventory of state forests was planned and this was undertaken in the years 1958 and 1959. It was called the "Census of Woodlands 1958/59". The emphasis was again on the available timber resource, excluding scrub and forest crops less than 11 years old. The census extended to 55,225 ha (O'Muirgheasa 1967). Twelve staff were involved and the survey took 1.5 years. Planning for the 1968 "Inventory of State Forests" commenced in the latter half of 1965 (O'Flanagan 1968). The survey period covered 2.5 years and 29 people were involved including survey officers, office personnel and mapping draughtsmen. The inventory covered 102,446 ha and crops less than 11 years of age were excluded. Similar to the Census of Woodlands 1958/59, this was also a stand-level inventory with emphasis on forest maps and quantifying the timber resource.

After the completion of the 1968 Inventory of State Forests, it was considered an opportune time to secure a complete picture of the national forest estate by undertaking an Inventory of Private Woodlands (Purcell 1979). The survey ran for 2 years and 3 months and was divided into two phases. Phase one included a complete stand-level inventory of all forests 40 ha or more in extent. In phase two the country was divided into four regions and a 9% strip sample was taken. The strips were 2.88 km (1.8 miles) wide and 32 km (20 miles) apart. This strip sample accounted for the smaller scattered private forests not already included in phase one. The survey covered 81,963 ha and identified 58% of the private forest estate as high forest, 40% being classified as scrub and the remainder unstocked.

In 1978 the Forest and Wildlife Service (FWS) updated the 1968 Inventory of State Forests. After this there was a continuous updating of the inventory records, the intensity of which was dependent on forest age. The geographical information system (GIS) was first introduced, as an inventory tool, operationally to the FWS in 1982. The 1986 inventory update was published in 1989, which took the 1976 inventory as the base and included areas which were updated between 1977 and 1989. Since the establishment of Coillte in 1989 there has been a continuous GIS based stand inventory of all crops (Quinn 1996).

18.2 The Use and Users of the Results

18.2.1 General Uses

The main reason the NFI was initiated, was to provide information for greenhouse gas reporting for the Land Use, Land-Use Change and Forestry (LULUCF) sector.

Going forward the NFI is the main reporting tool for the provision of statistics to international organisations such as the Ministerial Conference on the Protection of Forests in Europe (MCPFE). The NFI will also be used to provide information to monitor Sustainable Forest Management (SFM), which will guide future policy and strategic planning.

18.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

Under the agreed terms of the Kyoto Protocol, Ireland is committed to reduce greenhouse gas (GHG) emissions by 13% above the 1990-base year level. Current estimates (1990–2004) suggest that GHG emission levels are 23% above the 1990 level (McGettigan et al. 2006). Assuming a business as usual scenario, it is estimated that the contribution of national forests, under Article 3.3, may offset circa 16% of the required GHG emissions for the first commitment period of 2008–2012 (Black and Farrell 2006). However, the estimation of the extent to which forests sequester carbon in the mid to long-term is hindered by a high degree of uncertainty due to spatial heterogeneity and temporal variability. These estimates are continuously being refined and redeveloped as new research information and inventory data becomes available (Black 2007).

The Irish carbon reporting system (CARBWARE), initially described by Gallagher et al. (2004) was implemented to meet reporting requirements to the United Nations Framework Convention on Climate Change (UNFCCC) on national forest sources and sinks. Whilst this model indicated the likely contribution of forests to the national carbon storage (sink) potential, the system relied on the use of generalised stand growth models to describe changes in forest carbon stocks because of the lack of NFI data. The availability of detailed NFI data now provides the opportunity to redevelop and improve estimates of national forest carbon stock changes (Black 2007). This is in line with the recommendations outlined in the International Panel on Climate Change (IPCC) good practice guidance (GPG) for LULUCF, which defines good reporting practice as "neither over- nor under-estimating so far as can be judged, and in which uncertainties are reduced as far as practicable" (IPCC 2003).

18.2.3 The Role of NFI in Assessing the Status of Biodiversity

Ireland's forests represent an important biodiversity resource. As biodiversity is an important indicator of sustainable forest management, biodiversity related attributes were included in the NFI. The attributes assessed in relation to biodiversity include:

1. The volume and decay class of deadwood, including stump, lying and standing deadwood

2. The occurrence and abundance of ground vegetation species
3. The occurrence and abundance of tree lichens
4. The age and structural diversity of the forest
5. The type and amount of open spaces
6. Soil type and associated attributes, such as drainage
7. All tree species occurring on the 12.62-m plot
8. The origin of tree species

18.3 Current Estimates

The definitions employed in Ireland's first NFI (2004–2006) deviate from the COST Action E43 reference definitions. Work is underway to bridge the differences which will allow common reporting on the two primary variables, area and volume.

The basic area and volume estimates and the associated definitions and descriptions are given in Tables 18.1a and b, as well as standard errors, based on Ireland's NFI (2004–2006). The NFI is also an important information source for the carbon pools above-ground biomass, below-ground biomass, dead wood, litter and soil organic matter. Carbon stock estimates for these five pools are presented in Table 18.1c.

Table 18.1a Basic land area estimates from years 2004–2006

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Forestry land	625	9.0	Forest area with productive function	30
Non-productive forest land (open area)	62	0.9	Non-stocked forest area (>400 m^2) enclosed within the forest boundary	10
Forestry roads (national)	10	0.1	Greater than 6 m in width, from tree to tree	4
Forest land[b] (national definition)	697	10.0	0.1 ha minimum area 20% crown cover 20 m minimum width 5 m height at maturity in situ	31
Other wooded land	49	0.7	Groups of trees that do not meet the criteria of the forest definition From photo-interpretation, not verified in the field	9
Other land (reference definition)	6,229	89.3	Land that is not classified as forest land or other wooded land	32
Total land area[c]	6,976	100.0		–[d]

[a]Standard error.
[b]For UNFCCC LULUCF reporting the area of Forest land was assessed based on spatial datasets, it amounts to 587,000 ha.
[c]Total land area of Ireland is derived from Ordnance Survey Ireland (OSi) data.
[d]Assumed to be error free.

Table 18.1b Basic volume estimates from years 2004–2006

Quantity		Estimate	Description	SE[a]
Growing stock volume on forest land		70 million m^3 112 m^3/ha	Conifer: Ground to top diameter of 7 cm. Broadleaf: Ground to 7 cm or timber height. Timber height concerns merchantable material only, and is the distance from the base to the highest point on the main stem where the diameter overbark is not less than 7 cm	4 8
Annual increment of growing stock on forest land million m^3		n.a.[b]	To be computed after next NFI	n.a.[b]
Annual drain (average 2001–2005) on forest land		3.3 million m^3 4.4 m^3/ha	Estimated from sawmill/pulpmill returns	n.a.[b]
Dead wood volume	Log	2.7 million m^3	Minimum length = 1 m, minimum top-diameter = 7 cm	0.9
	Standing	1.9 million m^3	Minimum *dbh* = 7 cm	0.4
	Stump	1.1 million m^3	Minimum top diameter = 20 cm	0.2

[a]Standard error.
[b]Not available.

Table 18.1c Basic carbon stock estimates from years 2004–2006

Category	Estimate (million tonne)	Share (%)	SE[a] (million tonne)
Tree (above-ground)	21,980	6.8	1.3
Deadwood	1.4	0.4	0.3
Litter	8.6	2.7	0.3
Tree (below-ground)	8.2	2.5	0.5
Soil	281,445	87.6	11.5

[a]Standard error.

In subsequent NFI's both area definitions, national and COST Action E43 reference definitions, will be used during field assessment. The values of calculated timber volume are not fully compatible with European standards which are gradually being established as a stump to tip volume of the stem overbark. It is expected that the volume for Ireland will be re-calculated when the new national volume equations for Ireland become available.

18.4 Sampling Design

Ireland's NFI is based on a randomised systematic grid sample design. As a result of a pilot study in Co. Wexford, a grid density of 2 × 2 km was estimated to provide the frequency of plots needed to achieve a national estimate of volume with a

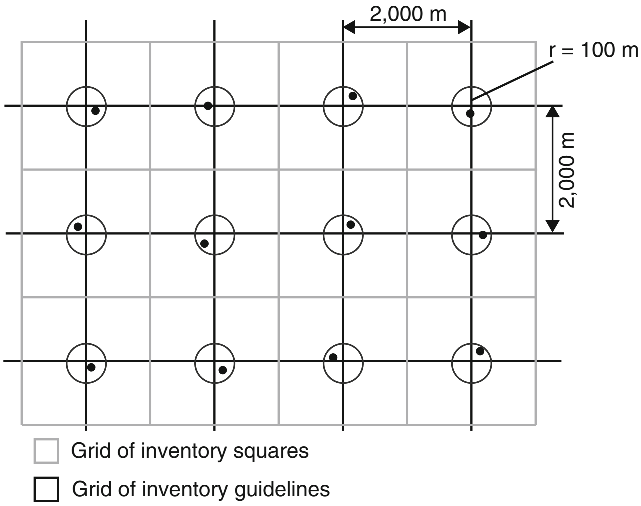

Fig. 18.1 Schematic representation of sampling design

precision of ±5%, at the 95% confidence level. This grid density equated to 17,423 points nationally, each representing approximately 400 ha.

The first element of the sample selection process involved placing a 2 × 2-km grid over the total land base of Ireland (6,976,100 ha). Air photo interpretation was used to classify sample points into land use types, primarily Forest and Non-Forest. This process identified plots that occur in forest or potentially in forest, and these became the focus of a detailed field survey.

A permanent inventory plot was established at a random location within 100 m of the 2 × 2 km intersection (Fig. 18.1). Thus the relationship between individual plots may be considered random. This displacement feature also ensures that plot locations are kept confidential, as knowledge of their locations could influence future management decisions.

As the grid is permanent, it allows for the re-assessment of the sample points at future dates, to monitor forest land use change (i.e. afforestation and deforestation). The location of the sample plots was given by x and y grid co-ordinates, available as six digit Irish national grid co-ordinates.

18.4.1 Overview of NFI Land Use Classification

There are three stages of land use classification undertaken in the NFI. These stages are land use type, category and class (Fig. 18.2). They form the basis of the NFI, as the classification process dictates whether the sample points are included in the NFI or not, and the range of attributes to be collected at the individual sample points.

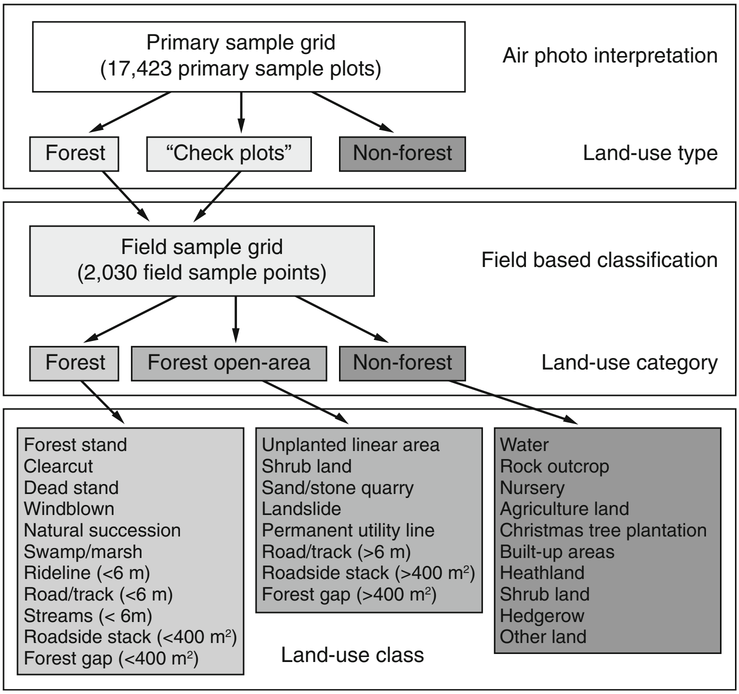

Fig. 18.2 Overview of NFI land use classification

The initial stage classified the points in the 2 × 2-km grid (17,423 sample points) into Forest and Non-Forest land use types (LUT) using air photo interpretation. This desk based exercise is detailed fully in the subsequent section.

NFI plots with a land use type of Forest and Check plot became the focus of the field survey. The first attribute to be assessed after locating the plot centre was land use category, which includes: forest, forest open area and non-forest. Plots classified as forest and forest open area were established as permanent sample points and became the focus of the NFI.

The final stage of classification involved the assignment of a land use class, which gave a more detailed description of the sample point. This information was also used to update the air photo interpretation results.

In total, 1,742 NFI permanent plots were established across the Republic of Ireland (Fig. 18.3).

18.4.2 Sample Plot Design

The concentric circle approach, comprising three concentric circles with different radii was used for tree assessment. Trees of different dimensions are mapped and

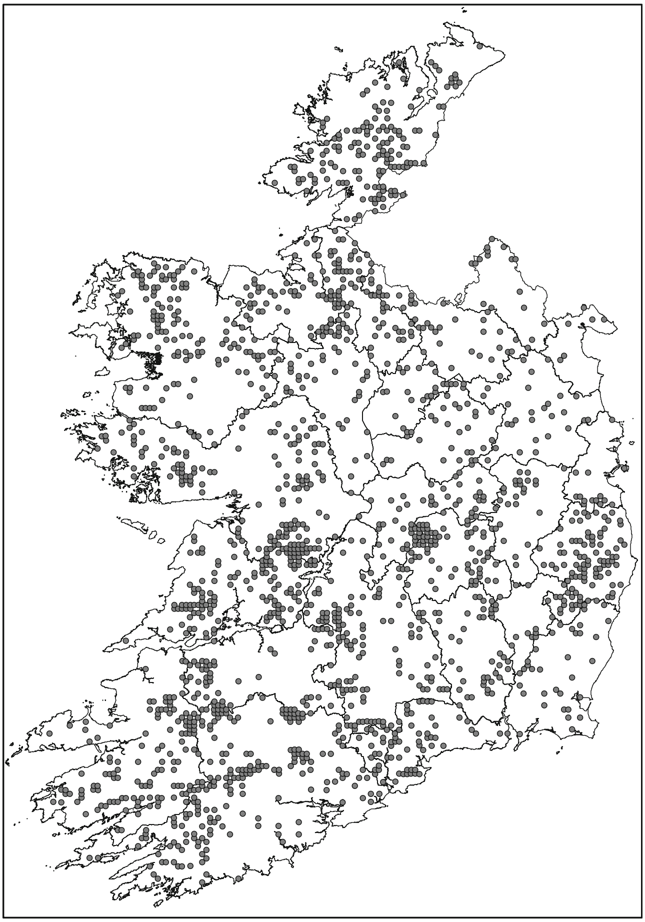

Fig. 18.3 Distribution of the 1,742 NFI plots. © Ordnance Survey Ireland, 2007

Table 18.2 Concentric plot design

	R_1	R_2	R_3
Sub-circle radius (m)	3	7	12.62
Sub-circle area (m^2)	28.3	153.9	500
Threshold diameter (mm)	70	120	200

described on each particular plot. The decision about which tree was considered for assessment was based in its position on the plot and its diameter at breast height (*dbh*). These sub-plot radii and threshold *dbh* for these sub-plots are presented in Table 18.2.

Table 18.3 Main NFI attributes

Plot	**Deadwood**
Plot id	Branch cover
Plot area	Stumps presence
Land use category	Stump diameter, height and decay status
Geographic coordinates	Dead logs presence
	Dead logs distribution
	Dead log mid-diameter, length and decay status
	Valuable site identification
	Game accessibility and food
Forest structure	**Site**
Stand layer type, canopy closure and composition	Altitude
Social status	Relief form
Fork	Aspect
Dead tree	Slope
Forest diversity	Erosion
Species composition	Anthropogenic factor
Species composure	Humus form
Diameter and height diversity	Soil condition
Production	Group soil
Dbh	Parent material
Upper diameter	Principal soil
Upper diameter height	Peat texture
Tree height	Soil texture
Live crown base	Drainage
Dead crown base	Moisture
Stem quality (straightness, branchiness)	Soil depth
	Peat depth
	Litter description
Damage	**Regeneration**
Negative factor limiting regeneration	Presence
Type, intensity and age of regeneration tree damage	Origin
Tree mechanical damage type, intensity and age	Protection
Peeling intensity and age	Regeneration distribution
Stem rot	Species mixture
Tree break	Species and age composition
Tree root damage type, intensity and age	Height class
Other tree damage type	Regeneration tree number
Defoliation	
Defoliation of tree top	
Type and intensity of discoloration	
Broadleaf damage	
Ecosystem	**Forest management**
Lichens presence and type	Ownership
Plants species and cover	Forest type
Shrub species and cover	Forest subtype
Grass cover	Forest naturalness
Herb cover	Cultivation type
Moss cover	Growth stage
Fern cover	Thin status
Brush cover	Rotation type
Shrub cover	Stocking

Ireland's NFI assessed the current state and development of the forest estate in relation to standing trees, forest structure, forest regeneration, deadwood, soil and other site characteristics. The primary attributes collected are displayed in Table 18.3.

18.4.3 Management

18.4.3.1 Personnel and Training

Six professional foresters were recruited for the purposes of data collection on Irelands first NFI. A 5-week intensive training programme was delivered by IFER and the Forest Service. Training covered plot navigation, plot set up, data collection procedures, precision of measurements, care and maintenance of the equipment and data storage. Site safety and first-aid courses were also undertaken. At the culmination of training, a test was held and the group was divided into three 2-person teams. Data collection proceeded throughout the year, as winters tend to be mild and damp, allowing work to proceed.

18.4.3.2 Hardware and Software

The underlying technology used in the NFI field survey consisted of an integrated system of hardware and software developed by IFER. The specialised inventory software, Field-Map™, allows for the preparation of a NFI database and background maps, and plot generation. This in turn provides for the creation of projects for field teams, which facilitates the field data collection process. The data was stored directly into a computer database in the field. Inventory data were uploaded to a central database via USB memory sticks.

The NFI database is a fully relational database, containing 127 tables. The database also features a spatial map component, which is a layer containing the locations of field plots and ancillary background map data used for navigation to field plots. Selected layers (e.g. trees) have a spatial reference (i.e. position relative to the plot centre).

18.4.3.3 Quality Assurance

The data are checked first time in the field computers using logical checks. The data were transmitted to the project coordinator via USB flash drives biweekly. The final thorough quality check is done after the field season, during data preprocessing.

18.4.3.4 Validation Methodology

The individual NFI field team make-up was subject to considerable and ongoing change over the course of the validation campaigns and thus validation plot selection had to be from across the range of the individual members and the team combinations. In order to select and achieve objective sampling of the validation plots, stratified random sampling was used. The sampling frame (i.e. grid of completed plots) was stratified by field team, with selection being proportional to the number of plots completed by each.

All validation plots were completely re-measured and described using the same technology and methodology as used by the NFI field teams. A direct, on-site comparison of the data collected by the field-team with the validation data was carried out at the end of each plot validation. The individual trees were identified from the field team data and all the tree attributes were compared using a customised Field-Map^{TM} software extension. Important differences were discussed directly at the forest plot, and trees with a significant *dbh* or height difference were re-measured to verify the validation measurements.

A total of 50 plots were included in the NFI validation exercise. The validation work was undertaken by one team, comprised of one Forest Service and one IFER staff member.

18.5 Estimation Techniques

18.5.1 Technology for Data Processing

The Field-Map^{TM} system has been designed for the whole NFI process, starting with the preparation of the data collection database, through to the field data collection and on to the comprehensive data processing.

The data was stored directly into a computer database in the field. During the field data collection the data were automatically checked and verified. Without any intermediate steps, the field data could be processed. All the data processing was done using the original field database without conversion. During the data processing the secondary attributes were added to the database, but the database retained its original format which can easily be used for the next inventory. Such an approach significantly increases overall productivity.

A comprehensive set of data processing procedures, i.e. calculation of secondary attributes and statistical data processing, is incorporated in the Field-Map Inventory Analyst software.

Field-Map Inventory Analyst facilitates the step-by-step calculation of secondary attributes. The statistical data processing tasks are formulated and easily implemented. The results of statistical data processing, in the form of standardised tables and charts, are produced automatically and can be used for NFI reporting.

18.5.2 Statistics

The statistical methods used within NFI represent standard methods used for simple and stratified sampling design (e.g. Cochran 1977). The following statistics (Table 18.4) were used in different data processing tasks: population total (e.g., the total volume of a certain forested area) and sample mean (for example, mean volume per hectare). The confidence interval ($\alpha = 0.05$) for each statistical variable was also estimated.

When calculating a sample mean, several alternative calculations can be employed in addition to the standard arithmetic mean (Černý et al. 2005):

1. A weighted mean can be calculated if the contribution of samples should depend on a certain other variable (e.g., mean tree defoliation weighted by tree diameter). Both, weighted and unweighted mean can be calculated for a tree (e.g., mean crown length) or plot (mean volume). In the second case, the mean can be expressed per plot or per unit area (hectare). There are two ways to calculate a mean value per unit area.
2. Arithmetic mean: mean value per hectare is calculated by dividing the arithmetic mean by the area of the inventory plot in hectares.
3. Normalized mean: It is calculated in such a way that the calculated value of the variable under consideration for a plot is divided not by the whole plot area, but by the area of the part of the plot where the given variable is present. For example, the mean stand volume per tree species is calculated in such a way.

18.5.3 Tree Height

18.5.3.1 Tree Height Measurements

A sub-sample of trees was measured for tree height during the field survey, with a maximum of seven trees ($dbh \geq 70$ mm) per species per plot measured. The sample trees were chosen regularly along the range of tree diameters within the plot. Based on this rule, 7,559 (i.e. 33.6%) of the 22,477 trees have been measured for height. For the height model calculations, only live and undamaged trees were used.

18.5.3.2 Modelling Tree Height

Based on the number of height sample trees per plot, a *dbh*-height model was calculated. Wherever the number of sampled height trees for a species within a plot was sufficient, i.e. greater than four, the local (i.e. plot) model was parameterised using linear or non-linear least squares methods. If the parameterisation of the local model was not carried out due to an insufficient number of measured trees or their unfavourable distribution then the global model (i.e. species model for all plots)

Table 18.4 Review of equations applied in the Inventory Analyst statistical calculations for individual inventory plots and for the whole dataset (Černý et al. 2005)

Variable	Calculation for plot	Plot weight	Calculation for the set of plots	Example
Total	$X_j = \sum_{i=1}^{m} x_j$	$w_j = 1$	$Y = \sum_{j=1}^{n} X_j$	Total volume for inventory plots
			$Y_{tot} = \frac{Y}{\sum_{j=1}^{n} s_j} S$	Total volume for the whole territory under study
Average sum	$X_j = \sum_{i=1}^{m} x_j$	$w_j = 1$	$\bar{y} = \frac{1}{n} \sum_{j=1}^{n} X_j$ $\bar{y}_{ha} = \frac{\bar{y}}{s}$	Mean volume (mean volume per plot; divided by plot area it gives mean volume per hectare)
Mean	$x_j = \frac{1}{m} \sum_{i=1}^{m} x_i$	$w_j = 1$	$\bar{y} = \frac{1}{n} \sum_{j=1}^{n} \bar{x}_j$	Concentration of carbon in the wood, mean wood density, etc.
Weighted mean	$x_j = \frac{\sum_{i=1}^{m} (x_i v_i)}{\sum_{i=1}^{m} v_i}$	$w_j = 1$	$\bar{y} = \frac{1}{n} \sum_{j=1}^{n} \bar{x}_j$	Mean tree defoliation (weighted by tree volume)
Normalized mean of sums	$\bar{x}'_j = \frac{\sum_{i=1}^{m} x_i}{\sum_{i=1}^{m} v_i}$	$w_j = \sum_{i=1}^{m} v_i$	$\bar{y} = \frac{\sum_{j=1}^{n} (\bar{x}'_i w_j)}{\sum_{j=1}^{n} w_j}$	Volume per hectare by species (tree volume of individual species is related to the representative area of this species) The plot weight can be, e.g., the sum of individual tree areas
Normalized mean of weighted means	$\bar{x}_j = \frac{\sum_{i=1}^{m} (x_i v_i)}{\sum_{i=1}^{m} v_j}$	$w_j = \sum_{i=1}^{m} v_i$	$\bar{y} = \frac{\sum_{j=1}^{n} (\bar{x}_j w_j)}{\sum_{j=1}^{n} w_j}$	Mean defoliation by species The plot weight can be, e.g., the sum of tree individual areas This approach points out the different share of the given species within a plot; in contrast with mean of weighted means the weights of different plots are not the same

where
x_i is the value of the variable under study for the ith entity (e.g., tree) within the plot j
v_i is the weight of ith entity within the plot j
m is the number of entities within the plot j
X_j is the sum of the variable under study for plot j
$\bar{x}_j$ is the mean value of the variable under study for plot j
$\bar{x}'_j$ is the mean value of the variable under study per unit v for plot j
w_j is the weight of the jth plot from the set of inventory plots
Y is the total of the variable under study for the whole dataset of plots
Y_{tot} is the total of the variable under study for the whole territory of interest
$\bar{y}$ is the mean value of the variable under study for the dataset of plots
$\bar{y}_{ha}$ is the mean value of the variable under study for the dataset of plots per hectare
n is the total number of inventory plots in the dataset
s_j is the area of inventory plot j in hectares
S is the area of the total territory of interest in hectares
μ_h is the stratum mean
N is the total number of units in the population

Table 18.5 Models for *dbh*-height relationship

	Model	Equation	Adjustment of global model
1	Exponential (Chapman-Richards)	$h = 1.3 + P_1 \times \left(1 - e^{-P_2 \times dbh}\right)^{\frac{1}{P_3}}$	P_1
2	Exponential	$h = 1.3 + e^{P1 + \frac{P_2}{dbh}}$	P_1
3	Logarithm	$h = 1.3 + P_1 + P_2 \times \ln(dbh)$	P_1

was used. However if at least one tree has been measured then the global model was adjusted using the available data.

Three *dbh*-height models were used (Table 18.5). Chapman-Richards exponential model, which is often used for growth modelling, is very flexible and accurately describes the *dbh*-height relationship. It is efficient, especially for global models where a large number of measurements are involved. The other two models were used if the model higher in the hierarchy could not be parameterised. Model number 1 was used in 14.8% of cases, model number 1 with P_3 fixed to 0.7 was used in 78.9% of cases, model number 2 in 6.0% and model number 3 in 0.3% of cases.

The overall model fit of predicted versus observed heights has a standard deviation of 1.0 m and correlation coefficient of 0.98, demonstrating a good fit.

The modelled tree heights were used for all analyses involving tree height, even for those trees for which height was directly measured in the field. In fact, there was very little difference when measured or modelled height was used, because the *dbh*-height model has been parameterised using NFI data and the sum of residuals is minimised – the estimate is unbiased. Consideration was given for future surveys where the use of modelled values will be more appropriate. The height increment will be calculated as the difference of the consecutive modelled tree height values for every tree. Since there is no guarantee that the particular tree will be again measured for height in the field, the calculated difference might combine growth and deviation from the model for those trees which were measured only once. This will not happen if modelled heights are used in both inventories.

18.5.3.3 Broadleaf Timber Height

Tree height is an important attribute for a number of subsequent calculations particularly for tree volume, biomass and carbon content. It was intended to use new national volume equations for Ireland which will be based on total tree height. This research project is currently underway and will provide an alternative to the Forestry Commission equations which were used in this NFI.

The Forestry Commission tariffs (Matthews and Mackie 2006), which have been used for broadleaf species, require timber height as an input variable. Timber height concerns merchantable material only, and is the distance from the base to the highest point on the main stem where the diameter is not less than 7 cm top diameter overbark (Matthews and Mackie 2006). The spring of the crown is frequently the

Table 18.6 The ratio between timber height and total height

Species	Mean value	Confidence interval ($\alpha = 0.05$)	Sample size
Oak	0.477	±0.012	330
Ash	0.470	±0.023	311
Beech	0.449	±0.013	310

timber point, but it may extend into the crown if there are merchantable lengths present. As the NFI collected total tree height, this had to be adjusted to timber height.

Three species were selected for sampling: oak, beech and ash. Thirty sites were sampled for each tree species across the land base of Ireland, with ten trees measured at each site. The *dbh*, total height and timber height was measured for each tree. The ratio between timber height and total height for oak, ash and beech was: 0.477, 0.470 and 0.449 respectively (Table 18.6). While this procedure may not represent the true situation at an individual tree level, it was deemed to be an acceptable procedure for the purposes of estimating broadleaf volume at a national level.

18.5.4 Tree Volume

The Forestry Commission single tree volume equations and tariffs (Matthews and Mackie 2006) were used to estimate standing merchantable overbark volume for each tree on the plot with a minimum *dbh* of 70 mm. Conifer stem volume was measured from ground to 70 mm top diameter. Broadleaf stem volume was measured from ground to timber height.

18.5.5 Carbon Stock Estimation

Carbon (C) stock estimation for the forest estate was completed for five pools (Black 2007):

1. Tree above-ground
2. Tree below-ground
3. Deadwood (lying, standing and stump)
4. Soil
5. Litter

18.5.5.1 Tree Biomass

Dbh and height data from NFI plots were used to derive above and below ground biomass using species specific and generalised biomass equations (Black et al.

2004, 2007; Black and Farrell 2006; COST Action E21 2009). A carbon fraction of 50% was assumed for all species and biomass pools (Black and Farrell 2006).

In the case of the less common species including all broadleaves, it should be noted that the use of generalised biomass equations, could lead to a systematic error in the estimation. This error is due to country/regional differences in allometric patterns of individual trees associated altered management and/or growth characteristics. This will, however, be improved as new information from national research becomes available.

18.5.5.2 Deadwood

The volume of decaying deadwood, including lying log, stump and standing deadwood, was calculated. The density and C fraction of different decay classes was obtained from a study on Sitka spruce by Tobin et al. (2007). The decay equation and C fraction was assumed to be the same for all species. These estimates will improve as new research information becomes available.

18.5.5.3 Litter

Litter carbon pools were calculated as a function of plot age based on the International Panel on Climate Change (IPCC) good guidance practice (IPCC 2003) using net annual accumulation rates of 0.8 and 1.3 t of C ha^{-1} per year for broadleaves and conifers respectively, over a 20 year transition. This is the same methodology used to report C stock changes under Ireland's submissions to the EU and UNFCCC (McGettigan et al. 2006).

18.5.5.4 Soil

Soil types from the NFI were stratified into ten major soil groups and assigned a soils C stock reference value following a GIS overlay on a soil C stock database (Tomlinson 2004). This value provides a 1990 base line C stock (*SOCREF*). The soil sub-model component is based on the assumption that soil C reaches a steady state after 20-years following land use transition into or out of forestry. Estimation of the area associated with the transition into or out of forestry was based on an overlay of the NFI sample points with the CORINE 1990 and 2006 datasets. This was further stratified to derive a land use transition and soil type matrix. The mineral soil organic C (*SOC*) stock change factors following land use transitions were obtained from default IPCC equation:

$$SOC = \sum_{c,s,i} \left(SOCREF_{c,s,i} \times Flu_{c,s,i} \times FMG_{c,s,i} \times Fi_{c,s,i} \times A_{c,s,i} \right) \tag{18.1}$$

Where *SOC* is soil organic carbon, *SOCREF* is the reference stock as described above, *Flu* is the accumulation or emission factor associated from land use change into forestry from grasslands, wetlands or agriculture specific to soils type (*s*), land use intensity (*i*) and transition time (*c*), *FMG* is the management specific factor which was assumed to be 1 (i.e. negligible), *Fi* is the management intensity (assumed to be 1) and *A* is the area. *Flu* was the most important factor.

The only soil which was assumed to accumulate C was wet mineral gleys following afforestation from grasslands based on national research (Black et al. 2007; Black and Farrell 2006). All other mineral soils were assumed to be C neutral.

All peat soils were assumed to loose C following afforestation for the 20 year transition based on the following equation:

$$\Delta C_{FForganic} = A_{drained} \times EF_{drainage} \tag{18.2}$$

ΔC is the emission per year, $A_{drained}$ is the area of peat land afforested in the last 20 years and $EF_{drainage}$ is the emission factor taken from the IPCC guidelines 0.68 t C ha^{-1} $year^{-1}$.

18.6 Options for Harmonized Reporting

Above- and below-ground biomass as well ARD area estimates can be given on the basis of COST Action E43 reference definition (Table 18.7). There is still some harmonization work left in the NFI.

Table 18.7 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Estimate	ND	RF	Responsible	Remark
Forest area	Yes	No	NFI	ND ≠ RF, can be derived from data
Growing stock volume	Yes	No	NFI	ND ≠ RF ND includes trees with *dbh* ≥ 7 cm. Volume is from ground to 7 cm top diameter
Above-ground biomass	Yes	Yes	NFI, models	ND = RF
Below-ground biomass	Yes	Yes	NFI, models	ND = RF
Dead wood volume	Yes	No	NFI	ND ≠ RF Stump: Minimum diameter 20 cm Standing: Minimum *dbh* 7 cm Lying: Min log length 1 m. Top diameter 7 cm
Dead wood volume by decay stage classes	Yes	No	NFI	ND ≠ RF
Afforestation Deforestation Reforestation (Kyoto 3.3)	Yes	Yes	NFI, statistics	ND = RF
Forest type	Yes	No	NFI	Can be derived from NFI data

18.7 Future Prospects

The sampling design implemented for the NFI1 (2004–2006) remains unchanged for the proposed NFI2 (2010–2012). Reassessment of the 2 × 2-km grid will take place using more recent aerial photographs which were obtained in 2005–2006. All afforestation since NFI1 will also be assessed using GIS datasets.

As Ireland has completed its first NFI, after the next NFI it will be possible to more accurately assess forest drain and the increment of the forest estate.

In NFI1 British Forestry Commission single tree volume equations were used for calculating tree volume, from ground to 7 cm top diameter. Work is currently underway to produce single tree volume equations using Irish data. These Irish single tree volume equations will be used in NFI2. These new equations will offer flexibility in deriving tree volume to different specifications, e.g. ground to tip or stump to tip.

The attributes collected in the NFI will be reviewed, to take on board the COST Action E43 outputs. To facilitate common reporting, this may include the addition of new attributes and amendment to the definition of existing attributes.

18.8 Influence of COST Action E43

COST Action E43 has afforded Ireland's NFI team the opportunity to see how other NFI's are undertaken and be involved in the harmonization process for common reporting. Ireland's NFI program has benefited immensely from being involved in COST Action E43.

As Ireland was undertaking its first NFI during COST Action E43, there was no opportunity to amend any of the variables included. However, as the next NFI is due to commence field-work in 2010, some of the COST Action E43 attributes and definitions will be incorporated.

For example in relation to stump diameter, Ireland's first NFI had a threshold of 20 cm. In the next NFI the minimum threshold will be reduced to 10 cm to facilitate common reporting.

The COST Action E43 also provided a forum to meet other people working on NFI's. This greatly enhanced the transfer of knowledge between people working on similar areas and facilitated the pooling of resources.

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Chapter 19
Italy

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19.1 Development of the Italian National Forest Inventory

The first Italian National Forest Inventory (NFI) was carried out between 1983 and 1986 and the results, published in 1988, correspond to the year 1985. For that inventory a single-phase sampling design was adopted with the sample plots for the field survey systematically distributed on a 3 × 3-km grid. The aim of the first inventory was to provide basic statistics on forest area and its main features at a national level using statistical sampling. The strategic decisions regarding this project were taken by a Ministerial Commission for the NFI of the Ministry of Agriculture. The Forest and Range Management Research Institute (ISAFA), known as the Forest Monitoring and Planning Research Unit of the Agriculture Research Council (CRA-MPF) as of 2004, designed the project plan and the procedures for data collection and processing, while the field surveys were carried out by the National Forest Service (NFS). The official statistics were not based on NFI results. Rather, the official statistics were provided by the Italian Institute for Statistics (ISTAT) and were based on annual questionnaires completed by the NFS to update information collected in the 1950s. However, in the last years the updating became less frequent. By the end of the 1990s the information provided by the first NFI and ISTAT appeared to be dated and insufficient to meet the information requirements resulting from the international processes such as the United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD) and the Ministerial Conference for the

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Protection of Forests in Europe (MCPFE). Therefore, in 1999, a feasibility study for a second NFI with proposals for various methodological solutions, funded by the Ministry of Agriculture and Forestry, was presented to the Ministry and the scientific community (Bianchi et al. 1999).

At the end of 2001, a departmental order (D.M. 13/12/2001) established a permanent NFI to be carried out by the NFS with the scientific and technical support of CRA-MPF. The order highlighted the importance of updating the NFI, and to balance costs and benefits, established a minimum cycle of 5 years (a new inventory every 5 years or more). The order also outlined compliance with international standards (i.e. the forest definition of the United Nations Economic Commission for Europe and the Food and Agriculture Organization of the United Nations (UNECE/FAO 1997)) and the provision of data for Kyoto Protocol reporting as main objectives of the new NFI. The 21 administrative regions were taken as the smallest reporting units.

During 2002, the sampling design and the survey procedures for the second Italian NFI called "National Inventory of Forests and Forest Carbon Sinks" (INFC) were designed (Fattorini and Tabacchi 2004). The first phase (photo-interpretation) started at the beginning of 2003 and ended in spring 2004, while the second phase field survey was carried out in 2005. This survey focused on checking and finalizing the first-phase classification and collecting qualitative variables on a sub-sample of the points classified as forest or other wooded land (OWL) on orthophotos. The third phase, aimed at collecting quantitative information on forest stands (basal area, volume and above-ground phytomass, growing rate, dead wood phytomass, etc.), was conducted during 2006 and ended in the first half of 2007. The final INFC area estimates were published in 2007, and estimates of quantitative variables such as growing stock and deadwood were published in the beginning of 2008 (Tabacchi et al. 2007; Gasparini et al. 2007). Since 2007, the Italian NFI has been the official source of information on Italian forests for international reporting, as mutually agreed by ISTAT and the Ministry of Agriculture.

At the sub-national level, regional or sub-regional forest inventories were carried out by half of the Italian regions between 1985 and 2003 (see Tables 19.1a and b), while other regions (Abruzzo, Sicilia and Calabria) will begin their own forest inventories. These regional or sub-regional projects differ quite a lot in their sampling schemes and survey procedures (Tosi and Monteccone 2004).

Table 19.1a National forest inventories (NFI) in Italy

Inventory	Ref. year[a]	Method	Sampling grid (km)	No. of field sample plots
NFI1	1985	Single-phase systematic sampling	3 × 3	9,639
NFI2	2005	Three-phase sampling for stratification with systematic non-aligned observations	1 × 1 (first phase)	6,865

[a]Ref. year: statistical reference year.

Table 19.1b Regional or sub-regional forest inventories (RFI) in Italy

Inventory	Ref. year[a]	Method	Sampling grid (km)
Friuli Venezia Giulia RFI	1985	Two-phase sampling for stratification	0.2 × 0.2
Emilia Romagna RFI	1985	Two-phase sampling for stratification	0.2 × 0.2
Lombardia	1985	Single-phase systematic sampling	1 × 1
Provincial Forest Inventory (2 out of 11 provinces)	1988		
Veneto RFI of Private Forests	1985	Single-phase sampling with pre-stratification	0.8 × 0.8
Liguria Multi-Resources RFI	1990	Two-phase sampling for stratification	1 × 1
Toscana RFI (western and eastern part)	1991, 1993	Two-phase sampling for stratification	0.4 × 0.4
Umbria RFI	1991	Single-phase systematic sampling	1 × 1
Lazio	1993	Single-phase systematic sampling	1 × 1
Provincial Forest Inventory (1 out of 5 provinces)			
Valle d'Aosta RFI	1993	Single-phase with pre-stratification	0.5 × 0.5 (temporary plots) 1.5 × 1.5 (permanent plots)
Marche RFI	2000	Two-phase sampling for stratification	1.5 × 1.5
Trentino Provincial Inventory of Forest Carbon Pools	2003	Two-phase systematic non-aligned sampling	1 × 1

[a]Ref. year: statistical reference year.

19.2 The Use and Users of the Results

19.2.1 General Use

Italy does not have a long NFI tradition. The information collected by NFI1 primarily addressed preparation of the National Forestry Plan, a document which gave general long-term silvicultural and forest planning guidance at the national level; the plan was implemented autonomously by the 21 administrative regions of Italy which are responsible by law on this matter. It also provided information on forest resources to update the national statistics of ISTAT and the international statistics such as the Forest Resources Assessments of the FAO and, more recently, reporting for the MCPFE. As updating of the NFI was lacking for a long period, the information provided was less reliable near the year 2000 when the new NFI2 was launched to update the data on forest resources. NFI2 also produces information on forest health status and damage, on forest biodiversity and above all on the carbon pools to be monitored for the Land Use, Land-Use Change and Forestry (LULUCF) reports of UNFCCC for which the Ministry of Environment is the responsible institution. Because NFI2 also provides reliable data at the regional level, it could serve as a central information source and tool in forestry, as well as for forest industry and forest environment decisions and policy making.

19.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

The Italian NFI is the main information source on forest carbon pools at the country level and will play a central role in reporting LULUCF activities under Articles 3.3 and 3.4 of the Kyoto Protocol. The land use categories reported are consistent with the IPCC Guidelines (IPCC 2003), and for the Kyoto Protocol, Italy has adopted the FAO definition of forest (UNECE/FAO 1997). Area estimates for land use categories reported by the Ministry of Environment, in cooperation with the Ministry for Agriculture, Food and Forest Policies, are based on the NFI for forest area and on other national statistics for land use. Land use change (LUC) matrices for each year for the period 1990–2005 have been assembled using time series of national land use statistics for forest lands, croplands, grasslands, wetlands and settlement areas. So far, the LUC areas in transition between different land use categories reported annually in the greenhouse gas (GHG) national inventory report have been estimated by experts (APAT 2006).

For the near future, data on LUC and on carbon pool changes will be provided by the National Register of Forest Carbon Pools which is in preparation and will be formed by different tools and surveys, including the NFI. Under Article 3.4 of the Kyoto Protocol and the associated additional activities, Italy reports only forest management activities. Italy takes a broad approach regarding managed forests under the Good Practice Guidance (GPG) for LUCLCF (IPCC 2003) and considers all forest land in Italy as managed. Presently, carbon stock estimates for above-ground biomass are based on statistical sampling methods. By the end of 2009, the NFI will also provide estimates for carbon stored in dead wood, litter, organic soil and in the small woody vegetation (see Section 19.7).

19.2.3 Role of the NFI in Assessing the Status of Biodiversity

In addition to the conventional forest inventory variables such as stand and tree age, tree species composition, diameter distribution of growing stock and tree number, as well as site variables, Italian NFI2 surveyed several groups of variables related to forest biodiversity. The most important ones follow:

- Occurrence and abundance of ground vegetation woody species for both trees and shrubs, divided into three size classes
- The volume and decay class of dead wood, divided into coniferous and broad-leaved species classes, both lying and standing, that satisfy a requirement of a minimum diameter of 10 cm
- Microhabitat occurrence and abundance: a list of more than 20 key habitats such as water streams, moist areas, den trees, anthills and human infrastructures (mines, quarries, electricity lines, etc.) have been recorded
- Human infrastructure occurrence and abundance, a possible source of negative impacts on animal population dynamics and the landscape
- Occurrence and types of forest edges
- Protection status of the area (national park, regional park, forest reserve, etc.)
- Naturalness of stand: even if not specifically assessed in the field, the naturalness of the forest stand can be derived from various NFI data on growing stock, dead wood, microhabitats, human infrastructures, silvicultural regime etc.

19.3 Current Estimates

The basic area estimates are given in Table 19.2a and volume estimats in Table 19.2b. The inventory domain is the entire forest and OWL area, as defined by FAO, of the country, which means land with a minimum tree crown cover of 10% (5% for

Table 19.2a Basic area estimates from the year 2005

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (%)
Forest	8,583		Forest land covered by trees	0.4
plantations for wood production	122		Stands with the same thresholds as forest but growing in agricultural land	4.5
Temporary unstocked land	54		(FAO – FRA 2000)	8.1
Forest land (UNECE/FAO 1997)[b]	8,759	29	0.5 ha of minimum area and at least 10% crown cover with minimum height of trees of 5 m at maturity in situ	0.4
Other wooded land (UNECE/FAO 1997)	1,708	6	0.5 ha of minimum area and 5–10% tree crown cover (minimum height of trees of 5 m at maturity in situ) or at least 10% shrub coverage	1.3
Other land	19,666	65		n.a.[c]
Total land area	30,133	100	Derived from ISTAT (2002)	–[d]

[a]Standard error.
[b]Forest land in UNFCCC LULUCF reporting is the same as forest land based on national definition. The NFI domain is forest and other wooded land. However, it covers all land classes including inland water.
[c]Not available.
[d]Assumed to be error free.

Table 19.2b Basic volume estimates from the year 2005

Quantity	Estimate	Description	SE[a] (%)
Growing stock volume on forest land		Minimum *dbh* 4.5 cm, all woody species included in the national list	
Million cubic metre	1,269		1.1
m^3/ha	144.9		1.0
Annual increment of growing stock of trees on forest land		See above	
Million cubic metre	35.9		1.1
m^3/ha per year	4.1		1.0
Annual drain on forest land	n.a.[b]	n.a.[b]	n.a.[b]
Dead wood volume		Any length, minimum diameter: 10 cm	
Million cubic metre	70.5		2.3
m^3/ha	8.1		2.3
Growing stock volume on forest and other wooded land	n.a.[b]	See above	n.a.[b]

[a]Standard error.
[b]Not available.

OWL), of more than 0.5 ha and a width of more than 20 m; to be included in the forest area the trees, which are listed in a national species list of 133 items, must be able to reach a height of 5 m at maturity in situ. Closed and open forest formations, young stands and temporarily unstocked areas, and also plantations with forestry purposes including poplar plantations, forest nurseries and seeds orchards are surveyed. Cork oak plantations and chestnut woods are included, even if they are devoted to fruit production, while hazel groves, fruit orchards, olive groves and vineyards are excluded. Forest roads, cleared tracks, firebreaks with a width of less than 3 m are included in the forest area. The inventory is also concerned with areas covered by shrub vegetation (about 140 shrub species are included in a national list), trees not able to reach a height of 5 m at maturity (i.e. low maquis) and scattered tree vegetation with crown cover between 5% and 10%; all these stands are classified as OWL. Data for sample points that intersect small woodlots (area less than 0.5 ha) and shelterbelts, windbreaks, hedgerows, riparian buffers or other linear stands with widths less than 20 m are also reported to provide a first estimate of the area of trees outside forest. These were investigated later with a specific research project, apart from the NFI.

19.4 Sampling Design

19.4.1 Sampling Design and Reporting Units

Italy is divided into 21 administrative regions (Fig. 19.1) that are the basic units for NFI statistics. These units also serve as a stratification criteria in the second and

Fig. 19.1 The Italian territory and its 21 administrative regions (19 regions and 2 autonomous provinces)

third phases, together with the area of forest and OWL and the proportion of the different inventory categories and vegetation types.

For NFI2, a three-phase sampling for stratification scheme was adopted (Fig. 19.2, Table 19.1a). In the first phase, a set of approximately 301,000 sample points was located on a 1 × 1-km grid with sample points randomly selected within each grid square. The point layer was then overlaid on black and white digital orthophotos to classify the land cover/use according to a scheme with five main classes (consistent with the first level of the Corine Land Cover system) and sub-classes relevant for the NFI (De Natale and Gasparini 2003).

A sub-sample of the first-phase points belonging to the forest and OWL cover classes was then randomly selected to be surveyed in the field in the second phase. The selection was made according to the land cover and regional stratification, meaning that for each administrative region of Italy, the size of the sub-sample depends on the proportion of points classified as forest or OWL in that region. The second-phase sample consists of approximately 30,000 points for the entire country. The first objectives of the second-phase field surveys were to check and finalize the classification of sample points, to estimate separately forest and OWL areas that had been assigned to the same land cover/use class by the photo-interpreters, and to separate the sample points into eight inventory categories, 23 vegetation types and 91 sub-types using a national classification scheme. Moreover, during the second

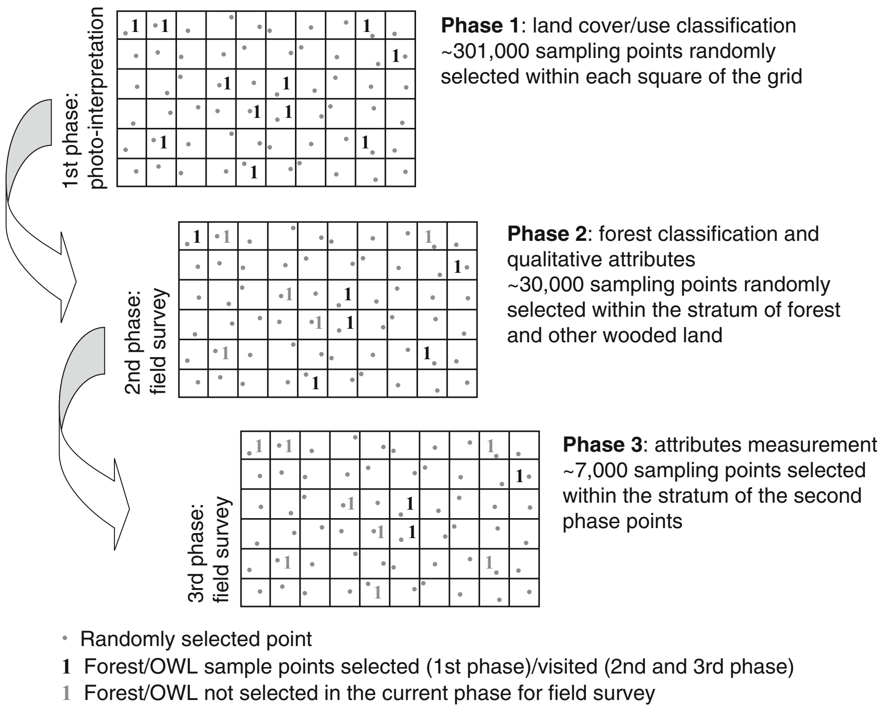


Fig. 19.2 Three-phase sampling for stratification adopted in the Italian NFI

phase, data on qualitative variables (ownership, protection status, management issues, vegetation structure and condition, etc.) of forests were collected (Gasparini and Tosi 2004). The classification of vegetation types was used for stratification in the third sampling phase.

The measurement of trees and the collection of other quantitative data (such as dead wood, regeneration and shrubs, etc.) as well as evaluations on silviculture practices were carried out during the third phase which consisted of a second field survey of 6,865 second-phase points (Tabacchi et al. 2006).

19.4.1.1 First Phase: Photo-interpretation

The aim of the photo-interpretation was to derive a broad estimate of forest area (forest and OWL) and to separate non-forest sample points from points belonging to the inventory domain. The results of the first phase were then used to stratify the second-phase sampling according to the proportion of forest area in each region. Another useful result of the first phase is the area estimate of trees outside forest (small woodlots and linear structures). The photo-interpretation was carried out using a geographic information system (GIS) developed by the NFS, the Mountain

Information System (SIM), for which special tools for the NFI were implemented. A central database was constructed and continuously updated with the results of the photo-interpretation which was performed by approximately 50 NFS photo-interpreters working in different regional offices. This activity was repeatedly checked by the researchers and technicians of CRA-MPF to harmonize the classification and to control data quality. Each photo-interpreter could classify approximately 150 points per day, but the entire first phase took about 12 months because the interpreters could not work simultaneously in all regions and because the time needed to solve technical and operational problems was quite long. Flight years for the orthophotos were between 2000 and 2003; the approximate scale of the images was 1:10,000 and the ground resolution was 1 m; and the scale used for interpretation was about 1:3,000.

19.4.1.2 Second Phase: Field Survey

Approximately one third of the NFI sample points belonging to forest and OWL were located on the ground with the help of a global positioning system (GPS) procedure that assured a very high location accuracy. A sub-sample of 30,000 points (approximately 1 plot per 3.5 km^2 of forest and OWL), was randomly selected according to a regional stratification. For each point, a circular plot of 2,000 m^2 was used to collect data on approximately 25 main variables (Table 19.3), most of which were directly surveyed on the plots; data for the remaining variables were obtained from different sources (orthophotos, cadastre, maps and databases, interviews). The sample plots were not permanent but the plot centre was marked with a nail driven into the ground so that the plot could be located again during the third phase. Each field crew consisted of 2–3 persons and could survey approximately three sample plots per day and 300 plots during the entire field work. The 101 field crews started the surveys in May 2004 after a training course of 1 week and completed the field survey 1 year later.

19.4.1.3 Third Phase: Field Survey

A sub-sample of 6,865 points (1 plot per 12.7 km^2 of forest land) of the sample units already surveyed during the second phase were randomly selected and surveyed in the third phase to collect new data through quantitative measurements. The field work of this phase aimed at measuring trees and stand variables using different sample units: two circular concentric plots for dendrometric measurements of standing trees and two small satellite plots for regeneration and shrubs measurements (Fig. 19.3). Lying and standing dead wood satisfying size requirements, including minimum diameter of 10 cm, were measured in the larger plot, while the remaining qualitative variables were assessed on a 2,000 m^2 circular area surrounding the sample point. The third-phase points were marked permanently by a metal plate in the soil that replaced the nail used in the second phase. Each field crew

Table 19.3 Variables surveyed by the three phases of the second Italian National Forest Inventory (INFC)

Data source	Variable
First phase	
Orthophotos	Land cover/use class
NFS GIS[a]	Region, province
	Protection status (national and regional level)
Second phase	
Orthophotos	Crown cover class
	Vegetation texture
	Forest edges
NFS GIS[a]	Ownership
Interviews	Protection status (local restrictions)
	Forest management, management plans
	Recreational function
Field survey	Inventory category (forest, low forest, shrub area, etc.)
	Vegetation type and sub-types (according to tree species composition)
	Site information (elevation, aspect, slope, land form, stoniness, natural hazards)
	Stand structure, development stage
	Conifers/broadleaves dominance
	Stand origin (naturalness)
	Disease/damages
	Microhabitats
	Human infrastructures
	Road conditions
Third phase	
Field survey	Variables of woody plants: tree/shrub species, stem size, type of tree, tree vitality and integrity, tree height, crown length
	Number of trees, stand basal area and phytomass/volume
	Stand growth rate
	Deadwood (standing and lying) (volume, type, decay class)
	Drain (stump survey)
	Regeneration (species, abundance, condition)
	Detailed survey of biotic damages
	Silviculture (harvesting and extraction method)
	Non-wood forest products, primary forest function

[a]Data are stored in a geographical information system (GIS).

consisted of three persons and surveyed one sample plot per day and approximately 80 plots during the entire field work. The 84 field crews started the surveys in late May 2006 after a training course of one week and completed the field survey in November 2006.

19.4.2 Sample Plots

The shapes and the sizes of the sample plots were different in the three phases to optimize the efficiency in data recording with respect to adequacy (a sample plot

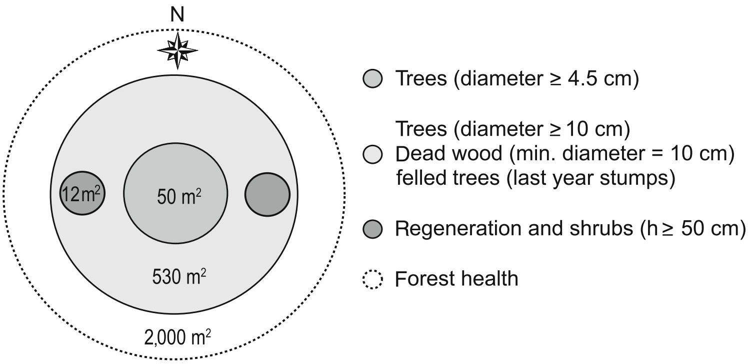


Fig. 19.3 Sample plots in the third phase

has to be large enough to collect the information) and time requirements (it should be possible to survey a whole fixed number of plots in each working day during the field work). A short description of the sample plots follows.

In the first phase, each sample plot for photo-interpretation was 150 × 150-m (Fig. 19.4), even though the classification of land cover was based on photo-interpretation of single point at the plot centre (pin-point interpretation) and not on the coverage of different land covers within the plot. The photo-plot, which consisted of nine 50 × 50-m (2,500 m^2) squares with the central square centred at the sample point, was used to help the photo-interpreters verify that the forest definition thresholds (crown cover, size and width of forest stands) were satisfied. The photo-interpreters had to decide if the sample point was in or outside the forest boundary and to check if the crown cover, size and the width of the woodlot were more than 10%, 0.5 ha and 20 m, respectively. For measuring crown cover, a grid of 36 dots in each square was overlaid on the interpretation area; the minimum crown cover had to be checked on the central square and, at least, on one or two other squares, respectively, for forest or OWL classification.

In the second phase, the sample plot was a circle with an area of 2,000 m^2 centred on the NFI sample point (white circle in Fig. 19.4). Moreover, to validate/integrate photo-interpretation evaluations (e.g., to distinguish OWL and forest land), the field crews observed the same plot used in the first phase that was visible on the field maps/orthophotos; generally the evaluations requested in the second phase survey did not require drawing the circle on the ground. A special case is the classification of species dominance. Because identification of the predominant species was the basis for classification of vegetation types, the crews were asked to walk along transects crossing the sample point and to observe the coverage after a fixed number of steps (Fig. 19.5).

In the third phase two concentric plots (horizontal radius 4 m and 13 m, approximately 50 and 530 m^2) are the main plots for data recording (standing trees, deadwood, stumps, sample trees for measuring variables such as height and

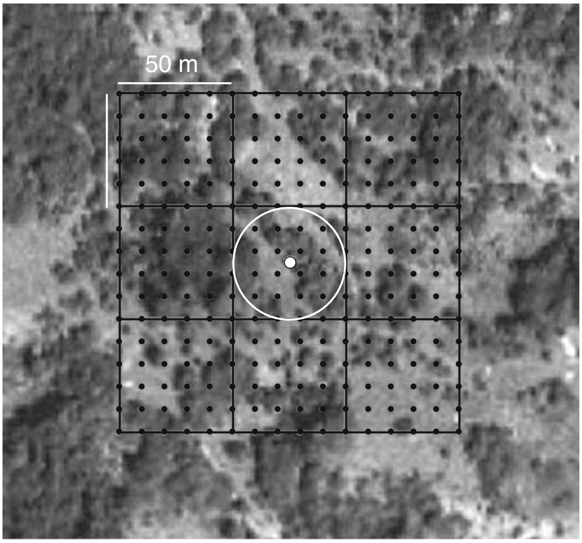
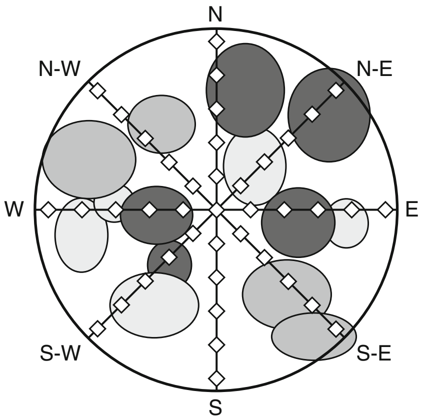


Fig. 19.4 First phase interpretation area (black squares) and second phase sample plot (*white circle*)

Fig. 19.5 Transects for species dominance



increment); two smaller areas (small circles in Fig. 19.3) which are 10 m from the plot centre are used for recording regeneration and shrubs. All the above mentioned circular plots were drawn on the ground, whereas the boundaries of the unit for forest health and silvicultural variable assessment (corresponding to the 2,000 m^2 plot of the second phase) were not marked.

19.5 Management

19.5.1 NFI Organization

Fig 19.6 represents the structure of the Italian NFI2. The main subjects are the NFS of the Ministry of Agriculture, Food and Forest Policies and a research institute, the Forest Monitoring and Planning Research Unit of the Agriculture Research Council CRA–MPF. The former provided, together with the Ministry of Environment, the project funding, carried out the surveys and provided the logistical coordination. The latter is responsible for the scientific aspects (survey design and procedures for data collection), crew training, as well as data control and processing. Further, other contributors have been involved to solve defined tasks, among them the University of Siena, Studio RDM Ltd and SIN Ltd.

19.5.2 Data Management and Reporting

Informative aspects of data flow are the responsibility of a private company under contract to the NFS, while data management including checks, corrections, validation and all other aspects related to data quality are a responsibility of CRA-MPF. The first-phase data flow was assured by an internal net which allowed the surveyors to download the digital orthophotos and sample point coordinates and to upload the results of their classification. A restricted area in the intranet was used by CRA-MPF personnel to check photo-interpretation. Data for the second

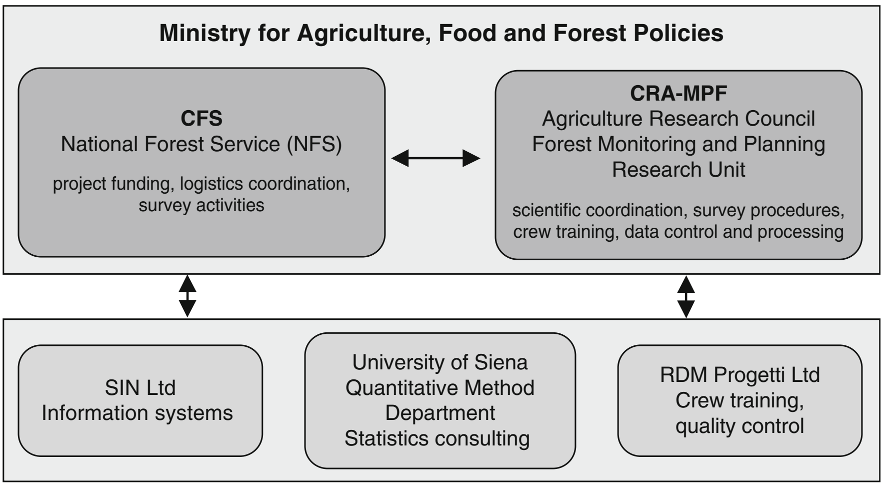


Fig. 19.6 Italian NFI organizational framework, main institutions and companies

and third phases were recorded on palm computers that included a GPS receiver (Trimble GEO XT or PRO-XR) and software developed for the NFI (INFOR2 and RAS3). The data were then sent through the Internet to a central server using a laptop computer and stored in the INFC database (DB2 in the second phase and Oracle in the third phase). A restricted area on the NFI web site allowed the central institutions involved (NFS, CRA-MPF) to check the data flow and data quality as in the first phase. In the third phase, the procedure was more flexible. Once in the central server, the data were visible and could be modified by the crews which could add information (e.g., the core measurement could be done later in the office) or correct mistakes. After modification or correction, the data were controlled by an automatic procedure and finally confirmed.

The CRA-MPF is responsible for designing the computing procedures for data processing and for presenting the results. NFI outputs are presented in tables (no maps) for the national and regional levels (the 19 regions and 2 autonomous provinces, Fig. 19.1). The second-phase and third-phase results have already been published on CDs and on the web (INFC 2008) where all the tables are freely available for downloading.

19.5.3 Quality Assurance

Quality assurance must be considered in the light of two kinds of difficulties: the NFI field crews are not permanent, and there is large variability in the environmental and vegetation conditions. These two factors may substantially affect the consistency of interpretations among people involved in data collection. Assuring consistency became the main priority for data quality. The goal was achieved due to a large effort to harmonize interpretation among surveyors using the following briefly described steps:

1. Training – a 3-day course in the first phase and 1-week courses in the second and third phases consisting of classroom lessons and exercises.
2. Start up – when the photo-interpreters started their work, the CRA-MPF personnel made a simultaneous classification to assist the photo-interpreters and to check their work for purposes of harmonizing the photo-interpretation; in the second and third phases all field crews were joined by the course teachers in their first field working days so that the field work season would begin with expert assistance.
3. Help desk – a help desk was established at CRA-MPF to provide daily assistance to field crews; all questions were recorded in a database for easy checking; the most common and important (in the sense of relevance for other field crews) questions were written down and fully explained as Frequently Asked Questions. A continuous exchange of e-mails and phone calls was of prime importance to resolve doubts and uncertainties during the three phases.

Table 19.4 Number of crews and surveyors of INFC

Sampling phase	Number of crews	Number of people
One	21	52
Two	101	~300
Three	84	~300

4. Data quality control – the accuracy of data collection was constantly assessed through random checks and control queries implemented in the database. The software used in the two field phases included warnings and automatic controls (logical checks) that contributed to correctness (consistency of data) and completeness (all data recorded).
5. Database correction and validation following the periodic and final checks of data storage.
6. Work in progress and final test for survey approval – measurement quality objectives were set depending on the importance of the variable surveyed and on measurement difficulty and used by independent control crews to check and certify the quality of field crew performance.

For the second and third phases, a total of 220 person-days were needed for the whole check work during the field survey and for the final control.

19.5.4 Personnel and Equipment

Table 19.4 provides information on the number of people involved in the survey activities. Generally the personnel belonged to the NFS (in some cases Regional Forest Services); the administrative regions provided local professionals for only very few cases. Approximately half of the people involved in the second and third phases had already been involved in conducting a previous phase; only infrequently the same worker participated in all three phases. The electronic devices used during the inventory were GPS, field computers and a height measurement instrument (Vertex).

19.6 Estimation Techniques

As already mentioned, the first two phases are aimed at estimating the area of inventory strata, the inventory categories (woodland, low forests, shrubland, etc.) and the vegetation types (fir forests, beech forests, etc.). The second-phase sample is also used to estimate the area of forest by qualitative variables (e.g., ownership, coniferous and broadleaved tree composition, naturalness, etc.). Finally, the third phase is aimed at estimating quantitative variables such as basal area, volume and increment (Gasparini and Tosi 2004).

19.6.1 Area Estimation

Area estimation is based on the total country area, which is known and assumed to be error-free, and on the proportion of sample points intersecting the different land cover/use and vegetation classes.

In the first phase, a grid of *NQ* squares with total area *R* (area *R*/*NQ* per square) was overlaid on the study area. Using one randomly selected sample point per square, the study area was then divided into $H = NW + W + 1$ land cover and land use classes and *L* administrative regions where *NW* is the number of non-forest classes, *W* is the number of forest classes and *1* denotes the class of unclassified areas which are not visible on orthophotos or difficult to classify. From the *HxL* photo-interpretation strata, each with N_{hl} sample points, a sub-sample of n_{hl} units was selected from each forest stratum (i.e., when $h = NW + 1, \ldots, H$) and visited in the field to check and definitely assign the land cover/use class and to classify the *K* vegetation types. The *NW* classes were assumed to be classified correctly on the basis of interpretation of the orthophotos, because any uncertain unit was assigned to the unclassified points. The areas of the *KxL* third-phase strata, to which final inventory data refer, were given by

$$\hat{a}_{kl} = R \sum_{h>NW} w_{hl} \, w_{khl} \,, \quad k = NW + 1, \ldots, K, \; l = 1, \ldots, L \tag{19.1}$$

where w_{hl} is the weight of the second phase strata ($w_{hl} = N_{hl}/NQ$) and w_{khl} is the weight of the third phase strata ($w_{khl} = n_{khl}/n_{hl}$, where n_{khl} is the number of the n_{hl} sampling units classified in the *k* vegetation type during the second phase). These estimated areas $\hat{a}_{kl}$ are then calibrated to reference them to the known country area A (ISTAT 2002) instead to the total area *R* of the grid (with $R > A$) (Fattorini et al. 2006).

19.6.2 Volume Estimation

In the Italian NFI, the stem volume of a tree is defined as the volume over bark and above stump of stem and main branches with diameters of at least 5 cm. The volume of growing stock includes all living trees and shrubs included in a comprehensive national species list with a diameter at breast height (*dbh*) of more than 4.5 cm (5 cm class). Standing volume includes living and dead standing trees, and the lower *dbh* limit for dead trees is the same as for living ones. Living and dead trees are measured for volume estimation in the same way.

To estimate tree volume, national prediction models developed during a research project carried out in the same years as the NFI were used, the results of which have not yet been published (for a sub-project concerning North-Eastern Italy see Gasparini et al. 2006). The objective of this project was the construction of a set of 26 models to predict the volume and above-ground phytomass of all Italian forest tree species. For model calibration, a sample of 1,300 trees from the entire country was used, from which data on stem plus main branches volume, and on the fresh and dry weight of above-ground phytomass were obtained by field and laboratory measurements. The above-ground phytomass was divided into its main parts (stem plus main branches, slash, stump), the weights of which are predicted by specific equations. The general form of the selected model is:

$$y_i = b_1 + b_2 d_i^2 h_i + b_3 d_i \tag{19.2}$$

where y_i is the volume or phytomass (dry weight), d_i is the diameter at breast height, h_i is the tree height, b_1, b_2 and b_3 are the model parameters which depend on the species and the dependent variable (volume or phytomass). The same models are used for both living and dead trees. Broken tree volume is estimated by the geometry of a frustum of cone.

Tree height was estimated by prediction curves obtained using the 5–10 sample trees for height and increment measurement in each plot. The independent variables of the model on which the curves are based are *dbh* and dominant height. The model parameters were estimated for 55 species or species groups using data for more than 49,000 sample trees.

The total volume and phytomass, X_i, of the plot was estimated as the sum of the individual tree values from Eq. 19.2, and the estimate, $\hat{x}_i$, of the variable for the grid square in which the plot is located was calculated as the Horvitz-Thompson estimate,

$$\hat{x}_i = \frac{SQ}{a_i} X_i \tag{19.3}$$

where $SQ=1\ km^2$ (the area represented by a plot) and a_i are the area of plots for tree *dbh* measurements (50 or 530 m^2 – see Fig. 19.3).

Total volumes and phytomasses, $\hat{t}_{kl}$, for the third-phase strata were estimated as,

$$\hat{t}_{kl} = NQ \sum w_{hl} w_{khl} \bar{x}_{khl}, \tag{19.4}$$

where $\bar{x}_{khl} = \frac{1}{m_{khl}} \sum_{i \in Q_{khl}} \hat{x}_i$ and m_{khl} is the third-phase sample size of each stratum. The total estimate for aggregated strata (a vegetation type at national level or all vegetation types of a region) is obtained as the sum of strata total estimates. Further details on estimation procedures including variance estimators for single and aggregated strata and the estimators for variable densities (e.g., biomass per hectare) are given in Fattorini et al. (2006).

19.6.3 Increment Estimation

Tree growth is estimated by the direct method using sample cores extracted at *dbh* level from the sample trees measured in the field plots (5–10 per plot). The annual volume increment is estimated as the average over five years based only on full growing seasons. Because the Italian NFI is not continuous and is implemented for entire country in the same year and growing season, the length of the five measured rings corresponds exactly to the same period for all sampled trees. Moreover, because the field work is carried out during summer, to avoid measuring incompletely formed rings (the increment from the growing season of the field work) the last annual ring is ignored which means the mean annual increment measured is that of the five years preceding the survey.

Volume increment is estimated at the plot level using four steps:

1. Prediction of the percentage volume increment $pv_z$of each sample tree z in the plot through the radial increment Δd and the height increment Δh (predicted by *dbh*-height models)

$$pv_z = 100\left(\frac{2\Delta d}{d} + \frac{\Delta h}{h}\right) \tag{19.5}$$

2. Calculation of the mean weighted (to volume) percentage increment of the plot from the sampled trees in it
3. Calculation of the annual increment of each living tree in the sample plot, by multiplying its volume by the rate of growth (percentage weighted increment divided by 100)
4. Calculation of the current increment of the whole sample plot adding the annual increment of all living trees inside the plot.

Then, at stratum level, the total volume increment is estimated as for other quantitative variables using (Eq. 19.4). If fewer than four sample trees were cored, or fewer than four cores were usable because of ring width measurement difficulties, the increment information on the plot was considered missing and estimated using linear models (dependent variable increment, independent variables total plot volume and plot dominant height) calibrated using growth data for approximately 6,600 sample plots.

19.6.4 Drain Estimation

The drain estimates in the Italian Forestry Statistics are not currently based on NFI data. The data collected during the INFC third phase will allow estimation of the total cuttings (volume and biomass) for the last year. In case of stumps on sample plots, crews were asked to measure them and to determine if they were older than

1 year. A model of the relationship between the diameter of the stump (cutting height) and diameter at breast height is used to predict the volume of the removed trees in the year by conifer and broadleaf classes. INFC will not provide drain estimates by different drain components, regardless of the definitions adopted for them.

19.6.5 Specific Estimation Questions Related to LULUCF Reporting

Since 2007, NFI2 data for areas, growing stock and increments have provided the main information requested for the LULUCF reporting. For above-ground biomass, as already explained, specific models for each tree species or group have been developed. These models were used in NFI estimation procedures to provide the information for the next reporting (volumes and biomass of the above-ground tree elements). Previously, APAT, the national agency of the Ministry of Environment, reported forest area estimates for each year from 1990 to 2004 by interpolating between estimates from NFI1 (1985) and the preliminary NFI2 results (2003). The growing stock volume (and biomass) of the Italian forests for the same period was estimated by applying the increment estimated by NFI1 to the growing stock data of the same inventory. The estimates of mortality, drain and losses by fire came from other sources.

For other carbon pools, a comprehensive survey of dead wood was carried out by INFC to estimate the volume of lying and standing dead material above the minimum diameter of 10 cm. Soil, litter, small dead wood and underwood, that had been assessed roughly up to now for Kyoto Protocol reporting, will be further investigated in a supplementary field survey to provide accurate estimates.

19.7 Options for Harmonized Reporting

Table 19.5 presents a brief summary of the status of harmonization in the Italian NFI. Forest is already assessed in the field on the basis of the reference definition. Tree level measurements for volume estimates fulfil reference definition requirements. Deadwood has been partially estimated during the third phase; much of the available deadwood data satisfies the reference definition requirements.

Litter and soil will be surveyed using international definitions (according to IPCC Guidelines (IPCC 2003)). The reference definition for forest type can be derived from the national forest type definition and other variables surveyed in the NFI. Concerning occurrence and abundance of vegetation species, NFI provide data for woody species (trees and shrubs) but not for other species. The overall situation is that the estimates can be obtained from the NFI except afforestation, deforestation and reforestation, for which data can be derived from the National Registry.

Table 19.5 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current Italian NFI

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	ND = RD. The forest definition of UNECE/FAO 1997 is applied
Growing stock volume	Yes	Yes	NFI	–
Above- and below-ground biomass	Yes	Yes	NFI, models	Not the below-ground biomass
Dead wood	Yes	Yes	NFI	–
Litter	No	Yes	NFI	–
Soil	No	Yes	NFI	–
Afforestation Deforestation Reforestation (Kyoto 3.3)	No	Yes	National Registry, NFI	–
Naturalness of forest	No	No	–	–
Forest type	Yes	No	NFI	Can be derived from NFI data
Occurrence and abundance of vegetation species	Yes	Yes	NFI	Woody species only

19.8 Future Prospects

A special integrative survey using a sub-sample of the second phase sample plots to collect data on the carbon pools was done in 2008. Approximately 1,500 plots will be randomly selected in proportion to the size of the strata defined by the forest types within regions. With this integrative survey, crews will repeat measurements as in the third phase to investigate correlations between carbon content in each pool and forest's features such as basal area. The new survey will address estimation of biomass and carbon content of the following components:

- Underwood vegetation (trees, shrubs and lianas below 5 cm *dbh*
- Deadwood (INFC provided volume measurements of deadwood, the integrative survey and related laboratory measurements will provide data on the basal wood density of the standing and lying material with diameter of 10 cm or more)
- Small dead wood (below 10 cm of diameter)
- Litter and organic soil

The third NFI is not planned yet and will not be carried out before 2010.

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Chapter 20
Japan

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20.1 Introduction

In Japan, there are two independent forest inventory systems covering 25 million hectares of forest which account for 66% of the country's total land area. One system is the conventional forest inventory conducted under the Forest Planning System based on the Forest Act, in which forest registers and forest planning maps are prepared. The other system is the Forest Resources Monitoring Survey based on systematic sampling at 4 × 4-km grid intervals initiated in 1999. In both systems, surveys are conducted by prefectural governments for private forests and by the Regional Forest Offices for national forests.

Within Japan's policy framework, "private forest" is defined as any forest other than those owned by the national government. Therefore, in addition to privately-owned forests, "private forests" include forests publicly owned by prefectural or municipal governments and by communal bodies. While most of the nationally-owned forests are managed by the Forestry 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).

20.2 Forest Inventory Under the Forest Planning System

20.2.1 Background

All forests in Japan are managed under the Forest Planning System, which was established in its original form under the Forest Act in 1951, mainly to recover

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forests from degradation that occurred during World War II. Correspondingly, the conventional data collection system, which focused largely on productivity of forests, was developed to provide basic information required for forest planning. Data are collected and recorded in the form of forest registers and forest planning maps for forests of all ownerships 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 nation-wide forests, by prefectural and municipal governments for private forests and by the Regional Forest Offices for national forests. The structure of the Forest Planning System is shown in Fig. 20.1.

20.2.2 Methods

In the conventional forest inventory system, all forests are divided into compartments and sub-compartments. A sub-compartment can be defined by a unique set of

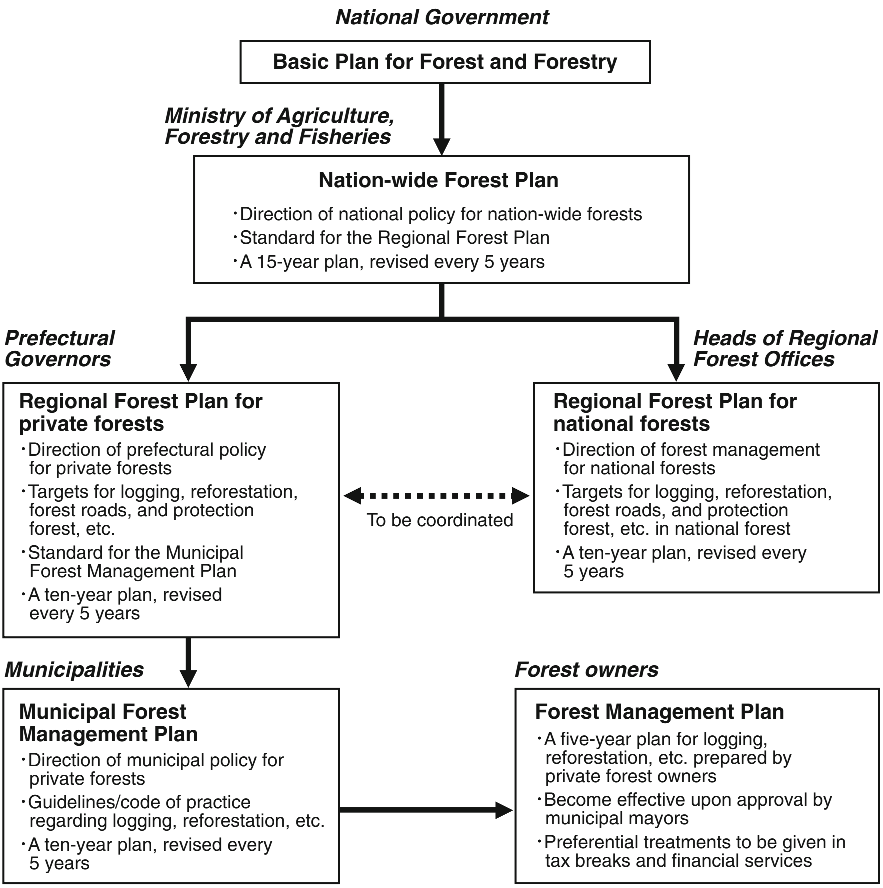

Fig. 20.1 Structure of the Forest Planning System

“attributes” and represents the smallest unit of forest management in Japan. The total number of compartments is 330,000 and that of sub-compartments is 35,000,000. The average size of sub-compartments in private forests is approximately 0.5 ha, reflecting the very small ownership scale and intricate stand patterns, whereas the average size of sub-compartments in national forests is 7.8 ha.

20.2.2.1 Forest Registers

Forest registers, the first component of the conventional forest inventory, are required for sub-compartments of all private and national forests, and record information on the status of stands on forest land including species, age, diameter at breast height (*dbh*), average height, and annual stand increment. Growing stock is estimated from empirical yield tables produced for each region. In addition, the location, name of the owner, size, site index and legal designations of sub-compartments are recorded. The standard format of forest registers is shown in Fig. 20.2.

20.2.2.2 Forest Planning Maps

Forest planning maps, the second component of the conventional forest inventory, are prepared on a scale of 1:5,000 for all forest areas (Fig. 20.3). The boundaries of compartments and sub-compartments listed in the forest registers are delineated on the corresponding topographical maps. These geo-data, including the information on forest registers, have been converted to geographic information system (GIS) data in most prefectures and the National Forest System for better data management, and thereby contribute to integrated policy making. Today, more than 90% of boundaries in private forests and all boundaries in national forests have been digitized for GIS.

Both forest registers and forest planning maps are updated at least every 5 years when Regional Forest Plans are revised. Because all logging activities in private forests are to be reported to the mayors of municipalities or to prefectural governors, information on harvested forests can be updated based on such reports. In this way, the latest state of forests is reflected in the conventional forest inventory. For forests that had not been logged during the 5 years’ interval of data-updates, information is updated either by using the results of field surveys implemented for formulating the Regional Forest Plans, or by simply applying standard yield tables.

20.3 Forest Resources Monitoring Survey

20.3.1 Background

The international agreement on sustainable forest management at the United Nations Conference on Environment and Development in Rio de Janeiro Earth

森　林　簿

広域流域	森林計画区	市町村	林班
41 イマイズミ	300 ヒラタ	400 ゴトウ	10

小班	森林の所在 大字	字	地番 本番	地番 支番	所有者氏名	在村・不在村	機能の種類	森林の種類	面積 ha	林種	施業方法区分 現在	樹種 現在	樹種 将来	混交歩合 %	面積歩合 %	林齢	齢級	樹冠疎密度	平均樹高	地位級 現在	地位級 将来	地利級 現在	地利級 将来	立地級 現在	立地級 将来	伐採の方法	更新の方法	公益的機能別施業区分	搬出方法特定森林等	材積 m3 ha当たり	総材積 針	総材積 広	総材積 計	成長量 m3 ha当たり	成長量 m3 総	伐期材積 m3	森林施業計画	分収林	保健機能森林
1	2	2	1	1	マスヤマ　トシ	在	1	普	0.9	人	1	スギ	スギ	100	100	53	11	3	14	12	12	15	16	180	192	1	2	2 1					59	6					*
2	2	2	1	2	マスヤマ　トシ	在	1	普	0.2	人	1	スギ	スギ	100	100	21	5	2	12	12	12	15	16	180	192	1	2	1 1					55	4					*
3	2	3	2	1	ヨウ　コ	在	2	普	1.2	人	1	スギ	スギ	100	100	59	12	3	16	12	12	15	16	180	192	1	2	2 1					60	6				*	*
4	2	3	3	1	ヨウ　コ	不	1	普	0.6	天	2	広	広			49	10	3	10	7	7	3	31	21	28	3	3	1 3					10	2					
5	3	1	1	1	ヨウ　コ	不	2	普	1.5	人	1	スギ	スギ	100	100	41	9	2	16	12	12	15	6	180	192	1	2	1 1					25	4					
6	3	1	1	2	ミヤゾノ　ヒロ	不	1	普	0.5	天	2	スギ	スギ	100	80	62	13	3	13	7	7	3	3	21	28	3	3	1 3					20	2					
7	3	1	1	3	ミヤゾノ　ヒロ	不	2	普	0.2	天	2	広	広			48	10	3	16	7	71	3	41	21	28	3	3	1 3					13	1					
8	3	2	1	5	ミヤゾノ　ヒロ	在	1	普	1.1	人	1	スギ	スギ	100	100	39	8	2	14	12	21	15	62	180	192	1	1	1 1					51	3					
8	4	1	1	2	ミヤゾノ　ヒロ	在	1	普	1.5	人	1	ヒノキ	ヒノキ	100	100	47	10	3	16	10	0	23	4	230	240	1	1	2 1					98	10					
9	5	2	1	1	ゴトウ　タケシ	在	1	普	0.9	人	1	スギ	スギ	100	100	53	11	3	14	12	12	15	16	180	192	1	2	2 1					59	6					*
9	6	2	1	2	ゴトウ　タケシ	在	1	普	0.2	人	1	スギ	スギ	100	100	21	5	2	12	12	12	15	16	180	192	1	2	1 1					55	4					*
9	2	3	3	1	ゴトウ タケシ	不	1	普	0.6	天	2	広	広			49	10	3	10	7	7	3	31	21	28	3	3	1 3					10	2					
10	1	1	1	1	ヒラタ　ヤス	不	2	普	1.5	人	1	スギ	スギ	100	100	41	9	2	16	12	12	15	6	180	192	1	2	1 1					25	4					
10	2	2	1	1	ヒラタ　ヤス	在	1	普	0.9	人	1	スギ	スギ	100	100	53	11	3	14	12	12	15	16	180	192	1	2	2 1					59	6					*
10	3	2	1	2	ヒラタ　ヤス	在	1	普	0.2	人	1	スギ	スギ	100	100	21	5	2	12	12	12	15	16	180	192	1	2	1 1					55	4					*

Fig. 20.2 Standard format of forest registers

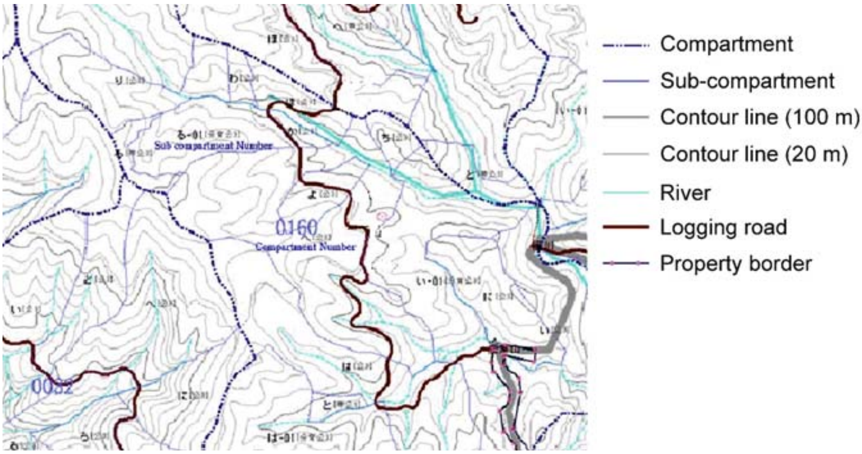

Fig. 20.3 Forest planning map

Summit in 1992, the subsequent progress towards the establishment of criteria and indicators for sustainable forest management, and the shifting of domestic forest policy focus from wood production to multiple benefits of forests, led to a need for a more sophisticated data collection scheme to take into account aspects of sustainable forest management. Additionally, Japan participates in the Montréal Process Working Group on Criteria and Indicators for Conservation and Sustainable Management of Temperate and Boreal Forests.

In response, the Forestry Agency of Japan launched the Forest Resources Monitoring Survey in 1999. This survey monitors changes in quality and quantity of forests on a nation-wide scale, incorporating some of the indicators identified in the Montréal Process. The objectives of this survey are to collect a broader range of data and information on forests, to monitor and assess the progress toward sustainable forest management, and to incorporate the results into forest-related policies. The first round of the survey was conducted during 1999–2003, and the second round during 2004–2008.

20.3.2 Methods

Under the Forest Resources Monitoring Survey, data are collected on 15,700 permanent sample plots, 10,500 of which are located on private forests and the rest on national forests. These plots are set up at 4 $\times$ 4-km grid intervals systematically covering forests in every 16 km^2 throughout Japan. Of the 15,700 permanent sample plots installed, approximately 3,000 plots are designated as special plots for collecting additional specific data. The survey is designed so that approximately

3,100 plots or one-fifth of the total number of plots are visited for data collection every year, or equivalently, each plot is remeasured every 5 years.

20.3.2.1 Plot Design

Plot locations are selected at 4 × 4-km grid intervals on the Japan-19 Plane Orthogonal coordinate system regardless of land use. For each plot, land use (forest or non-forest) is interpreted from aerial photographs and other available information. Then, sample plots located in forests are selected and marked on forest planning maps and aerial photographs. Finally, a field crew is sent to each forest plot for field survey. Routes used for accessing plot locations are recorded with the use of aerial photographs and global positioning system (GPS) for the next field survey.

Each plot is a circle of 0.1 ha and is divided into three concentric, circular sub-plots (Fig. 20.4) with radius of 5.64 m for the small circular sub-plot (S), 11.28 m for the medium circular sub-plot (M), and 17.84 m for the large circular sub-plot (L). However, surveyed areas for each of the sub-plots are defined partly as annular areas:

- Area(S) = Small circular area equals 0.01 ha
- Area(M) = Medium circular area minus Small circular area equals 0.03 ha
- Area(L) = Large circular area minus Medium circular area equals 0.06 ha

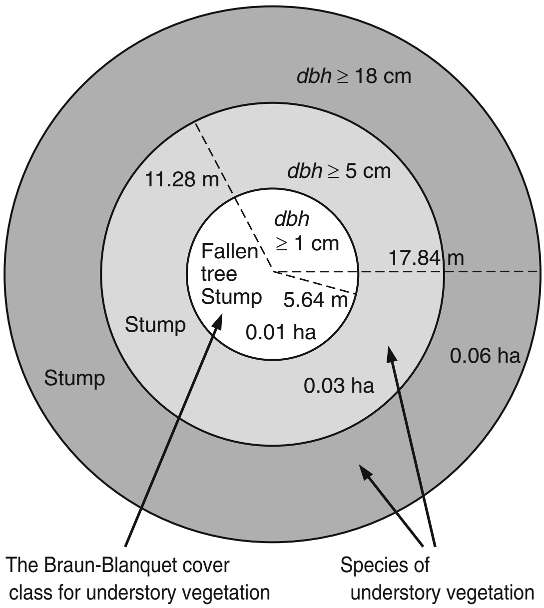

Fig. 20.4 Plot design of the Forest Resources Monitoring Survey

20.3.2.2 Survey of General Condition of the Plot

Plot-level assessments include 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 and operation records during the last 5 years. In addition, land-use type, legal designations and stand age are recorded from the forest registers.

20.3.2.3 Sample Tree Assessments

Species, *dbh*, viability, and state of bark and cavity of all standing trees with *dbh* $\geq$ 1.0 cm on small circular sub-plots, with *dbh* $\geq$ 5.0 cm on medium sub-plots, and with *dbh* $\geq$ 18.0 cm on large sub-plots are recorded. In addition, 20 trees are randomly selected across the plot to measure tree heights. Dead trees and animal signs e.g. trace and scat, are recorded if observed.

20.3.2.4 Survey of Stumps

Stumps with diameters $\geq$5.0 cm at the height of 20 cm above the ground are measured on small and medium sub-plots and stumps with diameters $\geq$18.0 cm at 20 cm above the ground are measured on large sub-plots. To estimate the *dbh* of felled trees from the remaining stumps, five standing trees on the plot are selected for measurement of their diameters at the height of 20 cm above the ground and their *dbh*s.

20.3.2.5 Survey of Fallen Trees

Fallen trees are surveyed only on the special plots. On the small circular sub-plots, fallen trees with a diameter $\geq$5.0 cm at the centre of the stem are recorded. The degree of decay is classified into six categories. All fallen trees are numbered so that they can be identified in the next field survey.

20.3.2.6 Survey of Understorey Vegetation

On the small circular sub-plots, cover rates of higher-tree layer (over 8 m), lower-tree layer (2–8 m), shrub layer, herb layer and bare land are estimated by visual assessment and the Braun-Blanquet cover class (Braun-Blanquet 1964) is estimated for all species of the shrub layer and herb layer. On the medium and large sub-plots, names of all herbal and fern species observed are recorded.

20.4 International Reporting

Japan's national forest inventories serve as the primary source of information for sustainability reporting based on the Montréal Process criteria and indicators. The inventories also provide baseline data for the Forest Resources Assessment (FRA) program of the Food and Agriculture Organization of the United Nations.

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Chapter 21
Latvia

Jurgis Jansons and Ieva Licite

21.1 Development of Latvia's National Forest Inventory

Since the first half of the nineteenth century, forest resources data for Latvia were based on stand-level inventories. Currently, these inventories provide the basic information necessary for forest management. Each forest owner is obligated to conduct an inventory at least once every 10 years. However, more reliable, precise and operative information for statistical requirements are needed.

The National Forest Inventory (NFI), Latvia's first sample-based inventory, is conducted by the State Forestry Research Institute (LFRI Silava). The inventory management, planning and field work are conducted by staff with specialist qualifications. The first cycle of the NFI is scheduled for 2004–2008, with the second cycle consisting of repeated measurements scheduled for 2009–2013. Thus, the NFI has been producing forest resources information for the country since 2004. LFRI Silava is responsible for NFI data quality control and storage.

The NFI introduced sampling methodologies in 2004 which has resulted in operative and precise estimates of forest resources for state and international reporting. The overall objective of the NFI is to survey all lands which, according to Forest Law, qualify as land used for growing forests without regard to ownership. All plots for the entire land area of the country are inventoried, not just those with forest cover, to provide observations on the dynamics of land ownership and evaluations of naturally or artificially afforested land. The immediate aim of the inventory is to collect quick and precise information as follows:

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Land use classifications for the NFI are similar to official land use classifications and are consistent with them. Land is classified as follows:

1. Forest land use
   (a) Forest (area $>$0,1 ha, potential height of trees $>$7 m, present or potential projection of crowns $>$20%):
       - Forest (main producer of organic matter is tree stand)
       - Clearing, burning, wind through, dead stand
   (b) Bog (moss, grass or transition bog)
   (c) Glade (natural glade, game feeding glade, heathland, sands)
   (d) Flooded space
   (e) Land under forest infrastructure objects
       - Forest road
       - Firebreak
       - Compartment break
       - Ditch
       - Canal
       - Ditch route
       - Other infrastructure objects
   (f) Seed orchard
   (g) Nursery Local watershed
   (h) Recreation place
   (i) Other special places
2. Agriculture land
3. Waters (rivers, lakes)
4. Other land

21.2 The Use and Users of the Results

The Latvian NFI is under development towards statistical sampling. Latvian legislation delegates to LFRI Silava responsibility for organizing the NFI and providing information. LFRI Silava gives the known accuracy information to the Ministry of Agriculture who are responsible for forest policy. Since 2008 LFRI Silava was given the task to collect information for carbon reporting, using NFI data in the calculations. It is planned that the NFI data will be the main source for forest resources information at the country level and will change from stand-wise forest inventory that previously carried out this task to sample-based surveys. The NFI will provide data for research needs in the forest sector.

21.3 Definitions of Forest and Growing Stock

The definition of forest land for Latvia's NFI requires a minimum potential tree height of 7 m; in the definition of forest of the Food and Agriculture Organization of the United Nations (FAO 2004) a height of 5 m is required. The greater height for Latvia relates to the distinction between bog and forest. In moss bogs the main producer of organic matter is ground vegetation, not trees, so bogs are not considered forest land where the main producer of organic matter are trees. The smallest height value for the Latvian forest site index calculation is 7 m, and only the bog ecosystem has a smaller potential height at maturity. However, for purposes of harmonized reporting, bog areas with potential tree heights of 5–7 m may be considered forest land.

The minimum area for forest land, as written in forest legislation, is 0.1 ha, whereas the minimum area of FAO and COST Action E43 is 0.5 ha. The reason for the difference is that 0.1 ha is the minimum area at which stand-level inventories are conducted and also the minimum area for clearcuts. Few forest areas are smaller than 0.5 ha, and they may be located easily using orthophoto maps and excluded from forest area and volume calculations.

The minimum diameter at breast height (*dbh*) of measured trees is 2.1 cm. Techniques for harmonizing estimates must be used to estimate the volume of growing stock for trees with $0 < dbh \leq 2$ cm. However, this volume component is very small relative to the total volume of growing stock. The differences between the Latvian NFI definition and the COST Action E43 reference definition are seen in Table 21.1.

21.4 Sampling Design

The sampling design is based on a 4 × 4-km grid of permanent clusters with four sample plots spaced at 250 × 250 m. To increase the precision of estimates, additional temporary clusters are established using a 2 × 2-km grid.

Table 21.1 Differences in growing stock definitions

Criteria	Latvian NFI definition	COST Action E43 reference definition
dbh	≥2.1 cm	0 cm
Top diameter	0 cm	0 cm
Stump	Excluded	Excluded
Branches	Excluded	Excluded
Bark	Included	Included
Newly dead trees	Excluded	Excluded

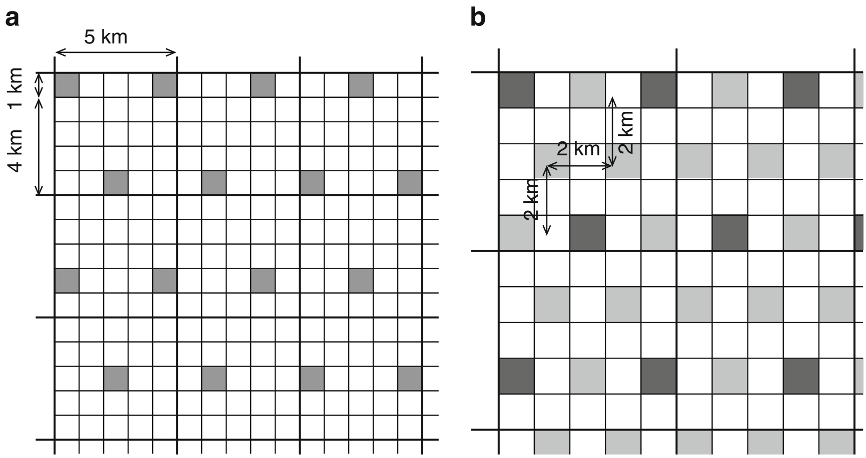

Fig. 21.1 Schema of layout of (**a**) permanent and temporary (**b**) sample plot clusters

21.4.1 Sampling Grid

Grids of permanent sample plot clusters and temporary sample plot clusters are created by selecting permanent sample plot clusters with four plots each and temporary sample plot clusters with eight plots each. The sampling grid of permanent sample plot clusters is placed systematically across the entire country using a 4 × 4-km pattern (Fig. 21.1a). Each year one fifth of the plots in permanent sample plot clusters are assessed.

Temporary sample plot clusters are placed using a 2 × 2-km grid with the aim of increasing precision of estimates (Fig. 21.1b). The number of temporary sample plot clusters measured annually is one third of the number of permanent sample plot clusters measured annually. Temporary sample plot clusters are not re-measured in subsequent inventories.

Using orthophoto maps, permanent plots within a 1 × 1-km quadrat are offset 25 m from the corners of 250 × 250-m quadrats (Figs. 21.2 and 21.3).

After the plot assessments for a single year, each temporary sample plot represents 6,000 ha, but over 5 years each temporary sample plot represents 1,200 ha. Taking permanent sample plots and temporary sample plots together, each plot represents 1,500 ha for a single year, but over 5 years each plot represents 300 ha. Observations and measurements on permanent sample plots and temporary sample plots together are used to estimate the current state of forest resources whereas repeated measurements of permanent sample plots are used to estimate changes within 5-year NFI periods. The time period between re-measurements of permanent sample plots is 5 years ± 20 days.

Ortho-rectified aerial photographic maps of 1–5 years of age are used to estimate the land use categories in the vicinity of sample plots. Field measurements are obtained for each sample plot that intersects forest land.

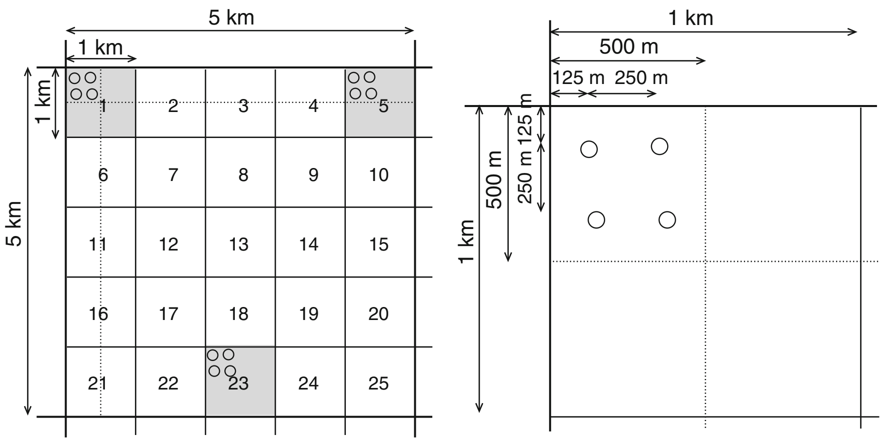

Fig. 21.2 Schema for selecting permanent sample plots on orthophoto

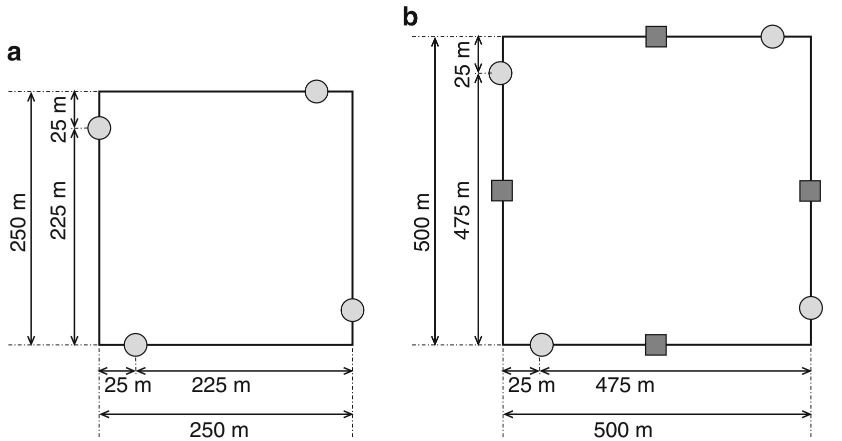

Fig. 21.3 Schema of placement of (**a**) permanent sample plots and (**b**) temporary sample plots

21.4.2 Sample Plots

For all permanent and temporary sample plots, trees are selected with the aim to evaluate height, age, increment, quality and damage. Trees are selected in proportion to the breast height diameter of a tree (*dbh*) of all existing trees within the plot and are selected to represent all diameter classes for each species. The intensity of selection is 20–30% of all trees, whose *dbh*'s are measured.

The permanent sample plot clusters are established according to a systematic schema of placement with a random starting point. Each plot represents 400 ha and is measured once within a 5-year NFI period.

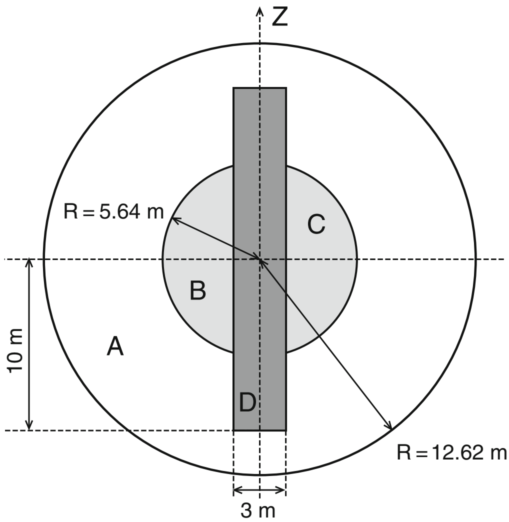

Fig. 21.4 Sample plot schema: Areas of sample plots A, B, C and D are equal to temporary clusters are 500 × 500 m (Fig. 21.3) 500 m^2, 100 m^2, 25 m^2 and 60 m^2, respectively

Temporary sample plot clusters are placed using a randomization procedure. Tables of random numbers are used to select 1 × 1-km quadrats for temporary sample plot clusters (Fig. 21.2) but excluding quadrats containing permanent sample plot or temporary sample plot clusters from previous inventories.

Temporary sample plots are assessed in the same manner as permanent sample plots, but measurements are made only once and without recording the geographical locations of trees.

Permanent sample plots are placed in 250 × 250-m squares with sides oriented in the north–south and east–west directions. Plot centres are offset 25 m from the cluster corners (Fig. 21.3a).

Temporary sample plots are placed in quadrats of 500 × 500 m and are divided into plots for measuring trees but without recording geographical locations of trees and stump plots. Plots for measuring trees are offset 25 m from the corners of the 500 × 500-m quadrat.

The main sampling areas are the permanent sample plots with constant radii of 12.62 m (area of 500 m^2). Measurements are obtained for trees with *dbh* ≥ 14.1 cm and dead wood (Fig. 21.4).

In the centre of a plot, a circular plot (B, Fig. 21.4) of radius 5.64 m (area of 100 m^2) is established for measuring trees and deadwood with diameter ≥6.1 cm. In the first quarter of this plot (turning clockwise from the north) of area 25 m^2 (C, Fig. 21.4) all naturally growing saplings and shoots with *dbh* ≥ 2.1 cm and stumps with diameter ≥2.1 cm at root collar are measured. Understorey and brushwood assessments are taken on a 3 × 20-m strip plot (D, Fig. 21.4). For sample plots 1 and 3 within a permanent sample plot, the strip plots are oriented in an east-west direction, and for sample plots 2 and 4, the strip plots are oriented in a north–south direction.

A sample plot is divided into smaller units called sectors when the plot is situated on the boundaries of compartments. Different compartments are characterized by different categories of ownership, land use, forest land category, origin of stand, forest site type, main species, age differences exceeding 20 years, or stocking level of the main storey differs by 0.3 or more. Each sector is described separately, with trees being measured as in undivided sample plots.

21.4.3 Management

21.4.3.1 Personnel and Equipment

The NFI staff consists of five field crews with three engineers in each group. The geographical locations of plot centres is determined using the Trimble GeoXT global positioning system (GPS) receiver which has sub-meter precision. Sample plot centres are marked with an iron pole beneath the soil surface.

21.4.3.2 Quality Assurance

Field work is controlled with the aim to prevent both mistakes during measurements and the causes of these mistakes. At least 5% of the plots measured by each field crew are checked for quality by a separate control group consisting of three specialists.

During field work, quality of assessments is checked for all variables that are re-measured in subsequent cycles (azimuth of trees, distance, *dbh*, and height). For variables that are not re-measured in subsequent cycles, (width of growth rings, present deadwood and stumps), measurement quality is checked on a random basis and control is performed each year.

Data gathered during assessments on sample plots initially are registered in working tables. After logical control, any mistakes found are returned to the field crews for correction. Finally, checked data are stored in a primary database according to the measurement year and 5-year NFI cycle. A permanent database may be supplemented with new data or data on new variables at any time. Information summarized during preparatory work and cartographic materials are stored as printouts until the next measurement when they are updated with new data, if possible.

21.5 Estimation Techniques

21.5.1 Estimation of Diameter Increment and Age

Radial increment is assessed with different methods, depending on the mean *dbh*. If the mean *dbh* < 10 cm, the annual increment is assessed by dividing the growing stock of the stand storey by age. For purposes of assessing age, a non-plot tree with average dimensions is felled at 1.3 m above ground level and the growth rings are counted. If the mean *dbh* exceeds 10 cm, the age is determined using boring methods. If the growing stock of the stand storey in the stand is less than 40% of total growing stock of at the stand, one tree with mean *dbh*, chosen by eye, is bored. If the growing stock of the stand storey exceeds 40% of total growing stock at the stand, two trees are bored for age assessment; if the age difference exceeds 15 years, a third tree is bored. Age is assessed for all stand storeys.

For increment assessment, additional trees, other than those assessed for age, are bored. The last growth ring is not measured. For increment assessment at least three trees are bored. Bored trees should represent different diameter groups. In general, increment is assessed for 1 or 2 of the smallest diameter stand trees, 1 or 2 of the largest diameter stand trees and 2 or 3 mid-diameter stand trees, including trees bored for age assessment.

During assessment of increment in forest, widths for the last 5 and 10 years growth rings are measured. Increment is assessed to the nearest 0.1 mm for conifers, oak and ash, and to the nearest 0.5 mm for other tree species, as well as thickness of bark to the current years growth ring. During age assessment the additional thickness of the woody part from the bark to the beginning of a possible rot is assessed.

21.5.2 Volume Estimation

The stem volume of a tree in the Latvian NFI is defined as the volume of stemwood over bark and above stump to the top of a tree. The volume of growing stock includes the stem volumes of all living trees, independently of species, and with a minimum *dbh* of 2.1 cm. The volume of dead wood includes the stem volume of all dead trees but with a minimum diameter of 6.1 cm at a height of 1.3 m. Volume is estimated for each tree, and tree volumes are added for stand storeys (one species, one storey and one generation) and then added to obtain plot totals. The calculations of growing stock is carried out using Liepa's algorithms (Liepa 1996).

21.5.3 Estimation of Volume Increment

Volume increment in the Latvian NFI is defined as the increase in tree stem volume over bark from above the stump to the top of the tree. At the first cycle of the Latvian NFI (2004–2008) increment is estimated, using boring methods, as an average over 5 years. Calculating the volume increment is in principle the same as volume calculation. At the time of writing no estimates have been officially published.

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Chapter 22
Lithuania

Andrius Kuliešis, Albertas Kasperavičius, and Gintaras Kulbokas

22.1 Development of the Lithuanian National Forest Inventory

The first stand level forest inventories on Lithuanian territory were started in 1801 (Table 22.1). Before 1912, some parts of Lithuania's forests had been inventoried up to five times, but the inventories were not conducted on a regular schedule and the whole country was not inventoried. Usually just the largest forest areas were inventoried (Brukas et al. 2002).

Regularly scheduled, stand level forest inventories of the whole country started in 1922. The forests of Lithuania were inventoried over a period of 10–20 years. Usually every year one tenth of the country's territory was inventoried. Forest mapping, using geographical information system (GIS) techniques, was started in 1995, and the sixth stand level inventory of Lithuania was started in 2002. The stand level forest inventories are the basis for forest management planning and regular forest resources assessment. According to Lithuanian Forest Law (1994), stand level forest inventories and mapping should be executed regularly every 10 years throughout the country independent of forest ownership.

Databases including descriptions and digital borders for all stands have been organized on the SQL server DB database (DB) management system since 1997 (Brukas et al. 2002). Since 2003 these data have formed the basis for Lithuania's state cadastre and are managed by the State Forest Survey Service.

A pilot inventory based on sampling methods was conducted in Lithuanian state forests in 1967–1969. Investigation of continuous forest inventory methods using permanent plots was started in 1976 in Dubrava forests (5,000 ha, 188 sample plots) (Kuliešis 1999b). Using the results of five repeated measurements obtained at 5-year intervals new methods for allocating plots, marking, data processing and analysis were developed. The results formed the basis for the theoretical and

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Table 22.1 Forest inventories in Lithuania

Inventory type	Years	Method	Remarks
Stand level	1801–1912	Ocular assessment – measurements	Irregular schedule, forest land level
Stand level I	1922–1956	Ocular assessment – measurements	Regular schedule, country level
Stand level II	1958–1963	Ocular assessment – measurements Use of aerial photographs for mapping	Regular schedule, country level
Stand level III	1966–1977	Ocular assessment – measurements Non-wood resources, forest soil and site inventory started	Regular schedule, country level
NFI, sampling	1967–1969	Measurements 5,000 sample plots, six plots per cluster	State forests, temporary plots 50–800 m^2
Stand level IV	1978–1987	Ocular assessment – measurements Prognosis of forest stand characteristics	Regular schedule, country level
Stand level V	1988–2001	Ocular assessment – measurements Geographical information system (GIS) technologies implemented	Regular schedule, country level
Stand level VI	2002– (in progress)	Ocular assessment – measurements Sampling of mature stands implemented	Regular schedule, country level
NFI I, sampling	1998–2002	Sampling using Geographic Information System (GIS)	5,600 permanents plots established
NFI II, sampling	2003–2007	Sampling using GIS, Temporary plots implemented	Remeasurement of permanent plots (~1,120 annually), establishment of new permanent and temporary plots
NFI III, sampling	2008–2012 (in progress)	Integration of National Forest Inventory (NFI) and Forest health monitoring (FHM). Inventory of decomposition level of dead wood	

methodological aspects of the sample-based NFI. In 1996, experimental NFI investigations in the forests of the Jūrė district (3,000 ha, 169 sample plots) helped to finalize preparation of a continuous sampling inventory in Lithuanian forests by improving the design, technical aspects of measurements, estimation methods, and data processing and analysis (Kuliešis 1996; Kasperavičius 1997). GIS techniques were adopted for allocating sample plots. On March 17, 1998, the vice-minister of the Agriculture and Forestry Ministry signed an order to begin a sample-based Lithuanian NFI (Ministry of Agriculture and Forestry 1998). The allocation and measurement of permanent plots was finished in 2002 (Kuliešis et al. 2003) and remeasurement of these plots and establishment of new temporary plots was started in 2003 (Kuliešis et al. 2009).

The aim of the sample-based National Forest Inventory (NFI) is to conduct a thorough monitoring of Lithuanian forests for efficient assessment of the main forest variables in the country or its regions. High priority was especially given to estimation of volume increment and its structure. In accordance with Lithuanian Forest Law, the focus of the NFI is the land portion of the country used for growing forests. Continuous management of the land area of the entire country is ensured by observing land property dynamics and evaluating forest land using data from permanent and temporary NFI plots.

The main tasks of the NFI in all Lithuanian forests according to ownership category are:

1. To manage the dynamics of forest areas
2. To estimate wood resources, increment, their structure and the dynamics with pre-defined accuracies
3. To determine the validity of other methods for inventoring wood resources
4. To guarantee the flow of information about:
   (a) Growing stock resources and their consumption
   (b) Gross increment and its consumption
   (c) Management efficiency at the state level
   (d) Control of forest felling, reforestation and carbon balance
   (e) Reliable strategic planning of forest development
5. To assess the state of forest sites, their yield dynamics and usage efficiency
6. To assess the current state of forests
7. To assess the dynamics of forest ecosystems, their health, damages and biodiversity

22.2 The Use and Users of the Results

The Lithuanian NFI provides government institutions with information of known accuracy for strategic large-area forest management planning and estimates of forestry efficiency. The NFI is the source of accurate forest information used for forest industry and its investments, environmental decisions and policy making, biodiversity estimation and carbon stock assessment. The Lithuanian NFI also provides statistical information about country forest resources for national and international reporting to bodies such as the Food and Agricultural Organization of the United Nations (FAO) and its Forest Resources Assessment, and the Ministerial Conference on the Protection of Forests in Europe (MCPFE). Further, NFI data is anticipated to serve as a basis for modeling forest growth under a variety of silvicultural scenarios. NFI data users include scientists in a wide range of disciplines such as forest management, silviculture, forest productivity, forest soils, and biology.

Table 22.2 The main NFI quantities and definitions compared with FAO definitions

E43 reference definition	National definition
Forest is land with tree crown cover (or equivalent stocking level) of more than 10% and area of more than 0.5 ha including wind breaks and shelter-belts of trees with area of more than 0.5 ha and width of more than 20 m	Stocking level – more than 30% Area – more than 0.1 ha Width of shelter-belts – more than 10 m
Growing stock is the volume of living and standing stems over a specified land area. Includes: stem volume above stump measured over bark to top (0 cm), all trees with *dbh* over 0 cm	Growing stock is the volume of living stems with bark Stem is defined from root collar up to terminal bud of stem
Gross annual increment is average annual volume of increment over the reference period of all trees measured to a minimum diameter at breast height (*dbh*) of 0 cm	Increment is the change of total stem volume including bark, increment of dead and felled trees and ingrowth during two successive inventories

22.3 Current Estimates

National definitions are given a legal basis within Lithuanian forest law (Parliament of Lithuanian Republic 1994) with more detailed definitions provided in the Statute of Lithuanian state forest cadastre (Government of Lithuanian Republic 2003), the Manual of National Forest Inventory (Kuliešis et al. 2005), and the instruction for stand level forest inventories (State Forest Survey Service 2007). The main differences between national definitions and COST Action E43 definitions, that are near UNECE/FAO TBFRA 2000 definitions (UNECE/FAO 1997, UNECE and FAO 2000), of forest, forest land, growing stock volume, annual increment are presented in the Table 22.2.

In Lithuania's Forest law, forest is defined as land not less than 0.1 ha, covered by trees or other forest vegetation or temporarily unstocked (cleared or burned areas). The definition of forest includes shelterbelts of trees with widths of more than 10 m. Forest stands with stocking levels (approximately equivalent to crown cover) less than 30% are not acceptable for high productivity forestry. Forest stands whose trees cannot reach or exceed the 30% stocking level should be removed and reestablished. All forest land, independently of current cover level, are under forest law protection, which means obligatory reforestation of such areas. According to national regulation, afforestation of abandoned agricultural lands is ascertained in case forest crown cover attains 30% of an area not less than 0.1 ha. The total area of Lithuanian forest land of less than 0.5 ha is approximately 7,300 ha and can always be estimated using forest cadastre data (Table 22.3). Characteristics and deviations of the main variables are presented using estimates from the 2003–2007 NFI in Table 22.3 3 (Kuliešis et al. 2009).

In the Lithuanian NFI, measurement of the main tree variables is based on the location of the root collar, which is the ground surface position when tree was planted or when it germinated, and the total length of the stem from root collar to the terminal bud of the stem. Inclusion or exclusion of various tree parts such as

Table 22.3 Basic area and volume estimates of Lithuania (NFI 2003–2007)

Quantity	Estimate	Deviation from FAO definition (%)	SE[a] (%)
Forest land area (1,000 ha)	2,108.1	+0.4	1.0
Forest land area covered by trees (1,000 ha)	2,036.2	+0.4	1.0
Other wooded land area (1,000 ha)	77.0[b]	–	n.a.[c]
Forest roads, technological lines (1,000 ha)	29.9	0	10.0
Growing stock volume on forest land (million cubic metre)	466.7	+1.7	1.3
Annual increment of growing stock volume on forest land (million cubic metre per year)	15.9	+1.7	1.2
Annual changes of growing stock volume (million cubic metre per year)	+2.9	0	17.2
Annually dead trees, million cubic metre (included stems with *dbh* > 2.0 cm)	3.3	0	2.7
Total land and inland water area (1,000 ha)	6,530.0	–	–[d]

[a]Standard error.
[b]Land Fund of the Rebublic of Lithuania (2007).
[c]Not available.
[d]Assumed to be error free.

stump, top of stem and size of branches is the main reason for growing stock volume definition changes during the last 7 years of global forest resources assessments. For the Lithuanian NFI, a stem without all of its parts (stump, stem top) or with only some parts (branches) is not a natural body and cannot be the basis for forest resources assessments. In addition, exclusion of the stump leads to difficulties because stump size depends on cutting techniques. Thus, unlike reference definitions, the Lithuanian NFI definition of growing stock includes aboveground stumps.

On the other hand, stump volume accounts for only 1.5–2.0% of growing stock volume for Lithuania and is within the accuracy limits for estimates of growing stock volume. In the Lithuanian NFI, all planted and naturally regenerated trees with *dbh* of at least 2.1 cm are measured. An analysis of the structure of growing stock volume showed that trees with *dbh* between 2.1 and 4.0 cm account for only 0.2% of growing stock volume. Thus, the volume of trees with *dbh* < 2.1 cm is negligible. Similarly, the proportion of gross annual increment in trees with *dbh* < 2 cm is also negligible. Gross annual increment estimated from permanent plots is differentiated into three main parts: volume of deadwood, volume of felled trees by final or intermediate fellings which includes drain, and volume increase due to growth. The mean annual change in growing stock volume is estimated by using differences in tree volumes for two successive inventories, as seen in Table 22.3.

22.4 Sampling Design

The NFI is based on continuous, multistage sampling and GIS technology and is organized in the same manner for all Lithuanian forests. Sampling is conducted using a 4 × 4-km systematic grid with a random starting point (Fig. 22.1).

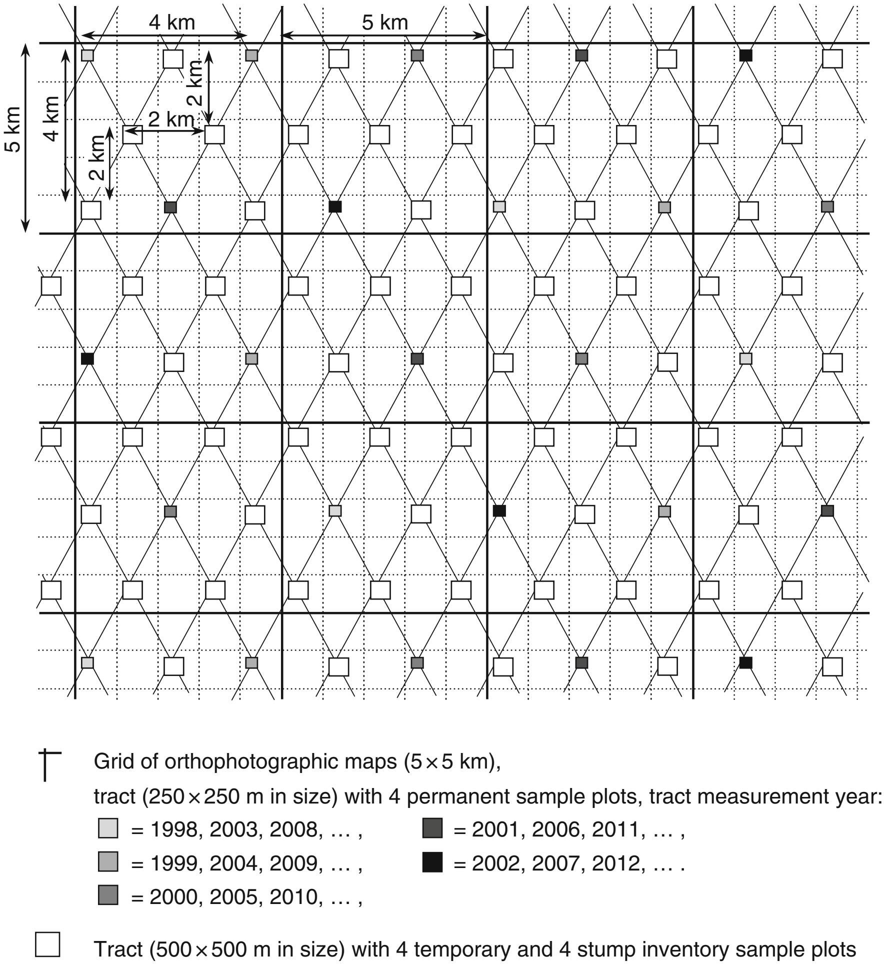

Fig. 22.1 Distribution of permanent and temporary clusters

The systematic grid assures a uniform distribution of plots over the entire country and regular management of conversion amongst land use categories. The sample plots are arranged into clusters (Fig. 22.2) and include permanent, regularly measured and temporary plots. Permanent plots are marked in a way which guarantees their visibility only for inventory teams and invisibility for all other persons. Taking into account the number of homogeneous stands (strata), minimal growing stock volume and increment estimation accuracy, 5,600 permanent sample plots were established on forest land over a 5-year period. Approximately 1,120 permanent sample plots are remeasured each year. The NFI plots cover the entire country each year with the total number of plots measured over the 5-year inventory cycle reaching a sampling intensity of one sample plot per 400 ha. The inventory

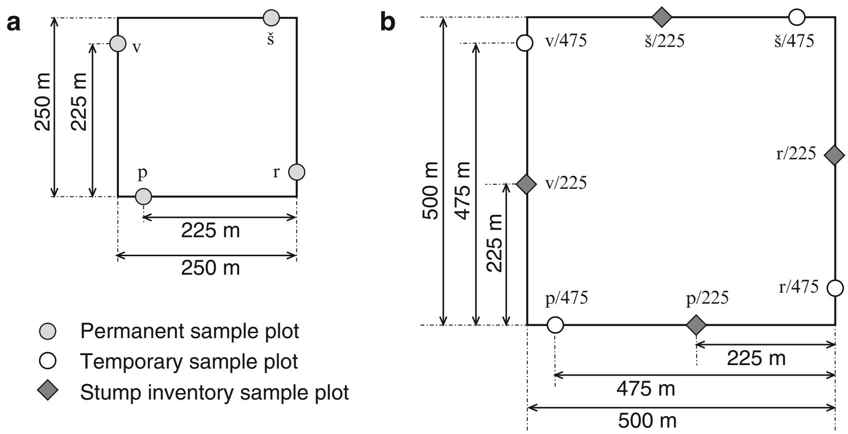

Fig. 22.2 Location of sample plots in clusters: a) permanent, b) temporary, and stump plots

cycle is 5 years. Additional temporary plots are established every year during the following 5-year period. The number of temporary plots in each 5-year period is one-third the number of permanent plots and averages 380 plots per year.

22.4.1 Sample Plots

The principal sample unit is a permanent or temporary plot of 12.62 m radius and area of 500 m^2 (Fig. 22.3). The radius of plots on sloping terrain is increased to accommodate the sloping surface. On the main 500 m^2 plot, all trees with *dbh* > 14.0 cm are measured (Fig. 22.3). In the center of the plot, another 100 m^2 circular plot is used to measure all trees with *dbh* > 6.0 cm. In the first quarter of the 100 m^2 plot, i.e. on 25 m^2 area, naturally growing saplings, shoots over 2.0 cm in diameter at 1.3 m height as well as all planted trees, regardless of their dimensions, are measured and mapped. Undergrowth and underbrush are recorded in a 3 × 20-m strip plot allocated within the main plot. At a distance of 20 m from the plot center, two angle count plots with basal area factor K = 2 are established. The data from this inventory are used to determine stand species composition, age and increment according to primary measurement data.

Permanent plot clusters are square with 250-m long edges orientated in the north–south and east–west directions and include four sample plots. Temporary plot clusters are square with 500-m long edges and also include four sample plots (Fig. 22.2). In the centre of each side of each cluster, a stump plot is also established.

Analyses are based on combining data from repeated measurements of permanent plots and measurements of temporary plots and data from assessment using satellite image maps and aerial photos (Kuliešis 1999a).

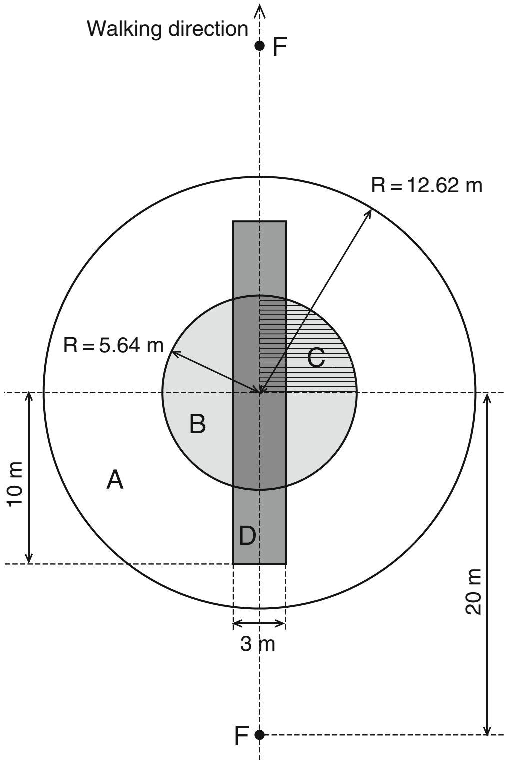

Fig. 22.3 Construction of the main sample plot: A, B – circular plots, C quarter of a circular plot, respectively 500, 100, and 25 m^2 in size, D – 60 m^2 strip and F – angle count plots

22.4.2 Management, Personnel, Measurement Techniques, Quality Assurance

The State Forest Survey Service is responsible for conducting timely inventories using current technology as described in fieldwork instructions and in statistical publications that report results. Forest measurements are done by three fieldwork crews, two in different regions (Fig. 22.4) for permanent plots and one for temporary plots. Each year one-fifth of all permanent plots in the country are assessed. The time between successive plot measurements should not exceed 5 years ±20 days. A group of five to six specialists plan the inventories; manage, process, and analyze the data; develop programs and prepare statistical reports.

Field teams use global positioning system (GPS) Pro XRS receivers, measurement tapes and compasses for plot location and re-location. Ultra sound distance measures "Forestor" are used for circular plots, and angle count devices with basal area factor K = 2 are used for angle count plot. Digital calipers "Mantax Digitech" automatically transmit data to Tablet PC "GoBook" (Itronix) field data recorders. Field computers, using logical checks do primary data quality control. For height measurement field teams use "Haglöf" instruments.

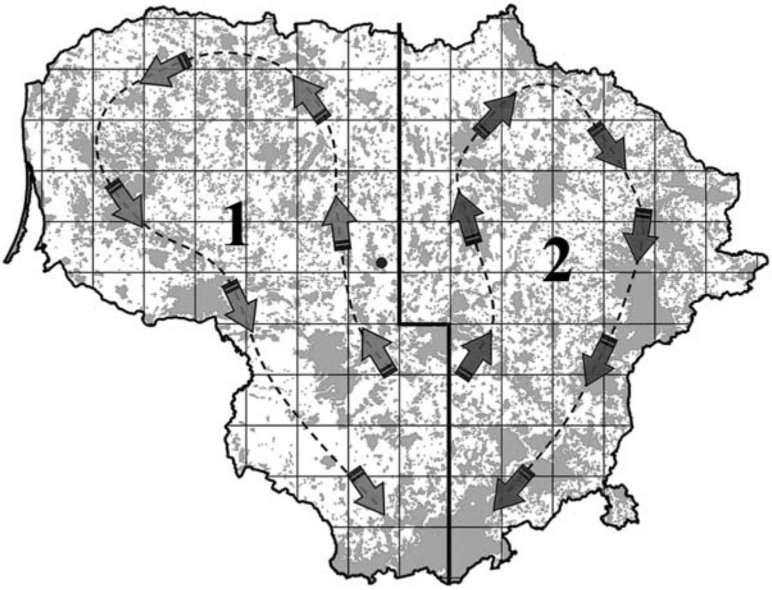

Fig. 22.4 Scheme of Lithuanian NFI inventory regions and the sequence of field measurements

Data are delivered to the State Forest Survey Service every week, where quality control data checks are performed using PC and manual procedures. The final quality check is done after the field season but before the data processing. Members of the quality control group regularly check measurements for permanent and temporary sample plots. Not less than 5% of all sample plots are checked. Quality control results are used to estimate the quality of work done and the competence of employees, to improve the methodology of measurement, and to correct major mistakes. Data quality control for the Lithuanian NFI includes assessment data reliability, accuracy and objectivity. The data quality control system includes:

- Documentation of field and data processing methods, models and algorithms (Kuliešis et al. 2003)
- Statute of Lithuanian NFI, approved in 2004 by Ministry of Environment (2004)
- Field manuals (Lithuanian) for the years 1998, 1999, 2000, 2004
- Grid of temporary plots (one third from permanent) for regular, annual measurement
- Training and control of field teams
- Statistical checks (logic, relationship between various inventory data) of every measurement
- Audit of the NFI by the Ministry of Environment.

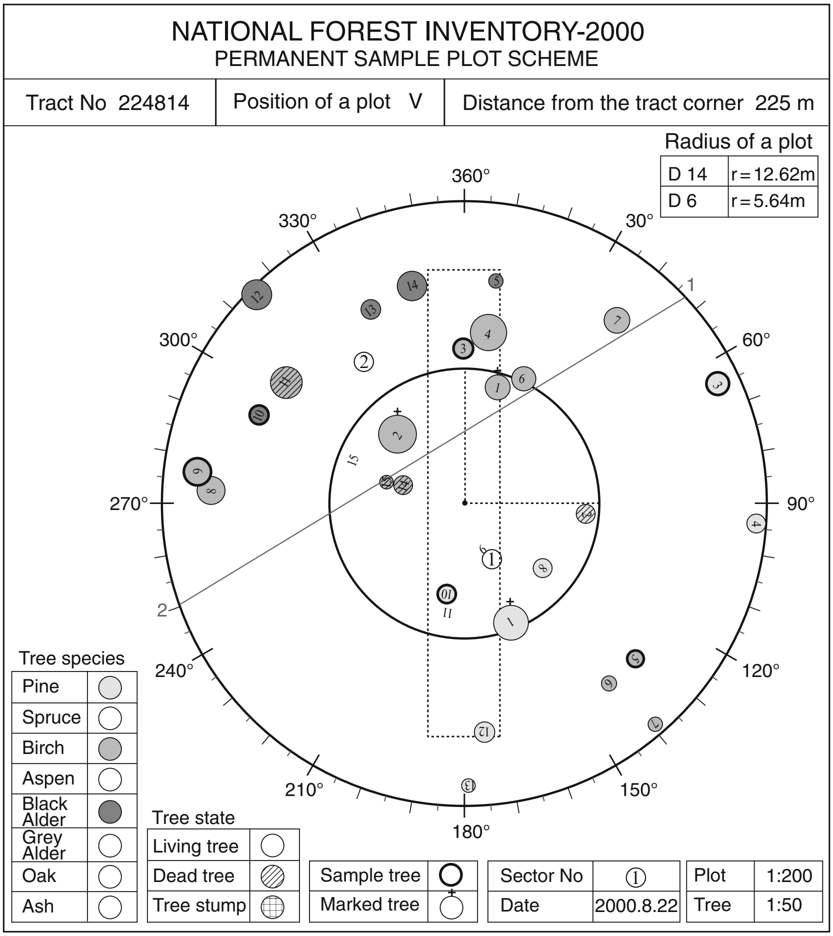

Fig. 22.5 Plan of tree location in a permanent plot

22.4.3 *Field Operations*

An ordinary work routine is carried out for detection of centers of sample plots and their location. Orthophoto maps, forest maps and GPS receivers are used to identify plot centers. Within a sample plot the usual measurements are carried out: mapping of trees (Fig. 22.5), callipering of trees and stumps, measurement of sample trees height and crown length, tree increment, defoliation and damages, description of soil, site and stand, inventory of understorey, regeneration and underbrush, inventory of cuttings for the previous 5 years, plantations up to 10 years, and assessment of a wide-range of other parameters. Sample plots occurring on the boundaries of several forest compartments or different land use categories are divided into smaller

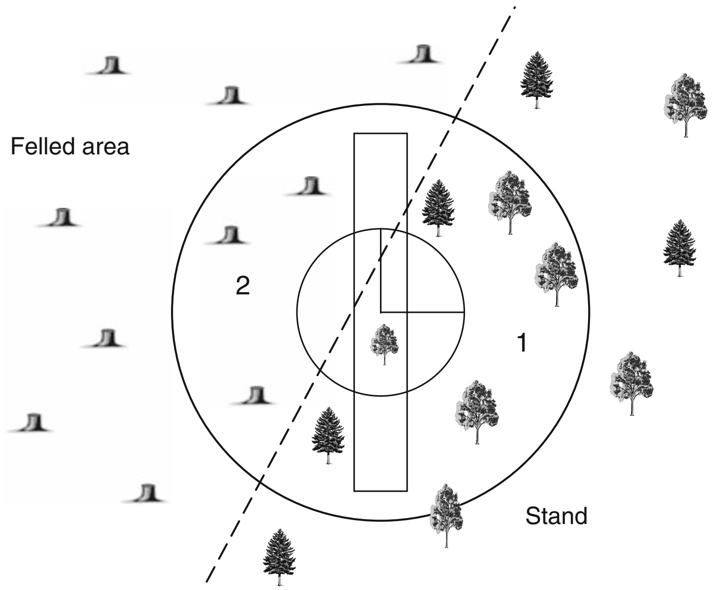

Fig. 22.6 Diagram of plot division into sectors (cutting area, stand)

units, i.e. sectors (Fig. 22.6). Each sector is described separately, with trees being measured in a separate sampling unit.

Using data from measured sample plots, the most important quantities are estimated: volume of growing stock and its increment, mortality and allowable cut. The observation cycle of a permanent plot ceases when the stand containing the plot is felled. In the same place a new observation cycle of forest regeneration and its further growth is started.

22.4.4 Production of Forest Statistics

The NFI supplies the data necessary for preparation of various forest statistical reports and for forest management. Estimation of current forest statistics is based on a combination of data obtained for the 5-year inventory period from remeasured permanent plots, temporary plots measured for the first time, and stump plots (Fig. 22.7). Evaluations of change on permanent plots permits efficient forest management, estimation of biodiversity changes, and estimation of land use changes (Fig. 22.7). Estimates of a large number of quantities required for various NFI users are based on a combination of plant measurements from plots and aerial plot assessments (Table 22.4).

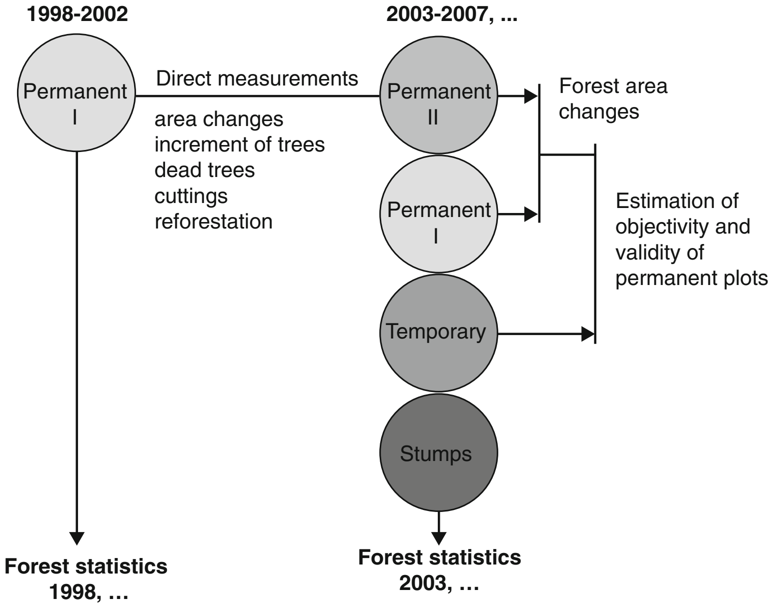

Fig. 22.7 Estimation of forest statistics and its changes using NFI sample plots

Table 22.4 NFI data structure

NFI data structure		
Dimensions of plants	State of plants	Aerial characteristics
Trees	Species	Ownership
Diameter 1,3 m	Storey	Land use category
0,0 m	Growing	Protective status (forest group, subgroup)
Height	Dead	
Length of crown	Cut	Administrative regions
Age	Quality class	Site type
Volume $V=f(D,H,F_{DH})$	Damages	Forest type
Increment $Z_V=f(V_A,V_{A-n})$	- type	Age class
Understorey	- cause	Site index H_{AB}
Height	- position	D_{AB}
Age	- intensity	Stocking level
Underbrush	Defoliation	Species composition
Height		

Estimates and their accuracy for the following variables are calculated for all Lithuanian forests by ownership categories, counties, site types and other administrative divisions:

- Area of a specified land class
- Area distribution by land category, tree species, age, stocking level, site type

- Tree species composition by area and growing stock volume
- Growing stock volume classified by tree species and diameter
- Current increment classified by tree species and diameter
- Area of cuttings and its distribution by kinds of cuttings
- Volume of removed trees classified by tree species and diameter
- Volume of dead, windthrown and windbroken trees classified by tree species and diameter
- Growing stock volume increment balance and its classified by tree species and diameter
- Extent of tree damages, their causes and intensity
- Abundance of understorey and natural regeneration, their structure and damages
- Abundance of underbrush and damages
- Resources of mature stands and potential final forest use
- Characteristics of Lithuanian forests by counties

Sampling conducted by the NFI is considered objective in the sense that instrumental methods are assumed to be reliable and of known precision. Thus, the data collected over the course of NFI form the basis for objective Lithuanian forest estimates which can be used to assess the validity of data obtained by other methods.

22.4.5 The General Characteristics of NFI Not Previously Noted

- Number of permanent plots: 5,737 for the previous 5-year cycle with approximately 1,150 measured annually, temporary plots – approximately 380 measured annually (Kuliešis et al. 2009)
- Permanent plots – with mapping of trees (tree position is recorded with distance from plot center to tree center and azimuth)
- Temporary plots – without mapping of trees
- Delineation of circular plots into sector by forest type, age, forest site, ownership, administrative unit
- Two angle count plots per each circular plot for estimation of age and increment of trees during establishment of permanent plots
- Number of trees per circular plot: approximately 30
- Number of trees per angle count plot: approximately15
- Number of sample trees approximately 7–12 in every plot
- Forest regeneration: on strip plots 3 m × 20 m size species, state of plants, height, number, damages
- Dead trees – standing and lying on every circle plot
- Forest type: development stage, vertical structure, species composition, stocking level, silvicultural treatment
- Forest site type and soil: indicators of forest site type, main characteristics of soil up to 1.2 m deep

- Protective functions of stand
- Damages of trees: type, source, position, intensity

22.5 Estimation Techniques

22.5.1 Area Estimation

Estimation of the total forest land area using data from annual plot measurements for a certain number of years.

$$Q_m = Q \cdot p_m, \tag{22.1}$$

or

$$Q_m = K_m \cdot q_R, \tag{22.2}$$

$$Q_m = \frac{q_m \cdot q_R}{500}; \tag{22.3}$$

where: Q – total area of Lithuanian territory, 6,530,000 ha

Q_m – forest land area, ha

p_m – part of forest land area

q_R – area, represented by one plot according to I year measurement data is equal to 2,000 ha, II – 1,000 ha, III – $666^{2/3}$ ha, IV – 500 ha, V – 400 ha. During remeasurements, together with temporary plots VI – 375 ha, VII – $352^{16/17}$ ha, VIII – $333^{1/3}$ ha, IX – $315^{15/19}$ ha, X – 300 ha

q_m – area of all plots and sectors on forest land, m^2

$$p_m = \frac{K_m}{K}; \tag{22.4}$$

K_m – sum of plots or their parts on forest land, estimated during inventory

K – total number of plots in Lithuania

$$K = \frac{Q}{q_R}; \tag{22.5}$$

The error P_{Qm} of forest land assessment, in percent

$$P_{Q_m} = \sqrt{\frac{1 - p_m}{(K - 1)p_m}} \cdot 100; \tag{22.6}$$

where: p_m, and K are as in formula (22.4)

22.5.2 Growing Stock Volume Estimation

Detailed algorithms for the estimation of all stand characteristics in a sample plot are given in a series of publications by Kuliešis (1985, 1989, 1993). Only techniques and algorithms for the most important parameters related to growing stock volume and increment are provided here. Estimation of growing stock volume and increment during remeasurements is based on tree-level observations and measurements.

For each tree in a sample plot, tree species, storey, and condition are observed and diameters at 1.3 m height are measured. For sample trees, which average 3–5 trees of dominant species and not less than 1–2 trees of other species, storeys, heights and butt diameters are measured. Using sample tree measurement data and regression or standard models of tree height based on diameter, the heights of all trees are estimated. Generally, tree heights and the corresponding storey and species are measured for at least five trees per plot, and the heights of remaining trees are estimated using the model,

$$h_{ij} = \bar{H}_i \cdot R_{ij}; \tag{22.7}$$

where: $\bar{H}_i$ – mean height of trees of i species on the analysed storey of a sample plot.

$$\bar{H}_i = \frac{\bar{H}_{ai}}{R_{ij}}; \tag{22.8}$$

$\bar{H}_{ai}$ – mean height of sample trees of i species
R_{ij} – reductional height value obtained from the dependence model of relative tree height on relative diameter

$$\bar{H}_{ai} = \frac{\sum_{j=1}^{k_{ai}} h_{aij} \cdot d_{aij}^2}{\sum_{j=1}^{k_{ai}} d_{aij}^2}; \tag{22.9}$$

h_{aij}, d_{aij} – height (m) and diameter (cm) of sample trees, respectively
k_{ai} – number of sample trees of i species in a plot (Kuliešis 1993)

$$R_{ij} = f(d_{ij}, \bar{D}_i); \tag{22.10}$$

d_{ij} – diameter of j tree at 1.3 m height, cm for i tree species
$\bar{D}_i$ – mean diameter of i species trees in a plot

$$\bar{D}_i = \sqrt{\frac{\sum_{j=1}^{k_i} d_{ij}^2}{k_i}}; \tag{22.11}$$

k_i – number of i species trees in a plot

Tree volume from the root collar to the stem top in a plot is estimated as,

$$V_{ij} = \frac{\pi d_{ij}^2}{4 \cdot 10{,}000} \cdot h_{ij} \cdot F_{h_{ij}d_{ij}}; \tag{22.12}$$

where: d_{ij} – measured diameter of *j* tree of *i* species at 1.3 m height, cm
h_{ij}– height of the same tree estimated by (22.7) formula, m
$F_{h_{ij}d_{ij}}$ – form factor of a tree, derived from its dependence on tree height and diameter (Kuliešis 1993).

The growing stock volume of stand storey, tree species or trees of a corresponding state is ascertained by summarizing the volume of trees having corresponding features.

22.5.3 Increment Estimation

Periodic increment is defined for each tree as the difference between tree volumes for successive measurements:

$$Z_{Vij} = V_{Aij} - V_{A-nij}; \tag{22.13}$$

where: Z_{Vij} – volume increment of *j* tree of *i* species per n years
V_{Aij} – volume of *j* tree of *i* species during measurement
$V_{A\text{-}nij}$ – volume of *j* tree of *i* species n years ago

With repeated measurements on permanent sample plots, annual stem volume increment is estimated directly using (22.13) formula. Periodic increment of felled or dead trees in the period between inventories is estimated as half the increment of trees of similar diameter and height for the same period.

For the first measurement of permanent plots or measurements of temporary plots, tree volume *n* years ago, $V_{A\text{-}nij}$, was estimated as,

$$V_{A-nij} = \frac{\pi \cdot d_{A-nij}^2}{4 \cdot 10{,}000} \cdot h_{A-nij} \cdot F_{hd_{A-nij}}; \tag{22.14}$$

where:$d_{A\text{-}nij}$ – diameter of *j* tree of *i* species *n* years ago, cm

$$d_{A-nij} = d_{Aij}^{*} - Z_{Dij}; \tag{22.15}$$

d_{Aij} – diameter of *j* tree of *i* species during measurement, cm
Z_{Dij} – diameter increment of *j* tree of *i* species, cm
$F_{hd_{A-nij}}$ – form factor of *j* tree of *i* species n years ago

* Tree diameter at present d_{Aij} is “debarked” using models for the dependence of bark thickness on diameter overbark, while later the diameter $d_{A\text{-}nij}$ is “overbarked”

using the functions of bark thickness dependence on diameter underbark (Kuliešis 1985).

$$Z_{Dij} = {}^{Z_{rij}}\!/_{5}\,; \tag{22.16}$$

where: Z_{rij} – radial increment of j tree of i species, mm, measured on sample cores. As far as sample cores are taken only from sample trees, then radial increment for each tree is obtained by regression functions

$$Z_{rij} = a + b \cdot d_{Aij}; \tag{22.17}$$

where: a, b regression coefficients. Having measured ten or more sample trees, coefficients a, b are found by the least squares method.

In other cases

$$a = (1 - b_r) \cdot \bar{Z}_{ri}, \tag{22.18}$$

$$b = b_r \cdot \frac{\bar{Z}_{ri}}{\bar{D}_i}; \tag{22.19}$$

where: b_r – coefficient, changed depending on tree species within 0.45–0.90 range, found as default value (Kuliešis 1985)
$\bar{D}_i$ – mean diameter of i tree species, obtained by formula (22.11)
$\bar{Z}_{ri}$ – mean radial increment of i tree species in a plot

$$\bar{Z}_{ri} = \frac{\bar{Z}_{rai}}{1 - \left[b_r \cdot \left(1 - \frac{\bar{D}_{ai}}{\bar{D}_i}\right)\right]}; \tag{22.20}$$

where: $\bar{Z}_{rai}$ – mean radial increment of sample trees of i species

$$\bar{Z}_{rai} = \frac{\sum_{j=1}^{k_{ai}} Z_{raij}}{k_{ai}}; \qquad 22.21)$$

Z_{raij} – radial increment of j sample tree of i species in a sample plot
$\bar{D}_{ai}$ – mean diameter of sample trees of i species obtained analogically to Eq. (22.11) formula
k_{ai} – number of sample trees of i species in a plot

Trees on permanent plots are not bored. Volume increment during the first measurement is estimated by integrating diameters measured in the permanent sample plot with diameters and radial increment of sample trees measured in the same stand, but in the angle count plots, established outside the permanent sample plot.

Tree height n years ago

$$h_{A-nij} = h_{Aij} - Zh_{Aij}; \tag{22.22}$$

where: h_{Aij} – height of j tree of i species at present, estimated by formula (22.7)
Zh_{Aij} – height increment of j tree of i species, m

$$Zh_{Aij} = \frac{\bar{Z}h_{Ai} \cdot h_{Aij}}{\bar{H}_{Ai}}; \tag{22.23}$$

$\bar{Z}h_{Ai}$ – mean increment of i species trees over n years

$$\bar{Z}h_{Ai} = \frac{\bar{H}_{Ai} - \bar{H}_{A-ni}}{C}; \tag{22.24}$$

$\bar{H}_{Ai}$ – mean height of i species trees at present estimated by formula (22.8)
$\bar{H}_{A-ni}$ – mean height of i species trees n years ago

$$\bar{H}_{A-ni} = f(H_{ABi,A-ni}); \tag{22.25}$$

H_{ABi} – site index, estimated by mean height of i species trees, their present age and a corresponding model (Kuliešis 1993)

A-ni – age of i species trees in a plot n years ago

C – correction coefficient, estimating the difference between mean height changes of trees and height increment due to a mortality of trees less than average ($C \cong 1.12$).

Form factor of a tree n years ago ($F_{hd_{A-nij}}$) is found using tree height and diameter n years ago and is based on a corresponding model (Kuliešis 1993).

Annual increment of a stand storey, tree species and trees of a corresponding state is estimated by summarizing volume increments of trees characterized by respective features and dividing by number of year of remeasurements period.

22.5.4 Increment Structure

Using data for repeated measurements, increment balance for every permanent sample plot is estimated as,

$$Z_M = \Delta_M + M_K + M_O; \tag{22.26}$$

where: Δ_M – volume change, i.e. volume change (during the period between inventories) of trees which comprised the stand n years ago and remained until repeated inventory. Volume change accounts ingrown trees or trees that changed the storey,

M_K – volume of trees felled by intermediate fellings
M_O – volume of dead trees

$$M_O = M_{OK} + M_{O\check{S}} \tag{22.27}$$

M_{OK} – volume of remaining dead trees that will possibly be used in the future
$M_{O\check{S}}$ – volume of dead and salvaged trees in the period between inventories

22.5.5 *Estimation of Stand Parameters and Their Variance per Area Unit*

For the estimation of stand parameters on a per hectare basis, ratio estimators (Cochran 1963; Kuliešis 1994) or simple expansion methods (Shiver and Borders 1996) are used. These methods are nearly identical when sample plots are of equal areas. For the NFI sampling design, the main sample plot is 500 m^2 in area, but more than one third of sample plots are divided into sectors. Because the sectors are of varying areas, assessments of their mean values and their variances must be taken into account. For this purpose, the method of weighting mean (Cochran 1963; Гмурман 1972) has been modified, taking into respect the peculiarities of NFI sampling design. In many cases, variance estimation using this method was considerably more efficient than assessment by earlier mentioned methods (Kasperavičius and Kuliešis 2002). The method was used to estimate growing stock volume and other characteristics (increment, number of trees, basal area) on a per unit area basis as well as their variances.

Stand parameters on a per hectare basis, using a modified NFI method, are estimated by the formula:

$$\bar{Y} = \frac{\sum_{i=1}^{n} Y_i \cdot p_i}{\sum_{i=1}^{n} p_i}, \tag{22.28}$$

while the variance in total,

$$\sigma^2_{\hat{Y}} = \frac{\sum_{i=1}^{n} (Y_i - \bar{Y})^2 \cdot p_i}{\sum_{i=1}^{n} p_i}; \tag{22.29}$$

where: Y_i – stand parameter value per 1 ha according to i sampling unit

$$Y_i = \frac{y_i}{x_i}; \tag{22.30}$$

y_i – parameter value in i sampling unit
x_i – area of sampling unit, m^2
$\bar{Y}$ – mean of stand parameter per 1 ha of the estimated group of stands, found out by formula (22.28)
p_i – part of sampling unit

$$p_i = \frac{x_i}{q}; \tag{22.31}$$

q – sample plot area equal to 500 m^2

The variance of the estimate of a stand parameter mean on per hectare basis is,

$$\sigma_{\bar{Y}}^2 = \frac{\sigma_{\hat{Y}}^2}{n}, \tag{22.32}$$

and the standard error of the estimates of means in absolute values is,

$$\sigma_{\bar{Y}} = \sqrt{\sigma_{\bar{Y}}^2}, \tag{22.33}$$

and as a percentage is,

$$P_{\bar{Y}} = \frac{\sigma_{\bar{Y}}}{\bar{Y}} \cdot 100; \tag{22.34}$$

$\sigma_{\hat{Y}}^2$– variance of stand parameter per 1 ha, ascertained by (22.29) formula
n – number of sampling units – plots, sectors

22.5.6 Estimation of Forest Characteristics in Inventory Object

The growing stock volume of trees, increment and their number for the entire area is estimated as the product of per unit area estimates of these variables and the area of the corresponding group of stands (strata)

$$\hat{Y}_i = \bar{Y}_i \cdot Q_i; \tag{22.35}$$

where $\hat{Y}_i$ – value of inventory index of i stand group
Q_i – area of i stand group, ha.

The standard error of tree volume, increment and their number on the whole area is estimated as,

$$P_{Ti} = \sqrt{P_{\bar{Y}i}^2 + P_{Qi}^2}; \tag{22.36}$$

where

$P_{\bar{Y}i}$ – error (%) of inventoried parameters of i stand group according to formula (22.34)

P_{Qi} – error (%) of area estimated of i stand group by formula (22.6)

The increment balance of the stand group or stratum is estimated by combining the volumes of all plots represented in this group including the volumes of these trees that were clear cut in the period between inventories. Volume change (Δ_M) in formula 22.26 is divided into two parts – accumulated in the stand (Δ_{M1}) and used (Δ_{M2}) by final cuttings.

22.6 Options for Estimates Based on Reference Definitions

Table 22.5 presents a brief summary of the status of harmonization in Lithuanian NFI. Although some national definitions deviate from COST Action E43 definitions, the estimates can be converted to correspond to the reference definition estimates.

22.7 Current and Future Prospects

Along with operational NFI work, research is continuously carried out to improve the NFI. The main improvements in the NFI are expansion of the assessment indices, increases in assessment accuracy and reliability of indices, a decrease in labor by expanding the use of remote sensing methods, analysis of forest resource dynamics, modeling and improvement of inventory standards, simulating stand growth and formation depending on many factors.

In the near future, inventories of mature stands on large territories using sampling methods are anticipated. Starting in 2008, more attention will be given to

Table 22.5 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Estimate	ND	RD	Responsible
Forest area	Yes	Yes	NFI
Growing stock volume	Yes	Yes	NFI
Increment of growing stock volume	Yes	Yes	NFI
Above- and below-ground biomass	Yes	Yes	NFI, models
Dead wood	Yes	Yes	NFI
Litter	Yes	Yes	NFI, models
Soil	Yes	Yes	NFI, statistics
Afforestation, deforestation, reforestation (Kyoto 3.3)	Yes	Yes	NFI
Naturalness of forest	Yes	Yes	NFI
Forest type	Yes	No	NFI
Occurrence and abundance of vegetation species	Yes	Yes	NFI

inventories of dead wood and wood residuals on cutting areas. The decay stages of dead trees will be assessed up to complete decomposition of wood.

Further modernization of the sampling design is planned so that the data can be used for scenario modeling of forest dynamics, studies to estimate the extent of thinning and other intermediate cuttings, and to guide decisions regarding optimal stand formation. The NFI sampling design will remain unchanged for NFI3 (2008–2012) relative to the design for NFI2 (2003–2007). The second remeasurement of permanent plots is anticipated with the establishment and measurement of the same number of temporary plots as in previous years. The main forest characteristics for the entire country will be estimated annually.

In 2008, the initial assessment of dead wood stages and assessment of stem wood pieces left in felled areas is anticipated. Dead wood will be assessed by the NFI in five decay classes based on newly developed techniques. Assessment of stem wood pieces left on felled areas was already started on an experimental basis in the NFI of 2007. After the improvement of assessment techniques, it will be implemented on whole scale.

Integration of the NFI and Forest Health Monitoring (FHM) Level I measurements will also be started in NFI3. The national network of FHM plots will be moved to coincide with the NFI network, but the existing European grid of FHM plots will be left unchanged for a minimum for 5 years. Therefore, assessment of defoliation of broadleaves will be started on NFI plots during June–August.

A NFI project currently underway is the development of an information system for state control of forest ecosystems. The system includes the continuous inventory program, implementation of silvicultural measures, scenario models, and judicial regulatory acts.

22.8 Implementation of COST Action E43 Results

The successful COST Action E43 has resulted in a considerable improvement of existing assessment methods and development of new assessment techniques used in the Lithuanian NFI. NFI3 was started in 2008. This is the first year for integration of FHM Level I and NFI measurements. Based on results from COST Action E43, assessment of dead wood stages and stem wood pieces left on felled areas was initiated. Dead wood is assessed in five decay classes using new techniques. In the context of COST Action E43, volumes of stumps, tree tops and small diameter trees were estimated which led to improved NFI algorithms and more accurate estimates of growing stock volume. NFI algorithms for international reporting were also developed as a result of COST Action E43.

Harmonization of NFI definitions was very important in the design of new assessment techniques for NFI3 (2008–2012). Most harmonized NFI definitions do not differ considerably from Lithuanian laws, especially Forest law – they broaden our understanding and can be considered during NFI assessments and international reporting. Therefore no legal changes were made.

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Chapter 23
Luxembourg

Jacques Rondeux and Marc Wagner

23.1 Development of the National Forest Inventory in Luxembourg

A permanent national forest inventory (NFI) was established in Luxembourg in 1999 and is conducted as a responsibility of the Luxembourg forestry commission ("Administration des Eaux et Forêts"). The survey methodology was developed in close cooperation with the University of Liège – Gembloux Agro-Bio Tech and, as a result, closely resembles the Walloon forest inventory (see Country report for Belgium). Luxembourg includes 90.05 ha of forest land of which 85.05 ha are classified as productive.

The NFI was planned and organized to reflect the multifunctional manner in which forests in Luxembourg are managed. The objectives are to provide information that not only relates to growing stock and its development over time, but to support development of a database that is flexible enough to accommodate varying quantities of information about forest types, biodiversity, recreation and other functions generally assigned to forest in a small country (Rondeux et al. 2003).

Luxembourg is characterized by scattered forest areas. Before 1998, the country used a full census (public forests) at the scale of forest compartments mainly to provide information on the types of stands, structures and volumes per hectare. In addition to traditional ground measurements, satellite imagery and digital maps were used to produce estimates for small areas and various thematic maps.

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23.2 The Use and Users of the Results

23.2.1 General Use

Users of NFI data include the forest service, forest authorities in charge of the forest policy, and government departments involved in the management of natural resources. The permanent NFI is becoming an important source of information for reporting to international organizations such as: Food and Agriculture Organization (FAO) of the United Nations (UN), Forest Resource Assessments (FRA 2000, 2005), the Ministerial Conferences on the Protection of Forests in Europe (MCPFE) and the United Nations Framework Convention on Climate Change (UNFCCC).

23.2.2 The Role of NFI in Assessing the Status of Biodiversity

To take biodiversity into account, the NFI includes a set of variables such as: stand structure, deadwood, tree and understorey species, key biotopes (trees and edges), specific composition of stands and open areas, regeneration and soil description. To collect all those attributes different plot sizes are used (see Section 23.4). The survey mainly concerns (Rondeux et al. 2005b):

- The volume of standing and lying deadwood by decay classes and species groups (the lying deadwood is measured inside the plot with radius of 9 m and it concerns all pieces of wood which have at least 1 m length and a minimum small end diameter of 7 cm)
- The stand structure (number of layers, plant species composition according to height classes)
- The location of key biotopes at local and landscape levels
- The forest edge (transition zone between the forest and the open land): description of type, width of herb belt, shrub belt and shelter belt, density and shape, species, biological quality through indices). That zone is observed in the cases where the plot with radius of 18 m intercepts an open land, two transects of 25 m are then observed on both sides from the interception point. As concerns the interfaces two transects of 20 m length are also defined from the interception point and two plots of radius 10 m are installed at their ends (all the species present are identified)
- The occurrence and the volume of keystone tree individuals such as veteran trees, trees with small cavities (birds)
- The soil description in the field and samples of soil for analysis in laboratory (inside the circle with 4.5 m radius)
- The regeneration (cover percentage of individuals by species and stage of development in plots presented in Section 23.4.1)

Table 23.1a Basic area estimates for the years 1998–2000

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Forest land	90.1	34.8	Ten percent crown cover with minimum height of trees of 5 m and at least 0.10 ha	–
Other wooded land	3.3	1.28		–
NFI coverage	All land including forest (so named in land use)			
Productive forest land	85.0	32.9	Comprising growing stock	–
Non-productive forest land	5.1	2.0	Roads, mud, moors, pools, clear cuttings	–
Total area	258.6	100		–

[a]Standard error.

Table 23.1b Basic volume estimates for the years 1998–2000

Quantity	Estimate	Description	SE[a]
Volume of growing stock, total (productive forest) 1,000 m^3	23,315	Stem volume to an upper girth limit of 22 cm	–
Volume of growing stock per hectare (productive forest) m^3/ha	274.3		
Volume of dead wood (DW) (productive forest) 1,000 m^3		For lying DW	–
- Standing	360	Minimum length 1 m	
- Lying	850	Minimum diameter 7 cm	
NFI is main information source for the following carbon pool changes:		Above-ground biomass, below-ground biomass and dead wood	

[a]Standard error.

- A phytosociological *relevé* concerning all ligneous and semi-ligneous species (plot with radius of 18 m) in terms of abundance (cover percentage)
- The health conditions and types of silviculture which are described inside a an “observation zone” with a radius of 30 m

23.3 Current Estimates

Tables 23.1a and b show the main variables used in the NFI. The definition of forest land is based on UNECE/FAO recommendations (UNECE/FAO 2000) wooded land which comprises at least 0.1 ha and include trees with a forest canopy of at least 10% (minimum height of trees of 5 m at maturity). Other types of land cover such as scrublands, muddy areas, open areas, and wooded zones with trees having a height of less than 5 m and a crown cover of less than 10% are also registered (Rondeux et al. 2005a).

23.4 Sampling Design

Sample plots are located at the intersections of a rectangular 1,000 × 500-m grid across the country. Approximately 1,800 permanent plots were established during 1999–2001 and will be remeasured during 2008–2010 so that national estimates will correspond to reference years 2000 and 2009 with no correction for time differences within 3-year measurement intervals. The sampling intensity is 0.2%.

Aerial photographs at the scale 1:20,000 dating 1994 were used to prepare field assessments and to classify the sampling points (e.g. forest, road, open area, etc.).

23.4.1 Sample Plots

The main sampling plot consists of four concentric circular plots (see Fig. 23.1) with radii varying from 2 to 18 m (0.125–10.0 acres). Living and dead standing trees with diameters (*d*) of at least 7 cm are measured on the three main concentric plots as follows:

- Trees with $d \geq 40$ cm are measured on plots with radii of 18 m
- Trees with 20 cm $\leq d <$ 40 cm are measured on plots with radii of 9 m
- Trees with 7 cm $\leq d <$ 20 cm are measured on plots with radii of 4.5 m

Five small plots of radius of 1 m are also established: the first is established at the plot centre and distances of 5 m from plot centre in the cardinal directions. These plots are used for measuring regeneration variables including cover percentage, height of saplings (taller than 0.3 m and diameter at 1.3 m < 7 cm), and number of individuals grouped by species.

A circular plot of radius of 30 m is used to obtain information on forest stand structure, health conditions, main forest functions (water protection, recreation, biodiversity), and for assessing sustainable management.

A sample plot of radius of 9 m is used to measure lying dead wood.

Edges and transition zones are observed along transects at the interception of the plot of 10 ares and the types of land uses or types of stands before shifting the plot into the dominant type (circle tangent to the intercept line).

23.4.1.1 Field Measurements

All the information dealing with this topic can be found in the country report for Belgium (Wallonia). Inside the plots, whilst soil is observed in the smallest plot, an additional ground sample is taken to the laboratory for analyses. Ground vegetation is not observed inside the plots. As in other European countries (except Belgium and especially Wallonia), tree diameter is measured at 1.3 m above the ground level.

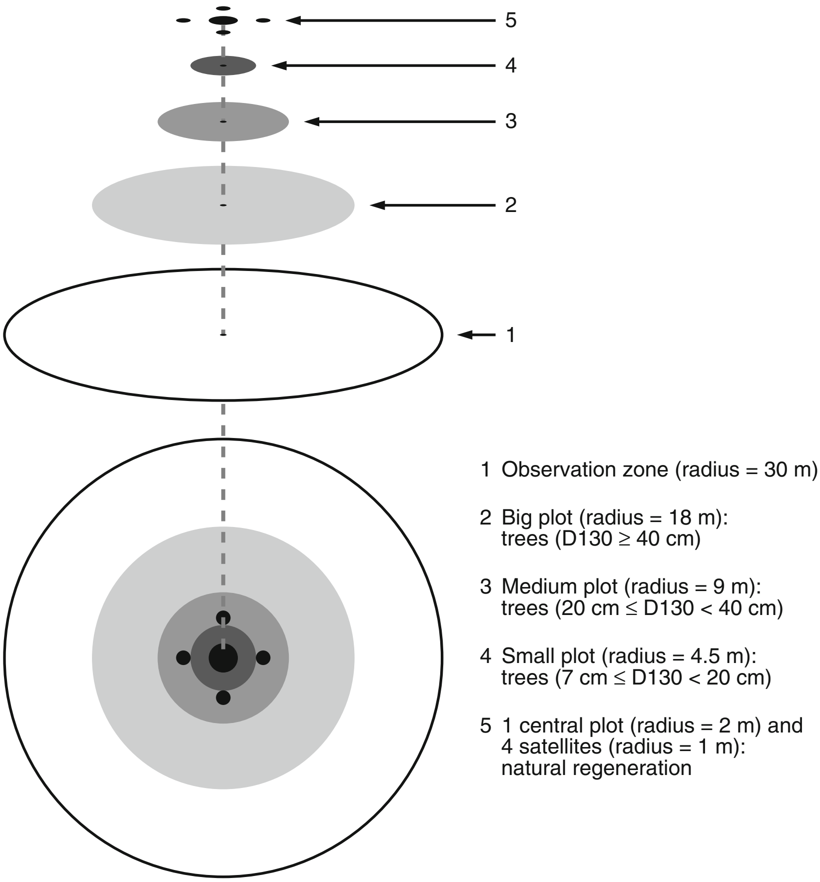

Fig. 23.1 General scheme of a sampling unit and nature of main data or information collected

23.4.2 Management

23.4.2.1 Personal and Equipment

The NFI in Luxembourg is managed and supervised by the forestry commission. The system that has been used since 1998 is based upon a permanent partnership between the national forest service (staff of two persons) and the University of Liège – Gembloux Agro-Bio Tech which acts as the scientific and technical partner for updating methodology, data processing assistance, field tests, etc. Field assessments are carried out by officers under the supervision of the forest service with the help of the university (staff of two persons). These two entities work on a contractual basis. Techniques of field measurements are the same as in the Wallonian region of Belgium (see Country Report of Belgium, this issue).

23.4.2.2 Quality Assurance

Field crews are trained each year before commencing measurements, and the forest service itself carries out control measurements on 5% of all plots distributed across the country. Computer and manual checks of data are also carried out.

23.5 Estimation Techniques

For area and volume estimation, the techniques given in the Country Report for Belgium (Wallonia) is used. Volume and taper models (Dagnelie et al. 1999) constructed for species and site conditions in the southern part of Belgium have been successfully tested in Luxembourg.

23.6 Data Processing and Analysis

Data processing for Luxembourg and Belgium (Wallonia) differ somewhat; in particular, more deliverables are expected for Luxembourg because of its greater intensity of forest management. The NFI is considered a very valuable complement to local forest inventories for purposes of verifying the extrapolation of information issued from the local inventories to larger areas.

23.7 Current and Future Prospects

Luxembourg's NFI is beginning its second cycle. This has created an opportunity to evaluate the methodology, to discuss possible simplifications or improvements and to implement an electronic system of data collecting.

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Chapter 24
The Netherlands

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24.1 Development of the Netherlands' National Forest Inventory

24.1.1 Introduction

The total Dutch forest area approximates 360,000 ha; 46% is owned by private owners and societies for nature conservation; coniferous forests dominate (60%); most forests were planted in 1940–1980; total above ground volume of living trunk wood amounts to 58.7 million cubic metre; most common tree species are *Quercus robur* L., *Pinus sylvestris* L., and *Betula pendula* Roth; most common shrubs are *Sorbus aucuparia* L., *Prunus serotina* Ehrh., and *Rhamnus frangula* Miller; most common other species are *Deschampsia flexuosa* (L.) Trin., *Rubus fruticosus* L. *s.l.*, and *Dryopteris dilatata* (Hoffman.) A. Gray.

In the Netherlands, forests occupy 10% of the land area. They are used for many purposes: economic, recreational, environmental, and biodiversity. Multifunctional use of forests is being stimulated by the Dutch government and other policy makers (Ministerie Landbouw, Natuurbeheer en Visserij 2000). Moreover, the Dutch government has the responsibility for formulating forest policies and an obligation to respond to current and foreseen international reporting requirements given by the Food and Agriculture Organization (FAO) of the United Nations, the sector of Land Use, Land-Use Change and Forestry (LULUCF) concerning the United Nations Framework Convention on Climate Change (UNFCCC), and Forest Focus. For performing these tasks a thoroughly new multifunctional forest inventory was required.

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Table 24.1 The methods employed in Dutch inventories

NFI	Period	Remarks to methods applied
1	1938/1942	Area census of forest and nature areas. Map 1:25,000 Forest definition according to topographical map, no thresholds
2	1952/1963	Area census of forest and nature areas. Map 1:25,000 Forest area definition: area >0.5 ha and crown coverage >60% Volume estimates based on volume-tables
3	1964/1968	Area census of forest and nature areas. Map 1:25,000 Forest area definition: area >0.5 ha and crown coverage >60% No volume estimates
4	1980/1985	Area census of forest (no nature area). Map 1:10,000 Forest area definition: area >0.5 ha and crown coverage >20% and width >20 m Volume estimates on plots in a stratified random sample (approximately one permanent plot /100 ha)
HOSP	1988/1999	Remeasuring permanent plots from the NFI4 in a 5 year-cycle Estimates of volume/increment/removals
5	2001/2005	GIS-based forest area (no nature areas) Map 1:10,000 Forest area definition according to FAO(2004) Volume estimates and vegetation description based on an unaligned systematic sampling design with one plot/100 ha; 50% permanent and 50% temporary plots No increment and removals/harvest estimates yet but will be performed in the next NFI-cycle (2010–)

Until 2001, national forest inventories (NFI) in the Netherlands were carried out four times (Centraal Bureau voor de Statistiek 1985; Dirkse 1998), all with government funding. The fourth forest inventory (NFI4) was finished in 1985. The data from this inventory became outdated and in 1998 the need for a new forest inventory was felt. However, by then, a NFI was supposed to deliver not just data on wood stock and harvest, but on land use, environmental quality, and biodiversity as well. Mainly for reasons of efficiency, a NFI was expected to become a multifunctional resource inventory. Consequently, the collected data should equally meet the information needs of policy makers and other interest groups. Since some information is only needed temporarily, the forest inventories were to allow for replacing variables according to these changes of interest. Other conditions to be met were simplicity of design and geographic information system (GIS) compatibility.

24.1.2 History of National Forest Inventories in the Netherlands

The history of NFIs in the Netherlands goes back to 1938 (Table 24.1). Until now, five NFI's have been carried out. Only the last NFI, which is called Meetnet Functievervulling (MFV) in the Netherlands, has been designed as a continuous forest inventory. A project HOSP (1988–1999) is additionally mentioned (Schoonderwoerd en Daamen 1999) because of the great value of this project for estimating increment and removals/harvest and constructing increment models. Note also that since 1968 the NFI has been restricted to forest area only; natural areas other than forest have not been included in the NFI since that year.

The new Dutch forest monitoring network is a policy-guided, multiple-use, GIS-oriented forest monitoring network. It is designed to provide the Dutch government, on a cyclic 10-year basis, with actual information about Dutch forests. Variables that reflect the information needs of policy makers and interest groups were selected by means of interviews and workshops. High-ranking variables are: wood stocks, ownership, stand age, management status, biodiversity, carbon stock, and recreational use. These and other variables are being measured on 3,622 forest sites, selected according to an unaligned systematic sampling design. The data are stored in an ORACLE data base, made accessible by Internet.

24.2 Sampling Design of NFI5

A digital forest map is constructed, indicating approximately 360,000 ha of forest in the Netherlands (Dirkse et al. 2001). A 1 × 1-km grid is laid over the forest map, and in each grid cell an X,Y-co-ordinate pair is randomly drawn and serves as a plot centre. Points falling within forest area become part of the NFI-sample and are visited in the field; 50% of the sample points are permanent, 50% are temporary. In total 3,622 points in the NFI were within forest area and visited.

Forest area is understood as a selection from digital topographical map 1:10,000 (Kadaster 2009), where forest area is >0.5 ha, width >20 m and crown coverage >10%. In natural growth conditions a tree height of 5 m should be reached. For clear-cut area and young plantation no thresholds are applied. The selection is considered as forest area according to the forest definition of FAO (2004).

The plot centre is given by the X,Y coordinates according to the Dutch standard (Rijksdriehoek-stelsel). Only plots with centres in forest area according to the forest map are visited in the field.

During assessment, different sizes of plots are established. For description of vegetation a plot of 300 m^2 around the plot centre is used for collecting occurrence and abundance of vegetation. Trees are measured and recorded on a circular plot around the plot centre with a radius that includes at least 20 trees. The radius is rounded upwards to whole metres with a minimum of 5 m and a maximum of 20 m. All trees within the plot defined by the rounded radius are measured. A consequence is that often more than 20 trees are measured. For the decision as to which tree must be measured in the NFI the following tree definition has to be applied: every standing, lying or hanging, dead or alive individual of a tree species from the *list of tree species*, with a diameter of at least 5 cm at a height of 1.3 m above the stump. Dead and lying trees are treated and counted as 'normal' trees.

In the follow-up NFI6, the procedure will be repeated; a new forest map will be constructed, and in the grid cells with temporary coordinates, new coordinates will be drawn. The points falling within forest area will be the next NFI-sample and visited.

This sampling design allows:

- Estimates of total forest area and land use change matrices
- Estimates of changes in forest types, ownership, forest composition etc within the forest area
- Estimates of volume, increment, removals/harvest and changes
- Post-stratification on basis of overlays with other digital maps such as Natura 2000 areas and soil maps

24.2.1 Levels of Assessment

In forest inventories, some variables are standard, such as dominant tree species, stand age (year of germination), tree species composition, tree diameter at breast height (*dbh*), forest protection (disturbances), ownership, and species composition of tree, shrub and ground layers. Most of these variables are related to economic uses of forests. However, because forests are no longer being used for wood production only, other variables needed to be incorporated. By means of a workshop and approximately 20 interviews, policy makers were asked for additional variables related to recreational use, ecological management, and environment. Policy makers were selected to represent most groups of interest. Interviews were structured by a protocol. The additional variables were ranked, and those with the highest rankings were added to the standard variables.

There are different levels of assessment as follows:

1. Point level: the decision as to whether the plot is in forest is based on the plot centre
2. Plot level: measurements/assessment based on the plot area
3. Stand level: measurements/assessments based on the forest stand as a whole
4. Tree level: attributes or state of trees to be assessed on sample plots
5. Complex level: observations based on the forest complex, i.e. forest area surrounded by other forms of land use

As to (3) Forest stand: forest area which, according to vegetation, tree composition, forest-management, age and ownership, can be considered a unit.

As to (5) Forest complex: a forest area surrounded on all sides by other forms of land use. The single *attribute* assessed is *accessibility*, e.g. signposted routes for biking, walking or riding.

Tables 24.2a–d summarize the observations/measurements incorporated in the field assessments of NFI5 from (1), the point level, to (4), the tree level.

As already stated above, the Netherlands uses a *species li*st. However, shrub-species are not recorded, even when their *dbh* $>$ 5 cm. Broken stems are considered as lying (dead) trees. In coppice, each stem with a *dbh* $>$ 5 cm is recorded as a tree. In case of a forked tree: if the fork is below 1.3 m, then each stem with *dbh* $>$ 5 cm is recorded as a (single) tree.

Table 24.2a The attributes assessed in NFI5 (point level)

Attribute	Remarks
Forest area	Plot will be inventoried when plot centre is in forest
Ownership	Information provided by the land register
Forest development stage within forest stand	Phase in forest development cycle: bare, young, dense, poles, dense stand of trees, sparse stand of trees
Area of forest development stage	Divided in four classes of magnitude
Soil	Seven soil classes, read from an auger core: poor sand, rich sand, calcareous sand, clay, calcareous clay, peat, loam
Humus	Thickness of L, F, and H layers in upper 40 cm of sand or loam

Table 24.2b The attributes assessed in NFI5 (plot level)

Attribute	Remarks
Harvest	Clear felling, group felling, single tree felling, no felling
Disturbances	Damage to the site such as by machines, motocross, etc.
Waste	Recreational residue, heaps of agricultural or garden waste, rubbish dumps from management
Species composition	Species list of vascular plants (including trees and shrubs) and mosses, with abundances in four vegetation layers (tree-, shrub-, herb-, and moss-layer)

Table 24.2c The attributes assessed in NFI5 (stand level)

Attribute	Remarks
Forest type	Forest for timber production, natural forest, spontaneous forest, other wooded land
Year of germination	Year of germination of principal tree species
Dominant tree species	Tree species dominant by crown cover
Dominant height	Mean height of highest tree per are
Method of forest establishment	Planted or natural regeneration
Open to the public	Restricted or unrestricted opening to the public
Accessibility	By bus, car, bike or on foot
Noise	Caused by nature (wind, trees, wild animals), voices of dogs, tractors or chain saws, cars, aircraft

Table 24.2d The attributes/state assessed in NFI5 (tree level)

Attribute/state	Remarks
Tree species	According to species concepts used in Dutch forestry (species of some large genera, such as Salix, lumped into a single category)
Diameter at breast height (*dbh*)	Radial diameter over bark relative to the plot centre on 1.3 m height, in mm with digital caliper. Only trees with *dbh* of 50 mm or more are recorded
State of tree	Living or dead (standing or lying)
Tree form	Classification according to length of stem, crown depth , branches
Stem quality	Number of branches among others
Tree height	Additional measurements on the first tree of every tree species in the plot

24.2.2 Management, Personnel, Measurement Techniques, Volume Estimation

Field work was carried out by three groups of two persons with each group consisting of a forest ecologist and a botanist. The groups worked in separate regions. To locate sampling points, each group was provided with a 1:10,000 field map, a measuring tape, a compass, and a global positioning system (GPS) receiver. The locations to visit were stored in the digital calliper and indicated on the field maps.

Species lists of vascular plants (including trees and shrubs) and mosses, with abundances were recorded in a circular sample plot of 300 m^2. Abundances were recorded for each vegetation layer (tree-, shrub-, herb-, moss layer).

Trees were measured and recorded in a circular sample plot as described in Section 24.2.1. For computation of growing stock, only stem volume over bark was considered, neither branches nor roots were taken into account. The computation scheme and measures included:

- Diameter-height regressions established with observations from sample trees
- Subdivision of relations for species (groups), tree form wherever possible
- Volume estimates for each tree with volume functions (species, measured diameter, regression-height)

Field work was designed to be carried out in four years starting in 2001. Each year a quarter of the total number of forest sampling points was inventoried. Sampling points were randomly assigned to measurement years (2001, 2002, 2004, and 2005).

Data are stored in a relational data base (ORACLE) with access by Standard Query Language (SQL). The main tables are: 'Plotopnamen' (plot-level), 'Boommetingen' (tree-level), and 'Vegetatieopnamen' (species-level). These tables contain uncoded and coded information. The latter is transcribed in ancillary tables. The key variable is the unique number of the plot ('Plotnummer'). Key variables permit tables to be joined in SQL queries. Input constraints on data help maintain the integrity of the data base and prevent errors. The entire data base may be downloaded in access format by authorized users (Environment and Nature Compendium).

24.3 Options for Harmonized Reporting

Table 24.3 presents a brief summary of the status of harmonization in definitions. Note that forest is assessed in the field on the basis of both national and reference definitions. Tree-level measurements for volume estimates and the volume estimates correspond to reference definitions. The national definition of forest type describes site fertility. The reference definition for forest type can be derived from other variables. The overall situation is that estimates for all quantities can be

Table 24.3 The availability of estimates based on national definitions (ND) and reference (RD) definitions with the responsible agency

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	The national definition is GIS based. The reference definition is applied in the field
Growing stock volume	Yes	Yes	NFI	The national definition is different from the reference definition because of *dbh* threshold 5 cm
Above-ground biomass	Yes	Yes	NFI, models	The national definition is different from the reference definition because of non-tree vegetation is excluded
Below-ground biomass	Yes	Yes	NFI, models	The national definition is equal to the reference definition
Dead wood volume (= $DW_{10\ cm}$)	Yes	Yes	NFI	The national definition is different from the reference definition because of *dbh* threshold 5 cm
Dead wood volume by decay stage classes	No	Yes	NFI	Not recorded
Afforestation Deforestation Reforestation (Kyoto 3.3)	No	Yes	NFI, statistics	Can be derived
Forest type	No	No	NFI	The national definition of forest type describes site fertility. The reference definition for forest type can be derived from NFI data

obtained from the NFI except for forest type for which the data can be derived from other variables. Estimates for afforestation, reforestation and deforestation areas are based on NFI data and can be enhanced using additional information.

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Chapter 25
New Zealand

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25.1 Development of New Zealand's National Forest Inventory

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 of the United Nations Framework Convention on Climate Change (UNFCCC), as well as the ongoing annual reporting of exotic forests established with the primary objective of wood production where the resource description is useful for policy advice and resource planning. The 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 of Agriculture and Forestry (MAF), 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.

New Zealand's woody vegetation (excluding horticulture) can be divided into three distinct types:

1. Indigenous Forest Land (6.3 million hectare)
2. Exotic Production Forest Land (1.8 million hectare)
3. Mixed Shrubland (Other Wooded Land) (2.6 million hectare)

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The characteristics of each type differ so substantially that assessment techniques, sampling designs and inventory management also differ.

Three quarters of New Zealand's indigenous high forests are publicly owned and protected within the conservation estate. The forest types are many and varied (Wardle 1991) with more than 100 tree species in total, ranging from almost pure stands of Southern Beech (*Nothofagus* spp.) to rich softwood-hardwood species mixtures of Podocarps (principal genera *Dacrydium*, *Prumnopitys* and *Podocarpus*), other hardwood trees and dense shrub under-stories. Kauri (*Agathis australis* D. Don) forests in the north can have quite large individuals over 2,000 years in age. New Zealand is a mountainous country with a tree-line that attains 900 m in the south to over 1,500 m elsewhere. The upland forests are extensive and often remote, in difficult, steep, heavily-dissected country where weather can quickly deteriorate to impede ground access, with some of the most difficult flying conditions in the world.

The exotic production forest consists of moderately fast growing (average merchantable mean annual increment 17 m^3/ha per year, under bark) intensively managed planted forests, principally Radiata pine (90% by area, with rotations of 26–32 years) and Douglas fir (5%). A proportion of the stands are well into their third rotation. Two thirds of the forests are corporate owned, the remainder under a variety of private ownerships, with many farm forests. Some 40% of the total area is on steep land that has no, or limited, traverse by wheeled vehicles but, relatively speaking, most areas are close to roads.

Shrubland is defined as other wooded land that is unplanted and where plant heights generally do not exceed 5 m. Communities are extremely varied. They include indigenous alpine shrubs above the tree-line, regenerating indigenous forest, regenerating shrubs and trees on lightly-grazed pasture and fast colonising "scrub" of exotic "weed" species such as Gorse (*Ulex europaeus* L.). The plants exhibit a range of forms from individual single stems to multiple-stemmed bushes, sometimes with very large numbers of individuals per hectare. The boundary between shrubland and indigenous forest is artificial and is often indistinct. Unstocked gaps within the exotic production forests can quickly be colonised by shrubs.

25.1.1 National Forest Survey: 1946–1955

Although the newly created State Forest Service conducted an NFI in 1920–1923, this was more properly described as an appraisal of the merchantable timber of the indigenous forest resource and was conducted using a variety of methods heavily reliant on ocular estimates. The first NFI conducted using remote sensing and systematic sampling (pseudo-random sampling) was the National Forest Survey 1946–1955 (Thomson 1946; Masters et al. 1957; McKelvey and Wardrop 1963) confined to the indigenous forest. Methods observed in the United States at the time were adapted for New Zealand conditions. Detailed forest type maps were prepared using aerial photogrammetry at an average scale of approximately 1:15,840. Field sampling varied from a simple reconnaissance walk in forests presumed to have no merchantable timber, through to measurement of 0.4 ha (1 acre) rectangular plots located at regular intervals on survey lines. When forests were measured, the intensity of sampling varied with the estimated timber production potential, from one plot every 65 ha (0.25 mile^2) on lines spaced 1.6 km (1.0 mile) apart to one plot every 520 ha (2 mile^2). The variety in method was essential as the majority of timber available at the time was deemed to be contained in lowland forests of restricted extent, while the upland forests were remote and relatively devoid of merchantable timber.

The sample plots were temporary. All timber trees were measured for diameter and merchantable height and assessed for merchantability factors, which for some species were regionally based. Volume statistics were therefore of potential timber yield. Non-merchantable trees were tallied by species and diameter class on a 0.02 ha sub-plot, along with a full list of flora and a soil description. In all, some 17,000 plots were measured over the 10 years of the survey.

The indigenous forests are dynamic in nature and the concept of a stable climatic climax has little application. Volcanic activity, long-term climate change that varied greatly with region coupled with longevity of the outgoing softwood species, the impact of man through uncontrolled use of fire and selective logging and the effect of selective browsing by introduced animals all contribute to change (McKelvey 1995). To provide scientific knowledge and information for policy and management, assessments following the National Survey were carried out at the project or catchment level. Plot measurement protocols evolved towards an emphasis on ecology, and permanent sample plots were installed and termed the National Vegetation Survey (NVS) (Allen 1993). However, no further formal NFI's were conducted and the sum of the NVS plot observations and measurements do not provide unbiased estimates at a national or large region level.

25.1.2 National Exotic Forest Survey

After the indigenous forests had been surveyed, a National Exotic Forest Survey was carried out with data collected between 1959 and 1963, separating the sampling method into "Major" areas, >20 ha, and "Minor" areas (Wardrop 1970). 2,449 temporary circular 0.04 ha plots were established in the "Major" areas, located randomly in stands stratified by region and species. At the time, the range of species in the production forests was much wider than today, Radiata pine occupied only 65% of the total estate. However, while the area information was available by 1966, it took 7 years to 1970 before the volumetric data was formally presented. Given the relatively fast growth of the production forests as well as a decision to increase the rate of afforestation, the total standing volume had changed considerably over that time and the rate of change increased in subsequent years as the level of harvest also increased. There was no commitment to remeasure the forests in any form of continuous large-scale inventory. With the dynamics of the exotic production forests, speed in assembling, analysing and reporting on data is essential and national forest inventories conducted periodically at wide intervals provide little information of value.

In 1982, the New Zealand Forestry Council accepted a recommendation to set up a regularly updated plantation forest resource information system to produce the National Exotic Forest Description (NEFD) in a cooperative approach between government and forest owners (Butler et al. 1985). Administered now by the Ministry of Agriculture and Forestry (MAF), this is a compilation of an annual survey of forest owners, managers and consultants who manage planted production forests, (Anon. 2008). Each year owners with more than 1,000 ha are sent a questionnaire (120 owners as of 2008) requesting area data by age and species plus further information on harvesting and planting. The response rate is usually above 95%, often 100%. It is assumed that these forests are professionally and well-managed and that the data are accurate. About every 3 years, known owners with more than 40 ha are also surveyed, approximately 2,500 with an 87% response rate in 2008, with owners thought to have less than this surveyed much less frequently. The amount of afforestation is now estimated from a combination of the results of the postal survey and imputation from a survey of forest nurseries and their seedling sales. Periodically, yield tables of the major species/region/silvicultural regime combinations are constructed as weighted averages of tables submitted by the major corporate forest managers, and these are used to calculate standing volumes. A yield regulation modelling system is used to predict the likely availability of wood for harvest into the future.

For many years from its beginning, the NEFD acted as an effective NFI, updated annually at a level of accuracy and detail that would have been too expensive for a conventional NFI. The number of forest owners was limited and the data they supplied were based on their own operational "in-place" inventories and yield prediction systems for forests that were sampled and measured intensively. However, over the last 15 years, afforestation has been largely conducted by the private small wood-lot owner such that they are believed to now own one-third of the estate. The completeness of the NEFD survey, the quality of the small wood-lot owner's data on net stocked area and the applicability of corporate forest yield tables to these private owners are now called into question. At the moment, most of the harvest is derived from professionally managed forests but within 10–15 years, the proportion of the harvest that will be supplied from the small forest owner will increase substantially.

25.1.3 The Land Use and Carbon Analysis System (LUCAS)

The Land Use and Carbon Analysis System (LUCAS) has been under development over the last decade (Ministry for Environment 2009), motivated by the need to meet New Zealand's reporting requirements under the UNFCCC and the Kyoto Protocol. Although it was envisaged that carbon stocks in the indigenous forests were in balance between growth and mortality, a decision was made to develop a system that would provide evidence on the state of the indigenous forests and shrubland that could meet future reporting requirements for carbon, biodiversity, and for climate change policy development beyond 2012. The need to report on greenhouse gas sources and removals by sinks associated with direct human induced land-use change and forestry activities led to the development of an inventory system for the post-1989 national forest estate (“Kyoto compliant forests”, afforestation on non-forest land at 31 December 1989) and proposals to extend this system at a lower sampling intensity to the remaining planted production forests, the pre-1990 forests. Systems involving a systematic network of permanently located sample plots were designed and tested for the indigenous forests and shrubland on a 60 km wide east–west transect across the South Island (Coomes et al. 2002) and then for planted forests on an operational pilot in the Nelson–Marlborough region (Moore et al. 2005).

A single grid has been established across New Zealand. The indigenous forest and shrubland have been sampled at 8 × 8-km square spacing with 1,256 permanent sample plots (PSP’s) established between 2002 and 2007, and the post-1989 planted forests sampled at 4 × 4-km spacing with 300 clusters of 4 PSP’s each established in 2007 and 2008. It is proposed that the pre-1990 planted forests be sampled at 8 × 8-km in 2010. Discussions with private land-owners subsequent to the pilot inventory concerning access to the planted forests delayed the start of the post-1989 forest inventory and led to the development and implementation of a double sampling scheme involving airborne scanning LiDAR (Light Detection And Ranging) as the first phase and ground-based PSP’s as the second. It was found that there was a good, direct relationship between total carbon per hectare and LiDAR variables (Stephens et al. 2007). LiDAR and digital aerial photography were flown during 2008 on all sample points that were likely to be in the post-1989 estate during 2008. This sampling method is still under development and is likely to be continued.

25.2 Uses and Users of NFI Information

25.2.1 General

The data collected by the National Forest Survey of the indigenous forests 1946–1955 indicated how much merchantable timber was left, what the growth rates were and how much regeneration was present. This contributed directly to forest policy and operational decisions of the day and over the next several decades. The concerns on the supply of timber from the indigenous forests supported by the data from the survey led to restrictions on logging and to the expansion of the exotic production forests.

The National Exotic Forest Description is used at national, regional and company levels, as well as by non-governmental organizations (NGO). It forms the basis for economic policy and planning, and influences areas such as infrastructure, transportation, export-port development, wood processing facility construction and environmental planning.

The data from the exotic forest description has been used particularly to underpin an understanding of the potential wood production of the estate and to indicate the place of the forest sector in New Zealand's export industry. They are used in conjunction with models to periodically provide wood availability forecasts that are used by central government, regional authorities and private forest companies to evaluate the development of the production forest estate into the future. Publications based on the analysis of the description provide international trade with up-to-date information on a rapidly changing resource. Scenario analyses evaluate the consequences of government policy, while some regional authorities have cooperated with local forest owners to issue their own analyses particular to their region.

The data are used for reporting forest resource information for international statistics such as the Global Forest Resource Assessment of the Food and Agriculture Organization of the United Nations.

25.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

New Zealand's reports to UNFCCC of its greenhouse gas inventory for its planted forests are based on the analysis of data from the NEFD and from LUCAS. At this point in time, greenhouse gas emissions and sequestration is assumed to be in balance in the indigenous high forests and there is no land conversion from protected indigenous high forest.

Policy advice on the role of planted forests in green house gas emissions/sequestration under the Kyoto Protocol is derived from analyses of different scenarios of afforestation and harvest levels based on data from the most recent NEFD available. These analyses utilise the area age class distributions calculated each year with the periodically calculated volume yield tables in conjunction with carbon prediction models (Beets et al. 1999). The analyses have produced forecasts of annual carbon amounts over planning periods that have extended from 1980 to 2040 and the results have influenced New Zealand's negotiating position for the Kyoto Protocol.

The situation with regards to Shrubland (other wooded land) is unclear, with some clearance for agriculture contrasting with extensive areas of regeneration in marginal agricultural land.

25.2.3 Biodiversity and Environmental Impact

Once the indigenous National Forest Survey was completed in 1955, the survey teams were dispersed. However, gaps in the knowledge of ecological communities and questions on animal pest induced changes to the indigenous forest led to establishing what was to become the Forest Protection Division of the New Zealand Forest Research Institute in order to continue the survey and research work needed to understand the dynamics of the indigenous forest resource. This work was carried out at a catchment and project level, with some long term monitoring plots established to provide information on the effects of animal control methods on the status of the forest and on its biodiversity. Ultimately the survey provided the base data towards a classification and typing of New Zealand's indigenous forests.

The National Exotic Forest Description is solely concerned with areas and merchantable timber volumes on its production forests, and collects no other information.

New Zealand is a signatory to the Convention on Biological Diversity (CBD). It has a high level of endemic biodiversity that makes a unique contribution to the world, but some 1,000 native animal, plant and fungi species are under threat. New Zealand is also one of 12 members of the Montréal Process and uses the criteria and indicators to assess the sustainability of its forest management at the national level. The absence of a statistically valid, mensurationally sound forest inventory at a national level led to the incorporation of the assessment of biodiversity in the current efforts of LUCAS.

25.3 Current Estimates

Basic area estimates for New Zealand with the associated descriptions are given in Table 25.1a and basic volume estimates in Table 25.1b.

25.4 Sampling Design

25.4.1 Indigenous Forest and Shrubland

Remotely-sensed imagery and maps generated from use of this imagery assisted in locating NFI plot sites. For the indigenous forest and shrubland inventory, the nation-wide Land Cover Database (Thompson et al. 2004) was used to determine the spatial location and area extent of these vegetation types. This land cover mapping was derived from Landsat ETM+ imagery taken about the year 2000, supplemented by field work.

A PSP was installed where an 8-km × 8-km sample grid superimposed on the land cover map intersected either indigenous high forest or shrubland that was at least one ha in extent. There were two exceptions to this rule. The first was where the sample point was inaccessible or dangerous; this happened infrequently. The second was where there was one or more existing NVS plots in forest within the 8-km × 8-km square surrounding the sample point. Here, this plot was found if

Table 25.1a Basic area estimates from the year 2008

Quantity	Estimate (1,000 ha)	Description	SE[a]
Forest land (Kyoto Protocol definition)	8,000	Land with at least 30% crown cover and a potential to attain a minimum tree height of 5 m in situ, and a minimum area of 1 ha, indigenous and exotic forest	n.a[b]
Other wooded land (FAO definition)	2,600	Shrubland	n.a[b]
Other land (FAO definition)	16,400	Not forest land or other wooded land	n.a[b]
Forest land in UNFCCC LULUCF reporting	–	Same as forest land	n.a[b]
NFI coverage	9,400	All New Zealand except for 1.2 million hectare Exotic Production Forest afforested prior to 1990	n.a[b]
LULUCF area estimates for the land classes	–	Forest land, cropland, grasslands, wetlands, settlements, other land	n.a[b]
Productive forest land (national definition)	1,790	National Exotic Forest Description as at 1 April 2007 (Anon. 2008)	n.a[b]
Total land area	27,000	Land area and fresh water areas (rivers and lakes) within Protected areas, i.e. National Parks, Nature reserves	–[c]

[a]Standard error.
[b]Not available.
[c]Assumed to be error free.

possible, re-established and re-measured by the new plot measurement protocols. If there were several NVS plots in the square, one was selected at random. The objective was to make use of measurements that could stretch back 30 years. The risk that including these types of plots in the new sample frame might bias the final results was small relative to the potential benefit. The set of re-measured NVS plots included in the inventory is a relatively small proportion of the total forest plots (15%) and the set is clearly not a true random sample of the total estate, with their average values of the parameters of interest not an estimate of the true national values.

By 2007, 1,256 plots were established with 889 plots in forest, 341 plots in shrubland, and 26 plots located in other land types, see Fig. 25.1. The expectation with this sampling intensity was that total carbon stocks could be estimated to within 5% and 12% of the mean for forest and shrubland, respectively. In the event, the preliminary, unverified analysis (as at February 2009) indicates that total above-ground carbon stocks can be estimated to within 4% (±7.0 t/ha) for forest and 15 % (±8.2 t/ha) for shrubland.

The network was deliberately designed to be simple and robust to change, (Coomes et al. 2002). It was installed over a period of 5 years with the few remaining plots added in the sixth year. These plots will be re-measured once on a 5-year cycle commencing early 2009 then the re-measurement interval

Table 25.1b Basic volume estimates from the year 2008

Quantity	Estimate	Description	SE[a] (1,000 ha)
Growing stock volume on productive forest land		Exotic production forest, merchantable volume, inside bark,	
Million cubic metre	434	NEFD survey, year to 1 April 2007	n.a[b]
m^3/ha	242		
Annual increment of growing stock (m^3/ha per year) of trees on productive forest land	17	Mean annual increment, merchantable, over the rotation, averaged for those stands harvested 2006 and 2007, NEFD survey, year to 1 April 2007.	n.a[b]
Dead wood volume on productive forest land	n.a[b]	–	n.a[b]
Annual drain (million cubic metre) on productive forest land	19,0	NEFD survey, year to 1 April 2007	n.a[b]
Total harvested volume[c]	20,0	Annual survey of forest product outputs	
Annual drain per hectare on productive forest land (m^3/ha per year)	444	Total harvested volume, all species NEFD survey, year to 1 April 2007	n.a[b]
NFI is main information source for the following carbon pool changes		Above- and below-ground live biomass, coarse woody debris, fine woody debris:	
		Indigenous forest carbon stock	3.5
		Post-1989 forest carbon stock	4.1

[a]Standard error.
[b]Not available.
[c]*Note*: There are two estimates of harvested volume, inside bark provided by MAF. The first is derived from the NEFD survey of forest owners. The second is derived from the application of conversion factors to the quantities of wood products from the various New Zealand processing facilities and log exports.

progressively converted to 10 years. Although five years is viewed as an unnecessarily short interval over the long term, the first re-measurement will enable unbiased change results to be obtained early. Many of the inevitable errors incurred from one visit under difficult conditions will be corrected and an early first re-visit will ensure that the plot can be more readily relocated on subsequent visits.

Measurement protocols were developed from the existing NVS methods (Allen 1993), modified and refined to cover the requirements to estimate the five carbon pools needed by LUCAS, (Payton et al. 2004). For forest, a 0.13 ha circular PSP contains a 0.04 ha, 20 × 20-m square plot that is divided into 16 segments and also has 24 circular sub-plots of 0.49 m radius for more intensive measurements of plant bio-diversity and occurrence. As larger trees contribute significantly more to biomass than small trees and shrubs but are more scattered in their geographic distribution, all stems with *dbh* > 60 cm and within 20 m of the plot centre are measured for diameter. Within the 20 × 20-m square plot, all stems with *dbh* > 2.5 cm are

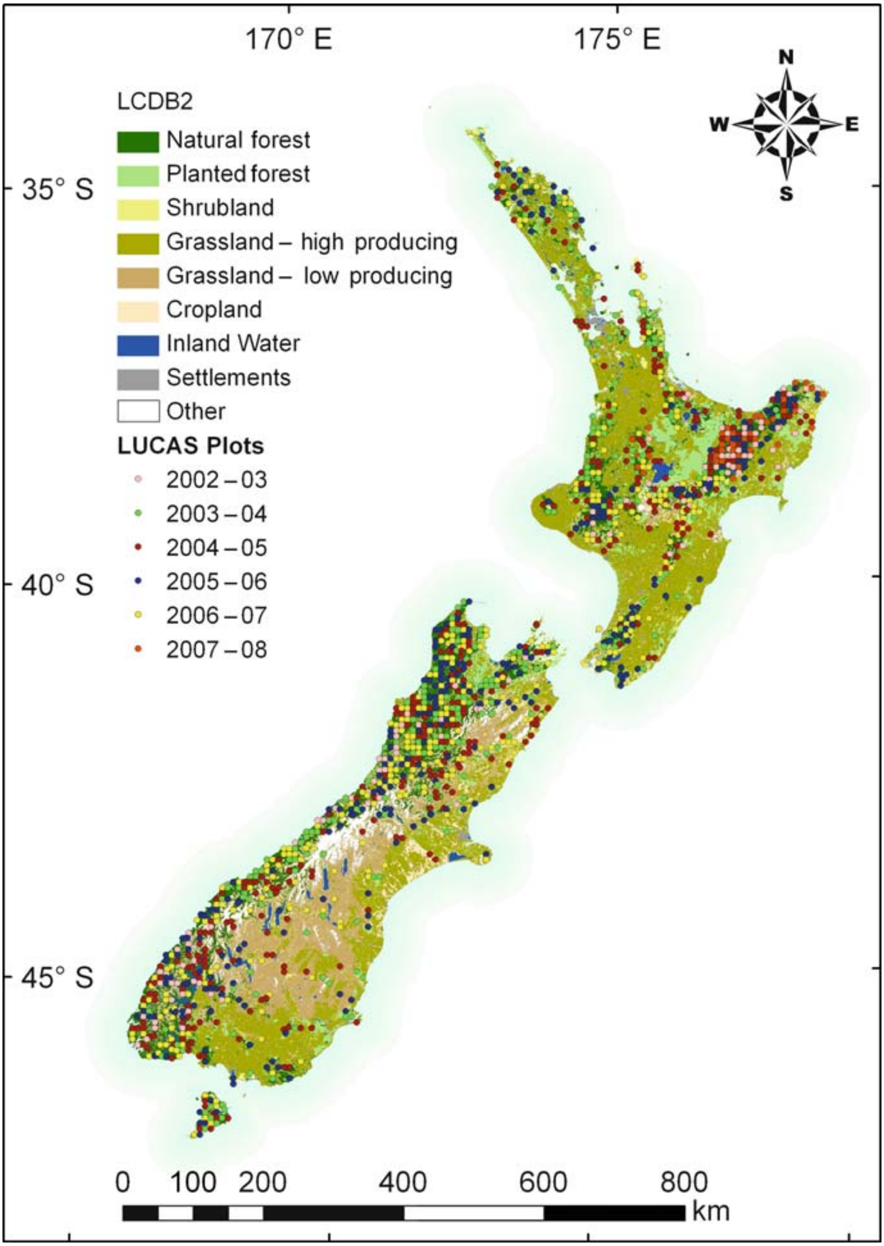

Fig. 25.1 Location of indigenous forest plots, located on the 8 × 8-km grid system, measured over the period 2002–2007. The map background is from the Land Cover Database

measured. A sample of trees is measured for height to establish a height diameter relationship. For shrubland, the protocols were modified to estimate height and percentage ground cover by major species where it is impossible to measure individual plants, or height and two orthogonal crown widths where individuals shrubs could be measured but have multiple stems with *dbh*s < 2.5 cm. Immediately outside the shrubland plot, either four individual shrubs or a 4 m $\times$ 1 m strip plot were destructively sampled to provide data to estimate above-ground biomass for the non-destructively measured shrubs within the plot proper. The shrub protocols are under revision. Every third site had soil pits dug, a soil profile described and soil samples removed for laboratory analysis to determine organic soil carbon, amongst other parameters.

Biodiversity measurements are included in the measurement protocols to widen the usefulness of the inventory and to cater to the inevitable demands for more information. Because of the logistics of widely dispersed sites coupled with the length of time taken to walk to a plot, the additional biodiversity measurements added less than 30% to the operational field time over a system devoted solely to carbon and significantly less than that as a proportion of the overall costs. Some plots with slow, difficult access might take up to 3 days to measure, from the time of departure to return, requiring camping at the plot site. Helicopters are used where necessary and there is a safe drop-off point.

25.4.2 Post-1989 Forests

New Zealand intends to claim carbon credits (net carbon stock change) over the first commitment period of the Kyoto Protocol from its post-1989 planted forests. This action requires that stock changes be estimated in an unbiased and transparent manner that meets the Good Practice Guidelines, along with determination of the uncertainty of the estimate. Nearly all post-1989 forests are privately owned, the majority by non-corporate owners with a significant proportion in small woodlots not under professional forest management. Field access to the forests is not guaranteed and a double sampling system involving LiDAR and ground-based permanent sample plots was implemented on all sample sites on a 4 $\times$ 4-km square grid coincident with that used to sample the indigenous forest (Stephens et al. 2007).

From the NEFD, it was estimated that there were approximately 680,000 ha of post-1989 forests, implying that there could be a network of some 400 permanent sample sites with the expectation that total carbon stocks could be estimated to within 7% of the mean. A super-set of 758 possible sample sites that included all known and probable post-1989 forests was constructed from evaluating the best aerial photography available regionally combined with telephone queries to the owner. This set was flown by LiDAR and digital colour photography in the late summer/autumn of 2008. It would be reduced to the actual sample frame following wall-to-wall land-use mapping from satellite imagery acquired in 1990 and again in 2008. The mapping was designed to meet the requirements of Kyoto reporting. For the 1990 land-use mapping Landsat 4 imagery was used; for 2008, SPOT-5 imagery was used. The mapping was still in progress prior to the inventory, but when completed will also provide an accurate estimate of the total areas of planted forest sub-divided into pre-1990 and post-1989 forests. Kyoto reporting also requires annual forest harvesting and deforestation mapping and MODIS imagery is being used for that purpose. The MODIS mapping will be supplemented with higher spatial resolution imagery (aerial photography and/or high resolution satellite imagery) where changes in forest cover are identified.

Two hundred and fifty three sample sites were measured in the field in the winter/early spring of 2008, the (mainly) dormant season, following a preliminary sample of 47 sites visited a year earlier. Thus only half an annual growth season separated the time of measurement from the start of the commitment period; this difference will be adjusted using a carbon growth prediction system. A key part of the field visit was to determine that the forest was indeed post-1989, resulting in a total of 273 sites in post-1989 forest, see Fig. 25.2. It is assumed that these sites are a random sub-set of the total set. The preliminary, unverified analysis of these field plots alone (as at February 2009) indicates that total above and below-ground carbon stock per hectare can be estimated to within 6% (±5.12 t/ha).

At each site a cluster of four circular permanent plots are installed (Moore et al. 2005) the centre plot of 0.06 ha, the other three of 0.04 ha centred 35 m from the central point, 120° from each other in a design similar to that used by the Forest Inventory and Analysis (FIA) programme of the U.S. Forest Service. In previous investigations it was shown that plot sizes larger than 0.04 ha did not decrease the variance among plots under New Zealand conditions, while the central plot size of 0.06 ha was deemed optimal for use with LiDAR. All plots are hidden, that is all visible markings, tree and plot numbering, are removed following installation. Three witness trees away from the cluster are marked, the location of tree stems mapped and a metal peg inserted below ground at the centre point which is accurately located using differential GPS. This way it is expected that there would be no question but that any future silvicultural operations would treat the area within which the plots were located the same way as the rest of the stand.

The field protocols are documented by Payton et al. (2008). Because of the fragmented manner of the small wood-lots across the countryside, boundary issues are significant for a third of the sites and the mapped plot design is used for plots located on stand edges, rather than the mirage or reflectance method. Trees are measured for *dbh* with a sub-sample measured for total-, crown- and pruned- height and tree health. Saplings and seedlings are counted and sub-sampled for height and root collar diameters. Shrubs are measured as for the shrubland inventory continuous cover method; ground cover (<0.3 m in height) is measured for height and percentage cover by area for each vegetation type. Thinning to waste, i.e. non-productive thinning, is practised extensively. Here the crew can encounter more felled trees lying on the ground than are left standing. "*Dbh*" and "height" measurements are made of the downed stems in a similar fashion to the standing trees, along with estimates of decay class. Radiata pine in the warm, moist conditions of New Zealand decays rapidly, in contrast to some of the more durable indigenous

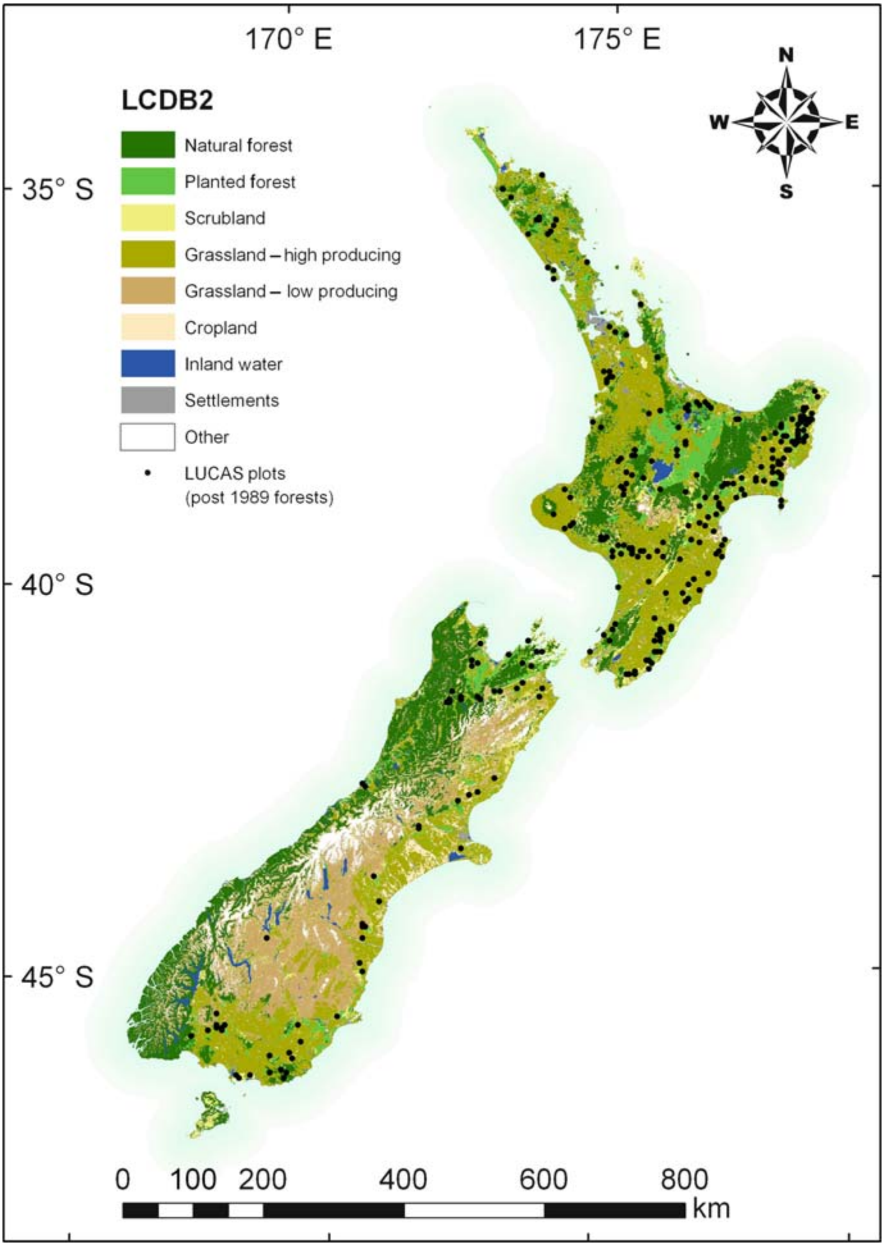

Fig. 25.2 Location of post-1989 forest plots, located on the 4 × 4-km grid system, measured over the period 2007–2008. The map background is from the Land Cover Database

tree species. No attempt is made at this stage to separate this felled biomass into coarse or fine woody debris as this would require more intensive measurements than for the live standing trees. An accounting system is used whereby if a felled tree was originally growing inside a plot boundary it is measured completely, rather than only to the plot boundary. Coarse woody debris (diameter >10 cm) also includes logs and piles of wood residues and these are measured individually. Fine woody debris not associated with a felled tree is measured using line intersect sampling, litter by a quadrat harvest. A bulk soil sample is collected from 20 small cores in the top 5 cm of mineral soil below the litter layer in order to assess soil fertility and predict stem-wood density. Finally a species list is compiled for biodiversity.

25.4.2.1 Quality Assurance and Control

Quality assurance and quality control (QA/QC) procedures were specified for both the field and airborne data collection. The field measurement of PSP's was formally audited by re-measuring 10% of the sites with a team independent of the company carrying out the inventory. These sites were randomly selected throughout the audit period and revisited shortly after the original measurement. Audit results for a site were provided to the measurement teams as soon as possible to prevent any longer term trends in poor practice. Should a site fail to reach an adequate standard, objectively and quantitatively scored, the site had to be re-measured. The Airborne LiDAR quality measures and results are described by Stephens et al. (2008). QA/QC measures were carried out by the aerial contractor and by the Ministry for Environment, the client, and specified in the project description. The key characteristics included sensor calibration, positional accuracy, density of first return, no data decimation, consistent classification of the ground returns within the point cloud and accurate data administration. The LiDAR sensor calibration was flown four times with 600 height difference samples taken, the point positioning tested on six occasions and a summary of first returns provided for eight delivery dates. Sites that failed to meet the required pulse density were reflown. The client used the FUSION LiDAR visual and analysis software (McGaughey et al. 2004) and ERDAS IMAGINE software for quality assurance of the delivered LiDAR data sets, continuously throughout the operation with results and feedback to the contractor within 10 days of data delivery.

25.4.3 Pre-1990 Planted Forests

The inventory of the pre-1990 forests is still in the planning stages but is scheduled for 2010 as a single, complete assessment of the population. Given the experience of the inventory of the post-1989 forest inventory it is expected that a similar double sampling option will be employed using LiDAR collected by air in combination with ground based PSP's. The relationship between carbon stock as measured on the ground and LiDAR variables is very good and there is potential to economise on costs compared to a field sample alone. This will be especially true where results for subdivisions of the total forest area are required, such as by regional authority or timber supply zones where reliance on field data alone may only provide imprecise estimates.

It was recommended that at least 200 field sites be sampled on the 8 × 8-km grid where this intersects a pre-1990 forest to ensure that a robust, unbiased regression model may be estimated. LiDAR data should be acquired over as short a time frame as possible in strips oriented in a common direction (at least within each forest) such that each intersection of the 8 × 8-km grid point with a pre-1990 forest is covered and LiDAR data is collected from forest edge to edge. The sampling bias with forest blocks smaller than 8-km^2 introduced by restricting the first sampling phase to this selection can be corrected. This sample intensity should be sufficient to estimate the stock of carbon to within 7% of the true total at the 95% probability level, excluding any error due to measurement or calculations of individual tree and carbon pool content. It should be possible to utilise all or a significant proportion of the strip LiDAR data.

If costs, operational requirements or policies are such as to prevent the use of LiDAR, then some 400 field sample sites on every second 4 × 4-km grid intersection point will be required to obtain a similar level of sampling precision as in the double sampling scheme.

25.5 Estimation Techniques

25.5.1 Estimates of Present State Within LUCAS

Comprehensive error checking is an essential first step. Particularly with regards to the indigenous forest and shrubland, techniques had to be developed to correct and/or predict missing or obviously erroneous within-plot measurements, given the difficult conditions under which the field crews were operating. Some of the NVS plots that have been incorporated into the sample have a long interval since the previous measurement, with a consequent increase in error rate. It is expected that many of these errors will be corrected on the first re-measurement. The establishment of plots in the post-1989 forests was considerably simpler resulting in fewer measurement problems and was audited by a concurrent sample re-measurement process.

25.5.1.1 Indigenous Forests

Estimation methods are a development from the methods described in Coomes et al. (2002). An individual tree allometric model is used for the indigenous forests to estimate tree stem volumes, tree above-ground biomass and above-ground carbon. Individual tree above-ground biomass is a function of density of stem outer wood (5–15 cm depth) at breast height, diameter at breast height and total tree height. Density may be measured directly or estimated by using an existing species/species group coefficient. The function is a composite function built by estimating three components: stem and branches >10 cm, small branches and foliage, and is of the form

$$B = \beta_1 DV + \beta_2 d^{\beta_3} + \beta_4 d^{\beta_5} \tag{25.1}$$

where

B is above-ground, oven-dry tree biomass
D is density of stem outer-wood (5–15 cm depth) at breast height
V is volume of stem and branch wood >10 cm, calculated from an individual tree model, $\alpha_1(d^2h)^{\alpha_2}$, where the α_1 term includes an accommodation for hollow stems
d is diameter at breast height (*dbh*) where breast height is 1.4 m
h is total tree height, measured or estimated from a *dbh*/height regression model
α's and β's are parameters

Carbon is assumed to be 50% of oven dry biomass. The results of the shrub, coarse and fine woody debris calculations are added to the sum of the trees to obtain per hectare totals for a plot. National and relevant subdivision totals are calculated by simple averages, with post stratification where appropriate.

25.5.1.2 Planted Forests

A different approach is used for the planted forests. Individual tree volume models that are a function of *dbh* and tree height are used to estimate stem total volume, inside bark. Where a tree has not been measured for height, its height is predicted from a height/*dbh* relationship estimated for each plot. Total standing volumes are the sum of the individual trees.

Given total standing volume, plot carbon per hectare is estimated by using the C_change/300 Index growth model (Beets et al. 1999; Kimberley et al. 2005). This firstly predicts volume increment through time such that the predicted total standing volume equals the measured volume. It converts these increments to biomass using wood density functions, then estimates total biomass by partitioning the annual increment each year amongst the tree components of stem, bark, branches, foliage and reproductive parts dependent on age, with a constant partition percentage for live root biomass. This system can be used for both estimating an existing stock and predicting its past and future development. Other carbon pools at the time of measurement are estimated from plot measurements or predicted from the model into the future. It is possible to estimate the national totals of volume and carbon from the field plot data alone, using the mapped, cluster-plot statistical methods described in Bechtold and Patterson (2005) for the US FIA programme.

Once the LiDAR data processing is finalised, a regression model will be developed to predict carbon per hectare directly from the LiDAR variables, with the parameters estimated from the paired field and LiDAR measurements. Previous development work (Stephens et al. 2007) with two test data sets produced models with R^2 of 0.81 and 0.57 for the two independent variables of the 30% LiDAR height percentile and the reciprocal of the total percentage of ground returns (a measure of vegetation cover). The better data set has a root mean square error of 21 t carbon per hectare. If an accurate count of tree stocking could be obtained automatically, a model with this as a third parameter would have a significant improvement, R^2 increasing from 0.81 to 0.87. The poorer results from the second test data set are thought to originate from the lengthy time interval of 1.5 years between flying and field measurement.

25.5.2 *Forecasts of Future Conditions*

The NEFD survey was developed especially to monitor and forecast the development of New Zealand's production forests. Periodically, regional wood supply analyses are carried out under a variety of scenarios, principally different levels of afforestation and harvesting constraints. It is emphasised that the forecasting of harvesting levels is a forecast of wood availability by major log quality groupings, not a prediction of the actual future harvest. This latter will be a function of markets which are not estimated in any of the analyses. Regional wood availability forecasts have been completed in 2009 for the whole of the country.

The plot measurements from LUCAS will only form a complete NFI after 2010. It is expected that the NEFD survey will continue as a very timely, cost effective approach. How the two systems will interact has yet to be determined, LUCAS will produce estimates of total standing volume from a sparse network of plots, the NEFD produces estimates of merchantable volume, based on detailed information in the case of professionally managed exotic forests, but of uncertain data quality for the remainder. In LUCAS, because the C_change/300Index growth model is used to estimate biomass and carbon at the plot level, predictions of change, including total volume, are integrated with the calculations of stocks.

25.6 Options for Estimates Based on Reference Definitions

The status of harmonization of the New Zealand NFI is presented in Table 25.2. Estimates for Indigenous Forest, Shrubland and Post-1989 Forests will be available by the end of 2009, those for Pre-1990 forests will be calculated late in 2010. A complete set of national estimates will be available after 2010.

Table 25.2 The availability of estimates based on national definitions (ND) and reference definitions (RD) with the responsible agency

Quantity	ND	RD	Responsible	Remark
Forest area	Yes	Yes	LUCAS	–
Growing stock volume	Yes	Crown cover >30%	LUCAS	See note
Above-ground biomass	Yes	Yes	LUCAS	–
Below-ground biomass	Yes	Yes	LUCAS	Model–based estimate only
Dead wood volume	Yes	–	LUCAS	–
Dead wood volume by decay stage classes	Yes	–	LUCAS	–
Afforestation Deforestation Reforestation (Kyoto 3.3)	Yes	–	LUCAS	–
Forest type	Yes	–	–	–

Note: National definitions: Breast height is 1.4 m above firm ground. *Dbh* is always calculated from the measurement of the circumference of the stem. Volume of growing stock is the total volume inside bark from ground (root collar) to stem tip.

25.7 Current and Future Prospective

By the end of 2008, a national inventory was completed for New Zealand's indigenous high forest, shrubland (other wooded land) and post-1989 planted forest. Data analysis based on the field plot measurements only will be completed early in 2009 comprising preliminary estimates of carbon stocks and their associated validation studies followed by predictions of change. Associated with carbon predictions, estimates of stem frequencies and stem volumes, by species and forest types in the case of the indigenous forests, will also be available. The LiDAR relationships and assessment of the impact of double sampling on the precision of national carbon stock and change estimates is expected to be completed by mid-2009.

Planning for the measurement of the pre-1990 planted forests is expected to be finished during 2009, with the forests flown early in 2010 and the field measurements made during winter when growth is dormant (April through to early September, depending on latitude). At that point there will be a complete inventory of New Zealand's forest and shrubland that is statistically and mensurationally sound.

The indigenous forest and shrubland re-inventory is already going ahead as a continuous forest inventory with the first tranche of re-measurements due to be completed before the winter of 2009 and the complete estate before the end of 2013. Planning for the re-measurement of the exotic planted forests will be required to enable re-measurement and analysis to have been completed in time to meet the reporting commitments of New Zealand's ratification of the Kyoto Protocol. This planning will depend on the results of the analysis of the impact of double sampling with LiDAR on the precision of national carbon stock and change estimates. It is to be hoped that the total planted forest estate could be measured for little more cost than that of the post-1989 forests alone. There are field operational advantages to be able to re-measure the planted forests as a continuous forest inventory, but this may be precluded due to reporting and analysis deadlines, as well as technical advantages through having the field measurements close in time to those from the air.

25.8 Influence of COST Action E43

The work and discussions with country members of the COST Action E43 group has greatly influenced the design and implementation of the NFI.

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Chapter 26
Norway

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26.1 Development of Norway's National Forest Inventory

The Norwegian National Forest Inventory (NFI) has been producing large-area forest resource information since 1919. The first inventory was carried out 1919–1930. The main reason for the start of the inventories was concern about the current forest situation and fear of lack of forest resources in the future. So far, eight inventory cycles have been completed, the last one taking place 2000–2004. Fieldwork for the ninth inventory was carried out 2005–2009 (Table 26.1).

The two first NFIs were strip sampling with an interval of 1–5 km between the centre lines of the strips, depending on the county being surveyed. Area assessment and tree measurements were carried out in strips with a width of 10 m. The length of individual strips assessed was 100 m, grouped into units of 2 km. Similar sampling methods with varying sampling intensities were used in subsequent inventories until 1953.

For a few years (1952–1955) sample plots were laid out along parallel lines, but beginning late in NFI2 (1956), cluster sampling with plots located on separate tracts has been used instead of continuous lines. Since 1964, fieldwork for a fixed proportion of sample plots has been conducted in all regions of the country each year. Fixed-area circular sample plots of varying sizes were maintained until 1976. From 1977 to 1981, the NFI produced estimates for some individual municipalities using data from the 1964–1976 inventory plus additional sample plots. During the years 1980–1983, three counties in western Norway were surveyed, and from 1982–1986 an inventory was carried out with regions consisting of two to three counties as reporting units. Unlike the previous inventories, angle count sampling (Bitterlich 1948) was used.

From 1986 to 1993, fixed-area circular permanent sample plots were installed in all counties except Finnmark. NFI6 was carried out on a county-by-county basis.

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Table 26.1 The national forest inventories of Norway

Inventory	Years	Method	Number of plots or similar
NFI1	1919–1930	Strip sampling	49,700 km of strips (20,872 on productive forest land)
NFI2	1937–1956	Strip sampling, line sampling with plots, cluster sampling with temporary plots	
NFI3	1957–1964	Cluster sampling with temporary plots	
NFI4	1964–1976	Cluster sampling with temporary plots, the entire country surveyed each year	
NFI5	1980–1986	Cluster sampling with temporary plots, angle count plots	
NFI6	1986–1993	Cluster sampling with temporary and permanent plots, county-based inventories	16,196 Permanent plots
NFI7	1994(95)–1999	Systematic cluster sampling with permanent plots, the entire country surveyed each year; cluster sampling with temporary and permanent plots in selected counties.	16,452 Permanent plots
NFI8	2000–2004	Systematic sampling with permanent plots, the entire country surveyed each year; cluster sampling with temporary and permanent plots in selected counties	16,522 permanent plots
NFI9	2005–2009	Systematic sampling with permanent plots, the entire country surveyed each year; cluster sampling with temporary and permanent plots in selected counties	

In 1994 the concept of continuous forest inventory was reintroduced with 20% of the sample plots inventoried each year. Since 1995, county-based inventories have been carried out together with remeasurement of the permanent plots in such a way that temporary plots have been measured in selected counties and completed over a 5-year period.

Limited inventory work in Finnmark county was started in 2005 with the primary aim of providing data for carbon reporting (UNFCCC and Kyoto Protocol).

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. However, the number of temporary plots and the distance between them have been adapted to the forest area in the county and to terrain constraints.

The Norwegian Forest and Landscape Institute (from 2006), previously the Norwegian Institute of Land Inventory (1988–2006), the Norwegian Forest Research Institute (1972–1987) and the NFI as an independent institution (1919–1972) have been responsible for the inventories. Responsibilities have included planning the design and estimation methods, field measurements, calculation of estimates and publication.

26.2 The Use and Users of the Results

26.2.1 General Use

The Norwegian NFI covers forests of all ownership groups, including protected forests and all other land use classes, and serves as a central forest information source for forest industries and forest environment decisions and policy making. Information generated by the NFI has traditionally been used for large-area forest management purposes such as planning harvesting, silviculture and forest improvement regimes at the regional and national levels, and to some degree decisions concerning development of forest industries. It also provides information to international bodies such as the Food and Agriculture Organization of the United Nations and its Forest Resources Assessment, UNECE/FAO Forest Resource Assessments and the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (FAO 2006; Ministerial Conferences on the Protection of Forests in Europe (MCPFE 2007). In addition, it provides information on forest health status and damage, biodiversity and carbon pools and changes for the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC).

26.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

The Norwegian NFI has been the main source of information for greenhouse gas reporting of the LULUCF sector to the UNFCCC since the mid-1990s, and it will also play a central role in reporting LULUCF activities under Articles 3.3 and 3.4 of the Kyoto Protocol.

Land use categories reported by Norway are consistent with the IPCC Good Practice Guidance (IPCC 2006). Area estimates by land use categories, excluding some sub-categories of cropland, are based on NFI data. IPCC land use categories are formed on the basis of national land classes using other variables assessed in the NFI. Data from the current inventory (2005–2009) and three most recent NFIs have been used for estimating time series of areas for land use categories from 1990 to the present (2009).

Some new land use related variables and classifications have been included in NFI9, because data from previous inventories do not provide adequate information about transitions between IPCC land use categories. These additions are expected to provide more accurate data for reporting emissions and removals from afforestation, reforestation, deforestation (ARD) activities under the Kyoto Protocol.

All the LULUCF related carbon pool change estimates are based either directly or indirectly on NFI data, except emissions per hectare from organic soils (Rypdal et al. 2005).

NFI is main information source for the following carbon pool changes: above-ground biomass, below-ground biomass, dead wood, litter, soil organic matter (dead wood, litter and soil: NFI data together with models).

26.2.3 The Role of NFI in Assessing the Status of Biodiversity

In addition to conventional NFI variables such as stand and tree age, tree species composition, diameter distribution of the volume of the growing stock, the number of trees and soil and site variables, variable groups describing forest biodiversity have been introduced to the NFI. Brief descriptions of the most important of these newly introduced variables follow.

1. The occurrence and coverage of shrub layers were assessed on all permanent plots from 1991 to 2004.
2. Measurements of the volume, diameter, tree species, decay class and appearance class (categories are, e.g., broken snags, uprooted stems, broken lying stems, logging residues etc.) of dead wood were introduced for NFI7 (1994–1998) for all permanent plots. In subsequent inventories, only trees that have died since the previous assessment have been recorded.
3. Concealment for game (shrubs, branches) was introduced in 1994, and the assessment was maintained until 2004 (end of NFI8).
4. Coverage of bilberry plants *(Vaccinium myrtillus* L.*)* was introduced on permanent plots in 1994, and the assessment is still ongoing.
5. Environmental Inventories in Forests were introduced in 2003. The principles for assessment were originally developed for use in forest management planning with the methodology later becoming part of the NFI. The data permits detection of regional distributions of the various habitats and their development over time. The information may also be linked to other NFI variables which would be helpful for purposes such as identification of forest types or structures where important habitats are likely to occur. Habitats are described in more detail in the manual: "Environmental Inventories in Forests – Biodiversity – Background and Principles" (Baumann et al. 2002). The primary habitat variables include dead trees with nutrient-rich bark, trees with pendant lichens, late successions of deciduous trees, old trees, hollow deciduous trees, rich ground vegetation, rock walls, clay ravines and stream gorges. The surveyed objects (habitats) are recorded as concentrations (areas with high density of environmental features and with area >0.2 ha) and as areas with scattered occurrences of environmental features according to threshold values: Minimum requirements for recording of

a habitat are based on qualitative and quantitative aspects. For each habitat different features are surveyed; for example dead trees' features include vegetation type, topographic position, area, vegetation layers (forestry definition), number, decay stage and diameter of dead trees and dominant tree species.

6. In cooperation with the Norwegian Genetic Resource Centre, a detailed assessment of some scarce tree species was initiated in 2003 and is ongoing. The aim is to determine if the occurrence and regeneration of the 11 tree species will be affected by climatic changes.
7. Assessment of the naturalness or the human impact on the ecosystem was introduced in NFI9 (2005–2009). The assessment is based on the structure of the growing stock, dead wood, and accomplished regimes. Three different categories are in use, corresponding to the MCPFE criteria and indicator classification.

26.3 Current Estimates

Basic forest area estimates for Norway with the associated definition descriptions are given in Table 26.2a. and basic volume estimates in Table 26.2b. The estimates and their standard errors are based on NFI8 (2000–2004). For forest, two sets of definitions are in use for field measurements, the old national definitions of productive and unproductive forest lands and the international reporting (FRA 2000) definitions of forest and other wooded land (OWL). Since 1994, the international categories of forest and OWL have been distinguished for reporting purposes on the basis of crown cover assessed in the field. Since the beginning of NFI9 in 2005, these categories have been assessed directly in the field and redefined so that forest, in accordance with the international definition, is the aggregation of the national productive and unproductive forest categories.

26.4 Sampling Design

Norway is divided into 17 regions (counties) and for NFI7–NFI9 (1995–2009) each has had a different sampling intensity based on experiences from previous inventories, especially the total land area of the county and the relationship between forest area and total land area (Table 26.3). The regional sampling designs to some degree also reflect the variability in land use classes and the values of forest variables (volume of growing stock by tree species). An observation unit is an individual field plot. For practical reasons and for purposes of increasing the efficiency of the fieldwork, field plots are organized into clusters. The shape of the clusters may vary between counties. Field plots cover all land use classes.

Table 26.2a Basic area estimates from the years 2000–2004 (NFI8)

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a] (1,000 ha)
Forest land (reference definition, applied parallel with national definition)	9,311	30.6	10% crown cover with minimum height of trees of 5 m at maturity in situ, minimum area 0.5 ha and minimum width 20 m	77
Other wooded land (reference definition, applied parallel with national definition of unproductive forest)	2,689	8.84		47
Other land (reference definition)	18,428	60.6		81
Forest land in UNFCCC LULUCF reporting	9,311	30.6	Same as forest land based on reference definition	77
NFI coverage	All land classes including inland water. Data on some areas in the mountains and in Finnmark county are still based on other data sources, but a process is going on to extend the NFI to cover these areas. Total land area and water area estimates are provided by the Norwegian Mapping Authority.			
NFI provides LULUCF area estimates for the land classes	Forest, cropland, grassland, wetlands, settlements, other land			
Productive forest land (national definition)	7,506	24.7	Average annual productivity ≥ 1 m^3/ha of stem wood over bark and over the rotation	72
Unproductive forest land (national definition)	2,291	7.53	0.1 m^3/ha $\leq$ productivity $<$ 1 m^3/ha of stem wood over bark and over the rotation	44
Total land area	30,428	100		–[b]

[a]Standard error.
[b]Assumed to be error free.

Table 26.2b Basic volume estimates from the years 2000–2004 (NFI8), or a specific year

Quantity	Estimate	SE[a]
Growing stock volume on forest land and other wooded land (million cubic metre)	847	11.1
Growing stock volume per hectare on forest land (m^3/ha)	90.15	0.94
Annual increment of growing stock on forest land and other wooded land (million cubic metre per year)	25.53	0.40
Annual increment of growing stock per hectare on forest land (m^3/ha per year)	2.72	0.04
Annual drain on forest land, average 2000–2004 (million cubic metre per year)	10.53	
Annual drain per hectare on forest land (m^3/ha)	1.13	
Volume of standing and lying dead wood (million cubic metre)	66.4	

[a]Standard error.

Table 26.3 The sampling design in different regions (counties)

Region number	Land area (1,000 ha)	Area represented by one field plot (ha)	Distance between clusters (km)	Distance between plots in a cluster (m)	Ratio permanent/ all plots
1. Østfold	418	180.0	3 × 3	300	0.20
2. Oslo – Akershus	537	296.7	3 × 3	300	0.33
3. Hedmark	2,739	899.1	3 × 3		1.00
4. Oppland	2,519	450.2	3 × 3	300	0.50
5. Buskerud	1,493	451.0	3 × 3	300	0.50
6. Vestfold	222	127.4	3 × 3	300	0.14
7. Telemark	1,532	449.9	3 × 3	300	0.50
8. Aust-Agder	921	302.9	3 × 3	300	0.33
9. Vest-Agder	728	226.6	3 × 3	300	0.25
10. Rogaland	914	75.0	3 × 3	200	0.08
11. Hordaland	1,563	150.0	3 × 3	200	0.17
12. Sogn og Fjordane	1,862	150.0	3 × 3	200	0.17
13. Møre og Romsdal	1,510	225.6	3 × 3	250	0.25
14. Sør-Trøndelag	1,883	301.9	3 × 3	300	0.33
15. Nord-Trøndelag	2,240	450.7	3 × 3	300	0.50
16. Nordland	3,833	300.0	3 × 3	250	0.33
17. Troms	2,598	300.0	3 × 3	250	0.33
18. Finnmark	4,864	Under preparation			
Total (permanent plots only)	32,376	≈900.0	3		1.00

26.4.1 Sample Plots

Multiple plot types are used in NFI9. The plot radius depends on the variable and, in some cases, also the value of the variable. Brief descriptions of plots used in NFI9 follow.

1. On forest and OWL, the radius of the sample plot for sample trees is fixed at 8.92 m (area 250 m^2). This plot type has been used for all permanent plots since 1994 for measuring trees with *dbh* $\geq$ 5 cm. Sub-sample trees are now being selected using an adjustable basal area factor that selects approximately ten trees on each sample plot on forest and OWL, when possible.
2. Temporary plots are circular with an area of 250 m^2 and include a smaller, inner plot with area of 100 m^2. All trees with *dbh* $>$ 200 mm are measured on the larger plot, whereas only trees with *dbh* $\geq$ 5 cm are measured on the smaller, inner plot. On temporary plots, all trees are considered sample trees for which only species is observed and *dbh* is measured. No sub-sample trees are measured on temporary plots because the same strata are represented by permanent plots.

3. For all permanent plots on forest and OWL, data for trees with *dbh* < 5 cm are collected in four sub-plots of radius 1.3 m with centres located 5 m from the plot centre in directions north, east, south and west.
4. Circular sample plots of radius 17.84 m (1,000 m^2) centred at centres of both permanent and temporary plots are used to assess area-related data such as land use type, crown cover, development class, site quality class. If a forest edge or stand boundary crosses the plot, the plot shape may be altered to obtain the minimum area of 1,000 m^2 within the stand.
5. "Environmental Inventories in Forests" also uses the NFI permanent plots, but areas of 2,000 m^2 (radius 25.23 m) around plot centres are considered. The 2,000 m^2 plot should completely or partially overlap a specifically defined environmental unit (habitat), in order to use the plot to assess the unit.

26.4.2 Management

26.4.2.1 Personnel and Equipment

The Norwegian NFI is a task of the Norwegian Forest and Landscape Institute. The number of field crews is currently about 30, each consisting of 1 or 2 (crew leader and assistant) persons. Usually, two-person crews work together on county inventories when measuring plots, whereas a one-person crew remeasures permanent plots for the continuous forest inventory. Until the early 1990s, field crews commonly consisted of three persons.

Field equipment generally consists of traditional inventory tools. Electronic devices include global positioning system (GPS) receivers, field computers and hypsometers (Vertex). The GPS receiver is used for orientation to the plots and for georeferencing of plot locations.

26.4.2.2 Quality Assurance

An essential part of quality assurance is the approximately one week annual training for field crews. During fieldwork approximately 4% of field plots are remeasured by a control team. This quality control check assessment is done by one of the most experienced field crews as part of its working time during the field season. The data are checked for the first time in the field computers using logical checks. Further logical checks are conducted daily using laptop computers indoors at location of the field crew lodging. The data are sent on diskettes to the Institute where further computer and manual checks are carried out during the field season. A final, thorough quality check is done during autumn and winter following the field season.

26.5 Estimation Techniques

26.5.1 Area Estimation

Area estimates are based on the total land and inland water areas, which are known or assumed to be error-free, and on the number of plot centres. In brief, the area estimate of a land stratum is the product of the known land area and the ratio of the number of sample plots in the stratum and the total number of plots. Because the number of plot centres on land is a random variable (depending on the design), area is estimated using ratio estimators (Cochran 1977),

$$a_s = A \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} = A \frac{\bar{y}}{\bar{a}}, \tag{26.1}$$

where a_s is the area estimate of the stratum s, A is the land area on the basis of the official statistics of the Norwegian Mapping Authority, y_i is 1 when the plot centre belongs to the stratum in question and 0 otherwise, x_i is 1 when the plot centre is on land and n is the number of plot centres on land. Examples of land strata are forest land, spruce-dominated forest land and forest land thinned during the last 5 years.

26.5.2 Volume Estimation

The stem volume of a tree in the Norwegian NFI is defined as the volume of the stem wood above stump to the top of the tree. Both volume under bark and over bark are calculated and stored in the database, but for national purposes volume under bark is commonly used. Growing stock includes stem volumes of all living trees, independently of species. For national reporting only the volume of trees with $dbh \geq 5$ cm is usually included, but from NFI9 it will be possible to report volume for all trees with $dbh > 0$ and minimum height of 1.3 m. Living and dead usable trees are measured for volume estimation in the same way. Note that the volume of lying dead wood includes the stem volume of all dead trees with minimum diameter of 10 cm and minimum length of 0.6 m. These thresholds are used when measuring dead wood but not for determining if the deadwood is usable for fuel wood. These measurements and estimates of dead wood are intended mainly for biodiversity assessment. The non-living part of standing volume is thus partly a subset of the dead wood volume and partly includes tree parts not belonging to the estimate of "total dead wood". A complete assessment of dead wood was carried out 1994–1998. Subsequently, only the trees that have died during the periods between two assessments of the permanent plots have been recorded.

The volume estimators are ratio estimators similar to the area estimators. Briefly, to obtain the mean volume for a given stratum, the mean volumes of all trees belonging to that stratum are added and the total is divided by the number of field plots in the stratum. The mean volume of a tree for this purpose is volume per hectare represented by the tree. The indicator variable y_i in the numerator of Eq. 26.1 is replaced with the volume per hectare represented by a tree, or the volume per hectare of timber class of interest represented by the tree, on field plot i when computing volume per hectare or total volume estimates. For total volumes, the volumes per hectare must be multiplied by the area estimate for the stratum in question.

Mean volumes (m^3/ha) and total volumes (m^3) are estimated as follows:

1. Volumes of individual trees and volumes by various strata are predicted for sub-sample trees (about ten in each sample plot) using volume functions based on *dbh* and *h*. These volume estimates are used directly in the following calculations. From the sub-sample trees, an average tariff is calculated individually for tree species classes spruce, pine and broadleaved trees occurring in the sample plot. Assuming a reasonably constant diameter–height relationship on the plot, volume can be estimated using only *dbh*. The volumes of sample trees are predicted by sample plots, applying the tariffs from the sub-sample trees.
2. Volume per hectare and total volume represented by each sample plot are calculated from volume per tree (and plot), sample plot size and area represented by each plot.
3. Mean volumes are tabulated by computation strata.
4. Total volumes are tabulated by computation strata.

In the case of partial plots (plots divided by a forest edge or stand boundary), each part is treated and stored individually, so (for example) a 30% part of a plot represents an area that is 30% of a full plot and is given a weight that is only 30% of a full plot when calculating mean volume.

26.5.3 Increment Estimation

Volume increment in the Norwegian NFI refers to the increase of stem volume under bark from the stump to the top of the tree. The annual volume increment is calculated as an average over 5 years, assuming a growing season from 20 May to 29 August and adjustments for deviations from five full growing seasons. The phases in calculating the volume increment of a stratum are:

1. Prediction of volume of sub-sample trees and sample trees on two different occasions
2. Calculation of the average increments for sub-sample trees and sample trees measured on two occasions as (volume occasion 2 – volume occasion 1)/5

3. Calculation of the increment of trees assessed only during the latest occasion (ingrowth, newly established plots) by estimating average values from trees on similar sites, of same tree species and dimensions
4. Calculation of the total increment on each sample plot by applying a methodology similar to that used for volume estimation (calculation of increment per hectare and total increment represented by the plot)

26.5.4 Drain Statistics Estimation

The total estimates of drain for Norway are currently only partly based on NFI data. Drain consists of the following components:

1. Cutting removals (data compiled by Statistics Norway)
2. Non-commercial roundwood removals, e.g. building materials and fuel wood from own forest used in dwellings (estimates based on survey by Statistics Norway)
3. Estimates of harvesting losses, including those arising from silvicultural measures (rough estimates)
4. Volume of unrecovered natural losses

The estimates of drain calculated by this method correspond very well to the estimates based solely on data from the permanent NFI plots. The disadvantages of using NFI data are that the estimates will describe an average for a 5 year period and that relatively few sample plots will have been subject to final felling during this period. Thus, from the NFI data, annual estimates cannot be provided, and regional estimates with a reasonable degree of reliability are also not possible.

26.5.5 Error Estimation

Error estimates are usually based on formulas traditionally used for random sampling under the assumption that they provide an adequate approximation to the errors for systematic sampling. For the sampling error of area estimates, the normal approximation of the binomial distribution (Snedecor and Cochran 1989) is used, and volume and area errors are combined in order to obtain the error of total volume estimates.

26.5.6 Specific Estimation Questions Related to LULUCF Reporting

NFI6 (1986–1993) was the last one where fieldwork proceeded by regions. Since 1994, the inventory has been continuous with all permanent plots remeasured every

5 years. For example, the reference year for data collected over the period 2001–2005 is 2003, and for the period 2002–2006 it is 2004. By using such a moving average, both annual land use changes and biomass changes have been estimated for the LULUCF reporting.

Norway uses the IPCC stock change method to estimate carbon stock change in living biomass. This method requires biomass carbon inventories for the forest area at two points in time. Biomass change is the difference between the biomass at time t_2 and t_1, divided by the number of years between the inventories. As described above, the reference year moves forward 1 year when data for a new season is included in the calculations and data for the oldest season is excluded. For the period 1990–1996 only, it was necessary to estimate an average over a number of years because of the change from regional inventories to the annual inventory of the entire country.

The carbon stock changes in litter, dead wood and soil organic matter are estimated with the Yasso model (Liski et al. 2005). Information about annual litter production from living tree biomass, natural losses of growing stock and harvesting residues are needed as input data for the model. Sub-sample tree level data measured in NFIs and Marklund's (1988) biomass models for tree elements are applied to estimate the annual litter production from living trees. The natural mortality of trees is based on model predictions.

26.6 Options for Estimates Based on Reference Definitions

Norwegian NFI is able to provide the most important area, volume and biomass estimates on the basis of the reference definitions (Table 26.4).

26.7 Future Prospects

The field measurements of the most recent inventory were conducted in 2005–2009, with the next rotation to be conducted from 2010 to 2014. Although the inventory is continuous and a fixed proportion of the permanent plots are surveyed every year, it has been an aim to keep variables and the design mainly constant during a 5-year period. Following the 5-year period, a more substantial revision of definitions and variables and, when necessary, the methodology, may be appropriate. The regional (county-based) inventory is, however, more clearly divided into cycles.

Significant changes are not foreseen for the 2010–2014 inventories. For many purposes, it is important to present a reliable time series of data. Thus, inventory systems, definitions, etc. should not be changed unless there is an obvious reason to do so. The northernmost county, Finnmark, has never been surveyed by the NFI because the commercial importance of its forests is very low. As previously mentioned, limited inventory work was started by the NFI in 2005. It is planned

Table 26.4 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Quantity	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	
Growing stock volume	Yes	Yes	NFI	
Increment of growing stock volume	Yes	Yes	NFI	
Above- and below-ground biomass	Yes	Yes	NFI, models	
Dead wood	Yes	Yes	NFI	
Litter	Yes		NFI, models	
Soil	Yes		NFI, models	
Afforestation, Deforestation, Reforestation (Kyoto 3.3)	Yes	Yes	NFI	
Naturalness of forest	Yes		NFI	
Forest type	No	No		Can be derived from NFI data
Occurrence and abundance of vegetation species	No	No		Vegetation type is assessed by the NFI, not individual species

to complete the inventory within a few years, and to cover all forests in this county as well, although with a lower sampling intensity than in the rest of the country. That would satisfy the requirements for carbon reporting, and also improve the quality of other forest statistics for international and national purposes.

Another issue that will be considered is the assessment of other lands with tree cover/trees outside the forest. A practically feasible method for the inventory of trees in parks, gardens and on agricultural land will be sought. Normal field sampling would be theoretically straightforward, but may involve a number of practical problems. Remote sensing methods are being evaluated to determine if they can provide a cost-effective and satisfactory solution.

There is still no final decision on how (or if) the regional (county-based) inventory will be continued although the most likely outcome is continuation in a manner similar to the current approach. The results from this inventory are mostly used by regional forest administrations, forest owners' associations, etc., and the focus is mainly on timber resources. To limit the expenses somewhat, it may be possible to restrict the area to that available for wood supply and also to carry out a more careful selection of variables to be collected in the field. With regard to the sampling design, one option may be to apply the same intensity everywhere, instead of varying the number of sample plots per cluster according to the total forest area of the county. The final decision on the regional inventory will be taken in cooperation with regional and central forest authorities.

26.8 The Influence of COST Action E43 and Related Projects

Norway's ongoing inventory was planned and started at an early stage of COST Action E43 when no results were available. However, some new variables have been introduced, and some modifications of field instructions have been made over recent years in order to meet the international requirements. Examples are definitions of forest and OWL, naturalness and assessment of trees with *dbh* ≥ 0 cm which are all consistent with the conclusions from COST Action E43.

Because the next main revision of our field instructions will take place prior to the 2010 season, the recommendations from COST Action E43 will be carefully checked to see if there is a need for including the more specific details from COST Action E43 definitions and descriptions. A complete assessment of dead wood has not been carried out since the mid-1990s. In this case the recommendations, threshold values etc. by COST Action E43 may be directly adopted.

International definitions are often rather "open" and leave many details to the correspondent for judgement. COST Action E43 has helped reduce the need for such judgement and will provide more firm guidance.

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Chapter 27
Poland

Roman Michalak and Stanisław Zajączkowski

27.1 Introduction

The beginnings of modern forest management planning date from the end of the eighteenth century; the oldest existing Polish forest management plan originates from 1793. For many reasons (including frequent wars and changes of national borders) there had been no uniform inventory system for the whole of the present Polish territory. When considering the evaluation of forest resources and their dynamics, national level activities that were initiated shortly after World War II should be considered. As a result of the ownership structure in place at that time, the prevailing majority of forest area became the state property. The relative uniformity of the ownership enabled application of regular, standardized inventories oriented for forest management plan preparation. These inventories were supported by additional information for private forests for a couple of decades had been considered sufficient for national forest resource assessment purposes. Because this system is still being applied, the first part of this paper briefly introduces this concept. The periodic inventories intended for forest management planning were supported by occasional inventories and monitoring (i.e. large area inventory, forest health state inventory) that assessed the condition of Poland's forest. The initial contemporary National Forest Inventory (NFI) was carried out in the 1990s. As a result, entirely new methodologies were elaborated, according to which the first cycle of this inventory has been carried out since 1995. In this paper, the main characteristics of the inventory are presented, accompanied by information on practical arrangements for its application.

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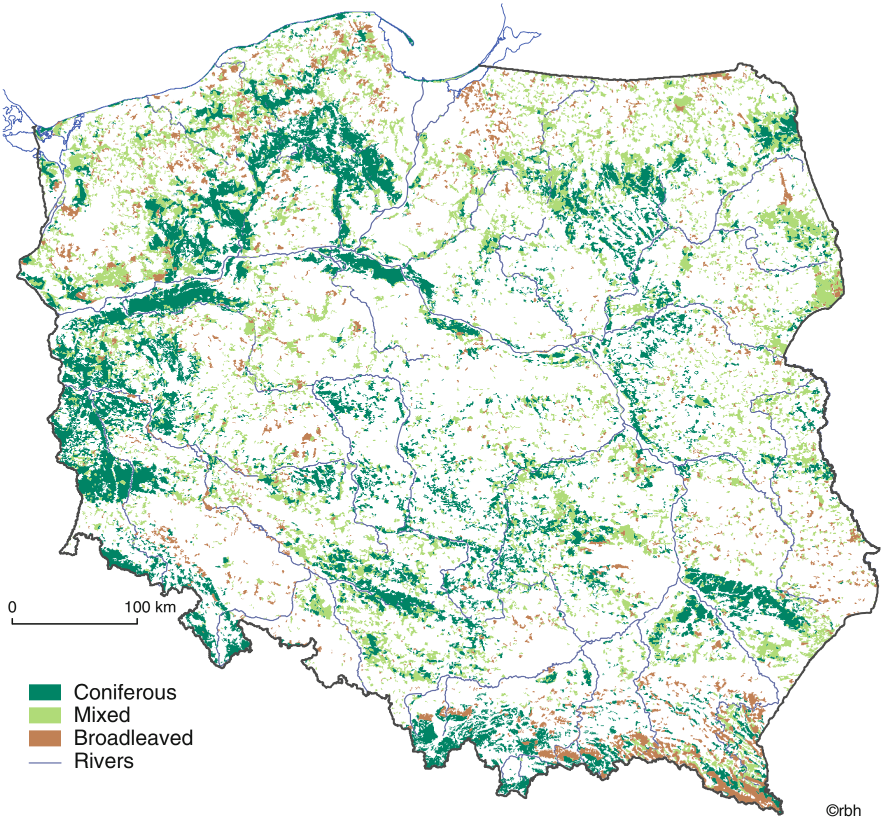

Fig. 27.1 Tree species composition of Polish forests

27.1.1 Forests in Poland

Forests cover 30.1% of the country's area, i.e. 9.23 million hectare. Although the area under forest increases consistently (332,000 ha in the period 1990–2006) the forest cover of Poland is still less than the target forest area set in the national forest policy (Polityka Leśna Państwa 1997). Due to Poland's relatively high population (38.13 million), the mean area of forest per inhabitant is approximately 0.24 ha. The main remaining land use categories are arable land (39.8%) and grassland (11.2%) (GUS 2007).

Coniferous species are the dominant species group (75.6%) in Poland's forests (Fig. 27.1) with pine comprising 67.4% and spruce and fir 8.2%. Broadleaved species account for the remaining 24.4% of forest area (oak 6.7%, beech 5%, birch 6.3%, and alder 5.3% mainly). Despite the increase of broadleaves compared to Poland's forests in 1945 (11.4%), their occurrence is still lower than this, which would respond forest site types (State of Forests 2007).

The total growing stock in 2006 was 1909 million cubic metre, an increase of 821 million cubic metre since the growing stock evaluation in 1967. The average standing volume of forests grown by the State was 231 m^3/ha, whilst in private sector forests it was 119 m^3/ha (State of Forests 2007). The total over-bark volume increment available for wood supply is approximately 67.6 million cubic metre, or approximately 8.0 m^3/ha (MCPFE 2007).

The level of wood harvesting expresses the intensity of the forest economy. This level was recently recorded as 30,228 million cubic metre measured under bark, giving an index of about 3.35 m^3/ha (GUS 2007). The ratio of harvest size to increment size is about 0.55 which assures a continual increase in forest resources in Poland (MCPFE 2007).

The share of forestry in the GDP is 0.32%. Employment in recent times has decreased, currently 47,000 people, in which 26,600 are employed in private sector (GUS 2007).

27.1.2 National Forest Resources Assessment Based on Stand-Wise Inventory

27.1.2.1 Stand Level Inventory Development

According to national forest legislation, forest management has been pursued in accordance with a forest management plan for forest properties other than those belonging to the State Treasury. The management plans are devised (Forests Act 1991) in line with the principles of the general protection of forests, sustainable maintenance of forests and the continuity of their use taking into account diverse forest functions and forms of nature and landscape conservation including the increase in forest resources.

In the course of creating the forest management plan in each forest district, an inventory is carried out every 10 years. The first (provisional) whole-country forest inventory was started in 1946 (Głaz et al. 1997). The first Polish instructions on forest management planning had essential significance; terms and definitions provided the basis for the system that is still in use today. In accordance with those instructions, the so-called “basic forest inventory” was carried out in 1956–1967. Subsequent versions of the instructions served further inventories starting in 1967 (first revision), 1979 (second revision) and 1992 (third revision). The current, fourth revision, began in 2003 and is intended to be completed by 2010.

Instructions, including the inventory methods, evolved along with the changes in societal expectations on the role of forests as well as the development of forestry research. The very first inventory cycles assumed a description of individual stands and a visual evaluation of growing stock by inventory specialists. During NFI2 and NFI3, statistical methods for stand volume estimation using randomly located circular or angle-count plots in stands older than 40 years, supplemented by other methods (intentionally located plots and diameter at breast height measured on each tree) were applied. The inventory method elaborated for the ongoing, fourth revision, is based on statistically representative sampling of the timber resource using age and species strata within the each district. This method is applied to stands of 20 years of age and older. Contrary to the previous revisions circular, temporary sample plots are being commonly established with this method (Smykała and Zajączkowski 2004).

Inventory methods applied in the forests outside State Forests National Forest Holding (SF NFH) are different. Compared to the complex measurements performed in national parks, the prevailing method is a visual assessment with the use of yield tables, a common practise in private forests.

27.1.2.2 National Forest Resources Assessment Methods and Results

The forest ownership structure that emerged after World War II characterises the vast prevalence of forest owned by the State Treasury. Public-owned forests constitute about 82.2% of the total. More than 7 million hectare (i.e. 78.2% of total forest area in Poland) are administered by SF NFH which currently consists of 428 forest districts grouped in 17 Regional Directorates. The area of private forest amounted to 1.61 million hectare and belongs mainly to individuals (about 94%) (GUS 2007).

Due to the standardized forest inventory procedures used within SF NFH, and to some extent in the remaining forest areas, stand level inventory data were considered sufficient for assessing national forest resources. The method applied for the SF NFH relies on aggregation of stand inventory data. In the second step, aggregated data is updated, taking into account year of data origin. For that purpose yield tables are used as source of gross wood increment, whilst data on removals are used for drain evaluation. For forests outside of the SF NFH, simplified aggregation procedures were applied. The result is that basic information on forest area and growing stock can be derived and reported for the whole country or regions. A standard format for reporting the data enables age structure and tree species composition to be seen clearly.

The results are published on annual basis; however since 1999 the so-called “Forest area and growing stock update” has included forest managed by the SF NFH only, for the remaining areas a simplified assessment has been carried out. Since 1967, the year of the first comparable update, a continuous increase in growing stock has been observed. According to this source, Polish wood resources increased by about 75% in 1967–2006 period (Fig. 27.2), (State of Forests 2007).

Further analyses, elaborated with the use of annually updated results, indicated that the overall increase in growing stock only partially resulted from an increase in forest area. The recorded increase must be also attributed to both change in the age structure of forests and stocking level increases within age classes.

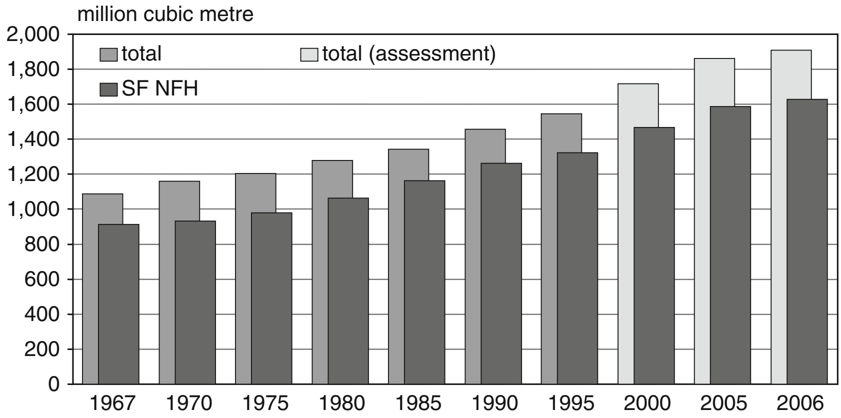

Fig. 27.2 Wood resources in Poland in 1967–2006 period (million cubic metre of merchantable timber)

27.1.3 National Forest Inventory in Poland

27.1.3.1 NFI Development

Damage on a large scale and the worsening health of the Polish forest resource in the beginning of the 1980s forced Polish forestry to carry out large area assessments of forest health in a short time period. These "large area forest inventories" were carried out in forests managed by SF NFH. In total five inventories were performed with the first carried out in 1983 and the last completed in 2001.

All these inventories covered stands older than 20 years. In each of the 17 Regional Directorates, approximately 1,300 circular, temporary sample plots were systematically placed. Sample plot areas varied depending on stand age. Using these plots, the volume of the dead trees, with a standard error of 15% at a 0.95 confidence level, was expected to be obtained. Results for the country were compiled as a sum of the results from the Regional Directorates. In 1991, over 23,000 temporary sample plots were put into SF NFH forests. The total volume of dead trees was estimated with a standard error of 4%. Total growing stock in forests managed by the SF NFH was estimated as 1.4 billion cubic metre with a standard error of 0.6%.

27.2 The Use and Users of the Results

It is expected that the NFI1 will be completed in 2009, therefore only planned application of the inventory results can be characterised now. Results of the NFI are intended to serve as an information source for three types of reports: (1) detailed results of the inventory, (2) generalized information for national decision makers, and (3) popular results for the public. Collected data will constitute the basis for a national data bank on forest resources and forest conditions in Poland. At the same time NFI results will contribute to national and international statistical publications and reports on the state of forests and their changes at regional and national levels. Finally, the NFI will be a key source of information for estimating indicators of sustainable forest management.

27.3 Sampling Design of the New NFI

The unsatisfactory quantity and quality of information on forests outside the SF NFH, and an increasing demand for new and more detailed information about forest ecosystems, created the need for an entirely new inventory. In the course of research and development work initiated in the last decade of the twentieth century, methods applied in temperate and boreal countries were analysed and selected methods were tested in Polish conditions. The final outcome refers to the best relevant solutions adapted to national circumstances as well as including original measurement methods (WISL 2004).

Following some general assumptions, the main goal of the new inventory is the assessment of the forest's state and its change through the application of relevant indicators at national and regional levels. The new inventory is a cyclic delivery of credible (with known accuracy) information on forests, starting from basic characteristics of woody biomass (volume, increment, fellings, mortality) and ending with specialised observations. The new inventory covers all forests in the country independently of type of ownership and stand age. The new method enables analyses by:

- Ownership forms
- First level units of administration and natural divisions
- Age, species and vertical structure of forest resources
- Protection and conservation forms, forest functions

Observations and measurements are carried out in permanent sample plots arranged into clusters and placed on tracts similar to the letter "L". Clusters are located systematically throughout Poland using a 4 × 4-km grid. Within each cluster, five plots are located with a 200-m distance between plots. All clusters are planned to be measured during a 5-year cycle with 20% of the clusters measured annually. Clusters are grouped into blocks of five (Fig. 27.3) so that measurements and observations may be obtained for one cluster per block each year.

About 28,000 sample plots will be established by this new sampling design in Poland's forests. Further, it is expected that the method will produce estimates of growing stock at country level with an standard error of 0.9%; standard error of estimates at the regional level will vary from 1.7% to 3.7%, depending on region's area (at the confidence level 0.95).

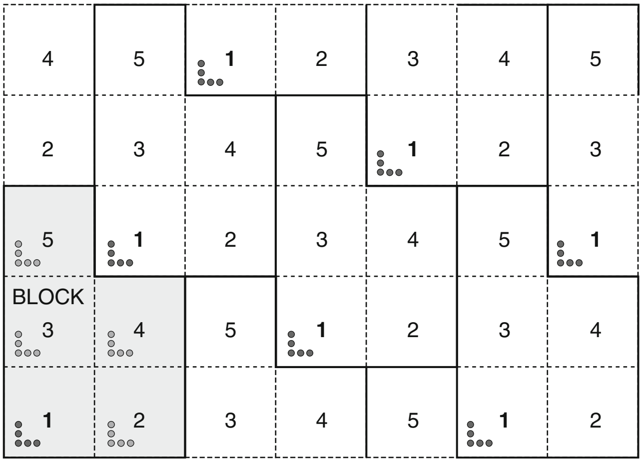

Fig. 27.3 General scheme of inventory, number indicates the year in a cycle (WISL 2004)

27.3.1 Sample Plots

Measurement of forest resources is performed on two circular, concentric sample plots, designated A and B, whose areas are adjusted according to the forest parametres being measured. In the A-type plots, general stand variables are assessed. Subsequently all standing trees, living or dead, with diameter at breast height (*dbh*) greater or equal to 70 mm are inventoried. Additionally lying deadwood and stumps are included in the measurements at this type of plot. The area of the A-type plot can be 200, 400 or 500, depending on the stand's features. B-type plots have areas of 20 m^2 and are intended to be applied for measurements and observations of trees and bushes with $dbh < 70$ mm.

27.3.2 Scope and Structure of Information Collected by the NFI

Location data, including plot identification numbers, geographical position and information on administration and natural units, are collected first. Then the basic characteristics of the sub-compartments in which the sub-plots were established are collected. Features of the forest within the circular plots are evaluated independently from those characterising the whole stand. Whole stand information includes type of ownership, land use, general tree-stand characteristics, observed economic activities, damage and forest site features.

27.3.3 Assessments on Trees with dbh $\geq$ 70 mm

For all trees (and bushes) meeting the minimum size criteria, distance and azimuth from the sample plot centre are measured. Each tree is classified according to the forest layer, for which mean age is estimated. Measurements include *dbh*s of all trees and heights of selected trees.

27.3.3.1 Tree Damage

For all sample trees, all damage as well as the symptoms of any damage and the pathological changes were recorded. Within this group of information the damage type (e.g. decay of shoots and buds, wood decomposition, root system damages, cankers, open wounds), locality and intensity are recorded. Additionally the length of a crown (in relation to tree height) and its completeness (comparing its potential volume) are evaluated as indicators of tree vitality.

27.3.3.2 Dead Wood

Dead wood inventory is performed in the A-type plot and encompasses measurement of stumps, and standing, broken, cut or fallen trees. Additionally the dead parts of stems, branches and tree tops, within the limits of the sample plot, are included in the measurement program. For each type of deadwood, detailed instructions for locality, volume measurement and decay level assessment were elaborated (Fig. 27.4).

27.3.4 Information for Trees with dbh < 7 mm

Trees and bushes that have not reached 70 mm *dbh* are inventoried in the B-type sample plots (20 m^2). Tree and shrub cover in the area are first evaluated in a general way (cover type and cover level), then a detailed inventory is carried out. For this purpose plants were divided into three groups:

- Height < 50 cm
- Height $\geq$ 50 cm and *dbh* < 30 mm
- mm $\leq$ *dbh* < 70 mm

For each of these categories, detailed instructions for measurement and assessment were prepared. Additionally the kind and intensity of observed damaged is evaluated for tree species within this type of plot.

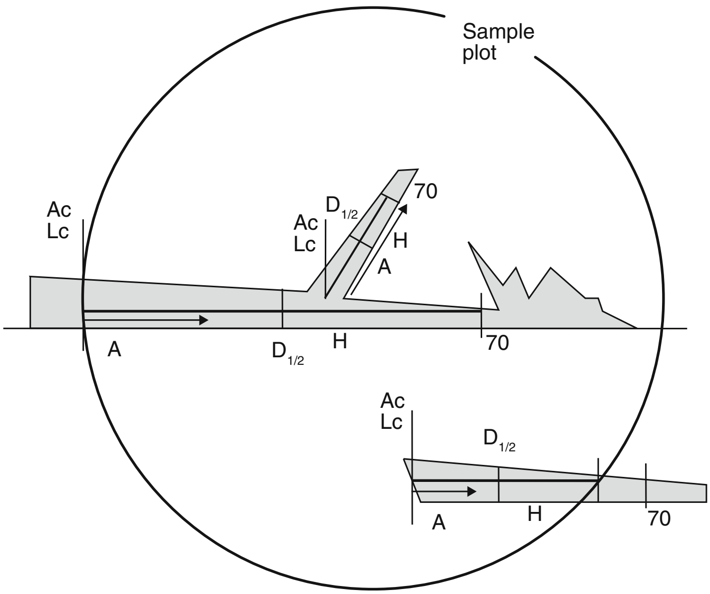

Fig. 27.4 Example scheme for measurement of trees and logs (WISL 2004)

27.4 Management

According to the Forest Act (1991), the Office of Forest Management Planning and Geodesy (OFMPG) is the unit responsible for the NFI in Poland. OFMPG is a state owned enterprise consisting of the central management unit and 12 regional divisions distributed throughout the country. The NFI in Poland is jointly financed by the State Budget and SF NFH on the basis of an agreement between the General Directorate of SF NFH and OFMPG which covers the entire 5-year cycle.

27.4.1 Personnel and Equipment

Field work is carried out annually by 65–68 teams, each with two persons, that are created by all OFMPG regional divisions. Inventory teams consist of the most experienced inventory specialists, having at least several years' field practice. Each inventory year is preceded by training organized in two phases. The first phase at the central level is followed by courses organized within each of the regional divisions of the OFMPG. Equipment for inventory teams includes all necessary tools, typical for the required measurements, including compasses, measuring tapes and laser range makers supplemented by global positioning system (GPS) receivers for determining sample plot locations. Sample plot boundaries are established with the use of *Forestor* laser range makers and tree height measurements are estimated using *Vertex* or *Suunto* devices. Standing and lying trees and their component parts' diameters are measured with the use of traditional calipers to an accuracy of 1 mm. Metal detectors are used by the controlling teams to locate sample plots.

27.4.2 Quality Assurance

Quality assurance of the field work is performed at several stages. The first is performed by the inventory team leader and includes checking the completeness of the measurement records as well as re-measurement of a random sample of tree positions. Since 2007, data are recorded using palm top data recorders which enables application of on-line formal and logic quality control checks of collected data, e.g. on the scope of applied codes and inter-connections between collected data, which increases the accuracy of measurement and recording. The second stage of the quality assurance process encompasses quality control measurements carried out on 4–5% of sample plots by OFMPG's own staff (inspectors from regional and central units). Finally measurements and observations on a similar number of plots are verified by external specialists from the SF NFH (within the 17 regional directorates of State Forests).

27.5 Integration of the NFI and Forest Monitoring

Observations on permanent sample plots were started in 1989 in accordance with the methodology of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). About 1,500 sample plots were placed in stands older than 20 years and composed of the main tree species, of these samples plots, 433 also provide data to the European Monitoring System. Moreover, in some of the plots additional variables were measured including soil condition, activity of insects and occurrence of fungi. However, the 433 plots for the European Monitoring System were not located using any systematic design.

Development of the new NFI methodology provided an opportunity to more closely link the NFI and forest monitoring. Following this approach, a decision was taken that the central plots of the clusters in the 16 $\times$ 16-km grid will be simultaneously measured in agreement with ICP Forests methodology. Subsequently an 8 $\times$ 8-km grid will be applied for increasing the forest monitoring sampling intensity as a means of collecting data for the preparation of national analyses (Fig. 27.5). Observations at National Forest Monitoring plots have been carried out annually since 2005 using a general methodology for collecting data on defoliation, and discoloration of foliage.

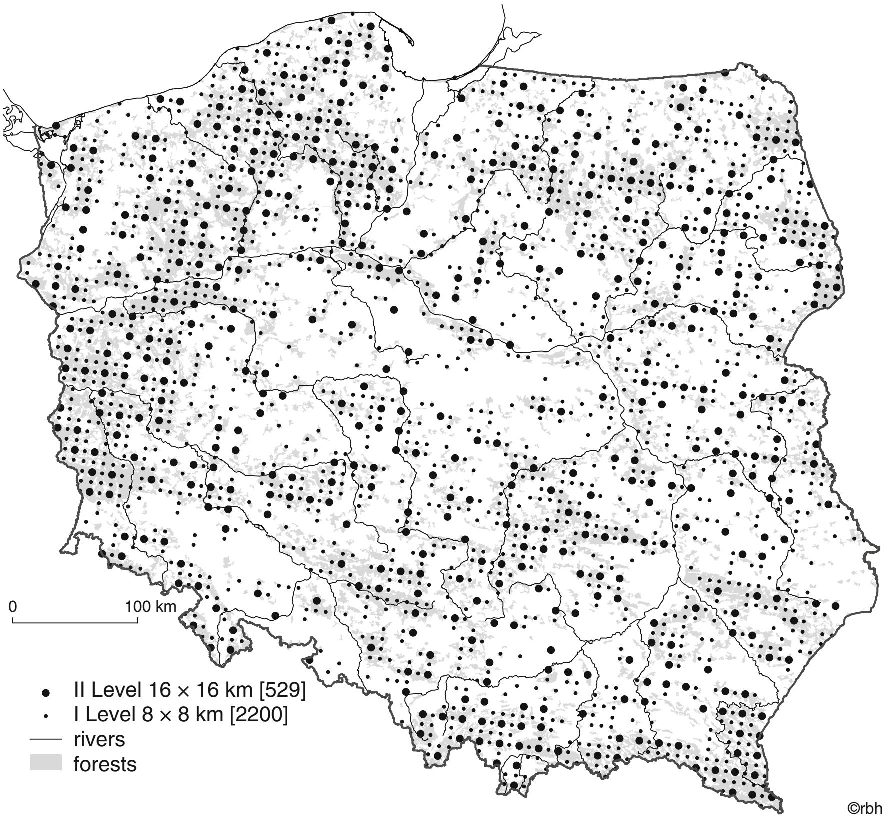

Fig. 27.5 Spatial distribution of monitoring plots in Poland's forest

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Chapter 28
Portugal

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28.1 Development of Portugal's National Forest Inventory

Of the 8.9 million hectare of continental Portugal, approximately 38% (3.4 million hectare) is covered with forestas (DGRF 2007). The main species are maritime pine (*Pinus pinaster* Aiton.), eucalyptus (*Eucalyptus globulus* Labill.) and cork oak (*Quercus suber* L.). These species appear mostly in pure stands. Maritime pine stands dominate the central part of the country north of the Tagus river, cork oak stands can be found mainly south of the Tagus river, while eucalyptus is spread along the coast and in the Tagus River basin (Fig. 28.1).

Forests are mainly privately owned (73%), with small percentages belonging to the state (3%). Communities and industry hold equivalent shares of forest land, 11% and 10%, respectively. The remaining 3% belong to a group designated by "other owners" which includes landowner's associations, charitable institutions, the church and municipalities (Baptista and Santos 2005). In general it can be said that the great majority of forest properties (owned by the same land owner, not always coinciding with the management unit) is of small size and quite fragmented. According to Baptista and Santos (2005) 67% of the landowners own properties smaller than 5 ha and only 2% of them own properties with more than 200 ha. The physiographic differences between the north and the south of Portugal (the north has 95.4% of the areas with altitudes higher than 400 m) (Ribeiro 1967) result in distinct property sizes between north and south.

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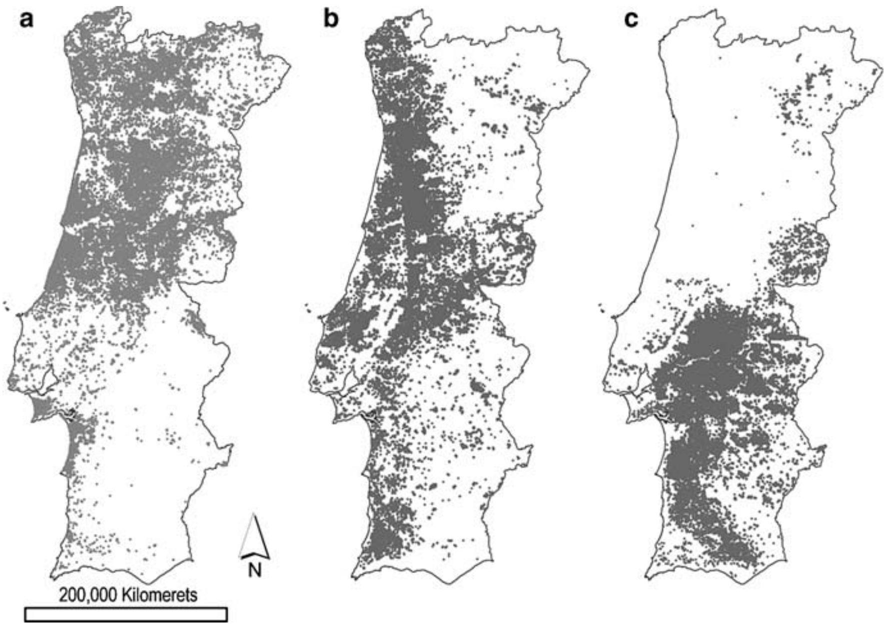

Fig. 28.1 Distribution of the photo-interpreted plots in 2005 NFI5 for the three most important species in continental Portugal: (**a**) maritime pine, (**b**) eucalyptus and (**c**) cork oak

28.2 Historical Overview

The National Forest Inventory (NFI) has been functioning on a permanent basis since 1965. From this year on, with a periodicity of approximately 10 years, NFI information has been updated throughout the collection and processing of new data. The updates have been traditionally designated as Revisions. Nevertheless, and because each Revision is based on an entirely new sampling design (there are no permanent plots) it should in fact be seen as a new NFI. Until the present, Portugal has had five NFIs.

The first NFI (NFI1), conducted on a national level, took place during the years of 1965 and 1966, as a result of the common interest of the Portuguese National Forest Service (Direcção Geral dos Serviços Florestais e Aquícolas – DGSFA) and the pulp and paper companies. DGSFA was responsible for the inventory south of the Tagus river (except for some counties in the Santarém district), while private companies were in charge of the inventory north of the Tagus river. In the region north of the Tagus river the inventory was based on panchromatic aerial photography obtained from 1963 until 1965, with a scale of approximately 1:15,000. On the other hand, in the region south of the river, the inventory was based on the Agricultural and Forestry Areas Map (Carta Agrícola e Florestal) which was corrected and updated through the delineation of the new areas afforested with eucalyptus (DGF 1999). The main objective of NFI1 was to evaluate the area, volume and increment of maritime pine and eucalyptus stands as well as their distribution by administrative regions (distritos). The results of this first inventory were published by administrative regions and also for some specific counties (concelhos).

The inventory's first Revision (NFI2) was entirely the responsibility of the Portuguese National Forest Service (Serviços Florestais) and aimed to update the information produced by NFI1. It was started in 1968 with the inventory in the region south of the Tagus river being based on new infrared aerial photography at the scale of 1:15,000. From 1974 to 1980, new aerial photography was produced for the regions north of Tagus river. In the course of this inventory all maritime pine and eucalyptus stands were sampled in the whole country to obtain new volume and increment estimates. As a result of this work, a Forest Inventory Map was produced at a scale of 1:25,000, representing the Portuguese forest cover for continental Portugal.

The third NFI (NFI3) was also carried out by the National Forest Service (Direcção Geral das Florestas – DGF) between 1980 and 1989 using new aerial photography coverage of the country obtained by administrative region. The aerial photographs were photo-interpreted by strata (with total delineation), and forest area was estimated by qualitative sampling instead of direct measuring on correct maps. Consequently, results were published by administrative region but not by county. During this inventory, *Quercus suber* stands as well as evergreen oaks (*Quercus* spp.) were the object of field work for structure and stands health condition evaluation and was restricted to the administrative regions where they were more abundant (DGF 2001). During this period, and as a result of the cooperation between DGF and the Association of the Pulp and Paper Industries (Associação das Empresas Produtoras de Pasta de Celulose – ACEL), an expedited inventory took place resulting in updated estimates of area and standing volume for maritime pine and eucalyptus stands by geographical region. This inventory was based on panchromatic aerial photography from 1985. The photographs cover the country partially in strips separated by 10 km.

The fourth NFI (NFI4) was conducted in the 1990s, lasted for an entire decade and was undertaken in two distinct phases. Phase 1 resulted in the '1990 Land Use Cartography' (Cartografia de Ocupação do Solo – COS'90) which was produced based on aerial photography from 1990 on false color infrared film. The 1990 aerial photography, belonging both to the National Forest Service (Instituto Florestal) and ACEL, was photo-interpreted by strata delimitation. In cooperation with the National Geographical Information Center (Centro Nacional de Informação Geográfica – CNIG) photo-interpreted strata were digitalized and new 1:25,000 approximate land use cartography was produced. Based on this cartography, the National Forest Service together with ACEL carried out field measurements in eucalyptus and maritime pine stands between 1991 and 1992 to estimate volume for both species and increment for pine. This phase was motivated by the need for recent forest information as the result of forest wildfires and eucalyptus expansion. During this updating, sampling intensity was not as high as in the previous NFI and therefore the results were not presented by administrative region, but rather by the three geographical regions: north, centre and south; a smaller number of strata were also considered (Tomé et al. 1997). Phase 2 corresponds to the so-called inventory which, in general terms, aimed to update the information resulting from the previously collected one. The inventory was planned at the same time as the 3rd Ministerial Conference on the Protection of Forests in Europe (MCPFE) was being held in Lisbon, and it was considered of major importance to perform an analysis on the Portuguese forest biodiversity. More specifically, this inventory intended to fulfill the following objectives: evaluate different land use areas; produce small scale land use cartography (1:1,000,000); evaluate stand structure taking into account the shrub strata and the use of vegetation diversity models; evaluate the standing volume, growing stock, and the production of non-wood goods such as cork, resin and acorn; and finally evaluate erosion, evidence of fire and vitality at stand level (DGF 2001). Phase 2 lasted 6 years and comprised the following steps:

1995	Aerial photography production
1996–1997	Photo-interpretation and area evaluation
1997–1998	Field measurements
1999–2000	Preliminary data processing
2000–2001	NFI information system creation
2001	Publishing of the results

The production of new false color aerial photography (1:40,000) resulted from cooperation between the National Forest Service (Direcção Geral das Florestas – DGF), the CNIG and the Association of the Pulp and Paper Companies (Associação da Industria Papeleira – CELPA). The forest areas updating was based on the photo-interpretation of enlarged photographs (1:10,000) resulting from the 1995 aerial photography by qualitative small plot sampling. Standing volume and increment (when applicable) estimation were also obtained for the most important tree species. Five different hierarchical land use categories were established, and area estimates were based on a 130,000 dots sample uniformly covering continental Portugal. Land use areas were evaluated in the Nomenclature of Territorial Units for Statistics (NUTS) by NUTS 1, NUTS 2 and NUTS 3 level (Tomé et al. 1997).

Aerial photographs were systematically sampled. One out of three photographs was sampled in every other flight line. A systematic grid of eight photo plots (cluster) was applied to each of the sampled photographs. This sampling corresponds to a grid of 4.2 × 5.7 km. Simple fixed-area circular photo plots were applied on 1:15,000 photographs. Each photo plot was classified according to the strata within an area of approximately 2,000 m^2 with the small plot in its centre corresponding to about 9 mm^2 on the photograph. All plots were temporary.

There was neither a field plot grid nor a systematic distance between field plots. They were systematically selected out of the interpreted photo plot list by stratum in proportion to the number of plots and the number of photo plots in the stratum. Field plots were marked on the aerial photographs and field locations were selected using both the photograph and a respective 1:25,000 scale map. As the field crew approached the plot, its location was determined by azimuth and distance measurement on the photograph and in the field. This method implies determining the scale of the photograph somewhere close to where the plot centre is located.

Stand evaluation in terms of structure, production and vitality was achieved through field work on 2,211 field plots distributed by nine types of forest stands all over continental Portugal. In each plot a wide set of measurements was made and other non-measurable information was gathered according to the field manual (DGF 1999).

The plots were designed as concentric fixed-area circular plots. In the inner circle (250 m^2) all trees with a diameter at breast height (*dbh*) $\geq$ 7.5 cm were measured. In the intermediate circle (500 m^2) all trees with *dbh* $\geq$ 17.5 cm were measured and in the larger circle (1,000 m^2) all trees with *dbh* $\geq$ 27.5 cm were measured.

Trees with 5.0 cm $\leq$ *dbh* $\leq$ 7.4 cm were counted on five small sub-plots of area 20 m^2 each (regeneration plots) within the perimeter of the NFI plot. The centre of the central regeneration plot matched the centre of the NFI plot, while the other four were 10 m from the centre in the cardinal directions. In each of the five sub-plots mean height and age of the trees were also estimated. The presence of regeneration below the 5 cm *dbh* threshold was also registered as well as an age estimate (DGF 1999).

Plots were delimited using a Blume-Leiss hypsometer and two circular references placed in a tube in the centre of the plot conveniently set apart from each other according to the area of the plot. Border maritime pine trees were considered to be included in the plot if half of the section of the tree at *dbh* height was inside the plot limits. Trees exactly on the border line of the plot were alternately considered in and outside the plot. All eucalyptus trees were included in the plot as long as any point at the base of the stem or coppice stool was inside the plot perimeter (A coppice stool is a stump with the ability to re-sprout.). Slope was corrected by adjusting the distance between the two circular references in the tube (DGF 2001).

There was an intention of transforming NFI4 plots into permanent plots. Therefore the five trees closest to the centre had their azimuth and distance to the plot centre annotated, and border trees were marked at eye level so that the mark could be seen from outside the plot.

A preliminary analysis was performed on field data followed by the development of the NFI information system, implemented on SQL Server database, which allowed storing, organizing and processing the information (DGF 2001).

The information produced during photo-interpretation was processed in a geographic information system (GIS) using the Thiessen Polygons method resulting in two sets of 1:1,000,000 maps for continental Portugal: Land Use Maps and Stand Type Distribution Maps (DGF 2001).

During all the inventory process quality control procedures were applied to data checking, processing and documentation of data, methodologies and terms.

28.2.1 The National Forest Inventory at Present

As a result of the vast area affected by wildfires in 2003 and 2005 it was crucial to obtain area and volume information for the main wood production species, maritime pine and eucalyptus. Therefore, the main objective of NFI5 was to evaluate and monitor national forest resources producing reliable information for establishing policies, plans and projects aiming at the sustainable management of national forests (Tomé et al. 2007e). In 2005, according to the National Forest Service (Direcção Geral dos Recursos Florestais – DGRF), the forest inventory had the following objectives:

- Evaluating the areas and spatial distribution of different strata
- Characterizing forest stands in terms of development phase, volume, productivity, non-wood goods' production, namely cork and pine-nut
- Characterizing vegetable biodiversity in forest stands
- Evaluating the forest health condition, signs of erosion and signs of fire in forest stands

Similarly to what had happened in the past, NFI5 was carried out in cooperation with the Portuguese Association for the Pulp and Paper Industries (CELPA). New aerial photography resulted from flights that took place in 2004, 2005 and 2006 covering the whole country at the same time as field work was being done (Tomé et al. 2007e). There are some important things to point out concerning this inventory:

- Set of dot grids (0.5 × 0.5-km, 1 × 1-km, 2 × 2-km) to be used in national and regional inventories was created.
- Field manual was prepared based on the previous manuals which allowed estimating most of the sustainable forest management indicators established in the MCPFE Conferences held in Lisbon (1998) and in Vienna (2002) (MCPFE 2003).
- Set of prediction models was adopted or developed to estimate volume and biomass.

28.3 The Use and Users of NFI Results

28.3.1 General Use

Presently, the information resulting from the NFI has various users and uses. The main users are governmental agencies, local and central public administration, forest industries and enterprises as well as international organizations such as the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Economic Commission for Europe (UNECE), and the European Union.

In past years, other groups such as scientists, researchers, professors and students from diverse areas such as economics or natural resources; environmental organizations; stakeholders and NGO's have shown an increasing interest in NFI results. Working groups related to biodiversity, climatic changes and desertification as well as those related to sustainability issues also increased the demand for NFI results (DGF 2001).

The information produced covers a wide range of possible uses. NFI information is often used as a supporting tool for policy making and as the basis for the development of planning and management tools. In the same manner, this type of information is vital when providing answers to national and international inquiries (e.g., for the Temperate and Boreal Forest Resources Assessment (UNECE/FAO 2000)) and for the development of Master's theses and PhD studies (DGF 2001).

28.3.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

As Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, Portugal established the National Inventory System of Emissions by Sources and Removals by Sinks of Air Pollutants – SNIERPA by the 17 March 68/2005 Ministers Council's Resolution. The National System contains a set of legal, institutional and procedural arrangements that aim at ensuring the accurate estimation of emissions by sources and removals, by sinks of air pollutants, as well as the communication and archiving of all relevant information. At an institutional level it defines the entities relevant for its implementation, based on the principle of institutional cooperation, and considering that the clear allocation of responsibilities is essential to ensure that inventory takes place within the defined deadlines (IA 2006).

28.3.2.1 National System and Articles 3.3 and 3.4

According to the Environmental Institute (IA) now called Agency for the Environment, the focal points and the entities involved, through the Portuguese National System (SNIERPA), in the process of defining the methodology for the identification of the areas and calculation of emissions/removals associated with activities of the Articles 3.3 and 3.4 are:

- The Agency for the Environment (APA)
- The Environmental Audit from the Ministry of Agriculture
- The Rural Development and Fisheries (AA-MADRP)
- The National Forest Service (DGRF)
- The Portuguese Geographical Institute (IGP)
- The National Statistics Institute (INE)

These entities have agreed on the most appropriate methods for the fulfillment of the additional information reporting obligations under Article 7.1 of the Kyoto Protocol dictated by the Articles 3.3 and 3.4 (afforestation, deforestation and forestry management). Other experts involved are the Superior Agronomy Institute (ISA), the Superior Technical Institute (IST), Évora University (UÉ), National Institute for Intervention and Cropland Guarantee (INGA) and Rebelo da Silva's Laboratory. They contributed with their expertise and advice making available the necessary information.

28.3.2.2 Forest Management and Article 3.3 Activities

Data gathered during NFI5 was to be used to characterize forest areas in terms of biomass, age of trees and tree fellings or forest wildfire occurrences in previous years (Tomé et al. 2007e). The information that will be gathered from the subsequent NFI's may be used to assess the changes in biomass during the first commitment period (2008–2012).

Land Use Maps

Work is ongoing to improve the 1990 Land Use Map (COS'90) with 1 ha resolution, so that it can be used to estimate land use coverage for 1990. A new Land Use Map will be produced (COS'05) based on the NFI5 aerial photography. On one hand, COS'05 will allow assessment of forest, agriculture and grazing land areas in the beginning of the first commitment period (2008). On the other hand, it will facilitate the identification of afforested/reforested and deforested areas between 1990 and 2008, which will be classified under the scope of Article 3.3. NFI5 plot description data will be used as support information throughout the procedure.

Burnt Areas

During the commitment period, DGRF intends to detect forest fires through satellite images which will be used to identify burnt areas. Even though 5 ha is the minimum area to be identified this will not result in significant errors, because the extent of burnt areas is usually considerably larger.

Harvested Areas

Tree fellings can be assessed by the use of growth models or simulators as well as by the use of updated data resulting from the future NFI's. Apart from this, if necessary data from an IGP project based on detailed satellite image can also be used.

Biomass and Annual Increments

Biomass in forest areas and annual increments will be assessed in detail using data from NFI5, subsequent investigations, and biomass models per species and region. Research is ongoing in collaboration between DGRF and ISA to:

- Develop and improve allometric models to estimate tree total biomass and biomass of individual tree elements, which resulted in new allometric models available for the most important species: eucalyptus, maritime pine, cork oak, holm oak, chestnut, Pyrenean oak and stone pine
- Improve existing forest growth and yield models and their integration into national simulators. Some results concerning carbon balance during the period 2008–2012 have already been provided by national simulators (Tomé 2007)
- Develop a pilot study. The study consists of comparing the classification of photo-plots from year 2005 with the classification coming from COS'90 so that land use changes can be identified, (with emphasis on areas planted after 1990), selecting field plots that correspond to these new planted areas and analyzing the sampling errors that will be obtained in the estimation of carbon sequestered by areas planted after 1990 during the period 2008–2012. Some preliminary results from the case study:
  - The number of photo-plots which had land use other than forest in 1990 and which were classified as forest in 2005 (representing afforestation) will be repeated or extrapolated for the whole country and will have associated sampling errors estimated
  - The photo-plots which were classified as forest land in 1990 and are classified as non-forest in 2005 will represent deforestation. Although it is important to stress that it is impossible to know whether shrublands' photo-plots in 2005 will remain as shrublands in 2008–2012 or if they will become forest lands.

28.3.3 The Role of NFI in Assessing the Status of Biodiversity

Apart from conventional NFI variables such as age, density, species composition, diameter at breast height, total height, crown base height, and standing volume, the NFI has begun collecting information on additional variables to provide information on biodiversity. NFI4 provided cover percentages for each of the three most abundant species (tree or shrub) per height class, total cover per class as well as average height. The NFI plot cover percentages were based on the left hand side example from Fig. 28.2.

The same tree or shrub can be part of different height classes. Taking the example on the right hand side of Fig. 28.2, the cover percentages in the height class below 0.6 m for species C (Esp. C) is 30%, for species D (Esp. D) and species E (Esp. E) are 10% summing up to 50% cover, while the cover percentages for the

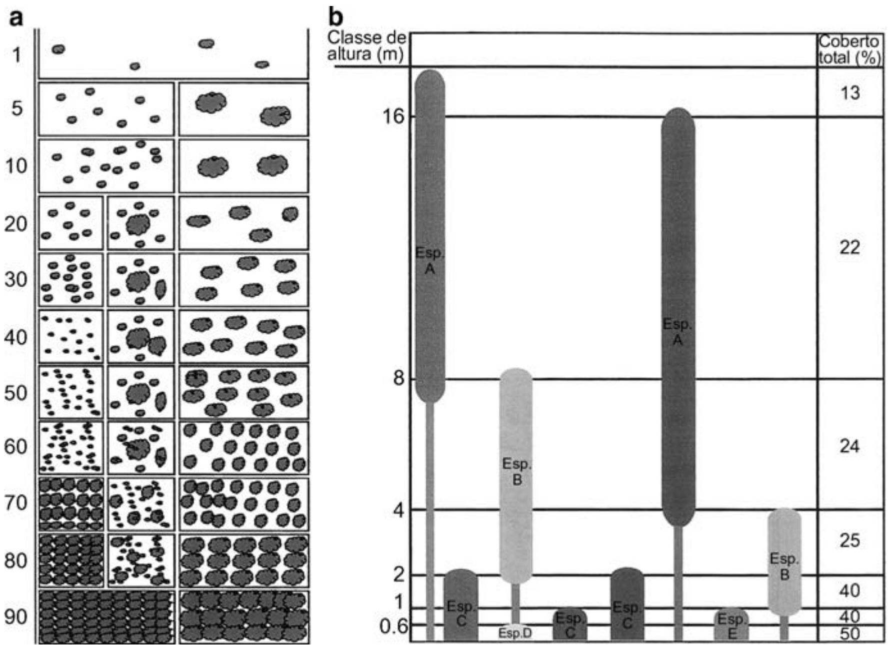

Fig. 28.2 (**a**) Cover percentages scheme and (**b**) example of cover percentage by height class where "Classe de altura" represents the height class, "Coberto total" the total percentage of coverage by height class and "Esp" represents the species (DGRF 2005a)

height class between 2 and 4 m is 20% for species B (Esp. B) and 5% for species A (Esp. A) summing to a total cover of 25% (DGF 2001).

Based on NFI4's information on vertical stand structure, the Portuguese Forest Typology Chart (Carta de Tipologia Florestal de Portugal Continental) was produced and a model for vegetation structural diversity (MDEV) was developed (Godinho-Ferreira et al. 2005).

Apart from the cover percentages occurring in each height class, NFI5 information on vegetation richness as well as lichen and moss presence was also collected (DGRF 2005a).

1. Vegetation richness was first assessed during NFI5 (2005–2006). To do so the number of species inside the plot was counted according to the following procedure (Braun and Blanquet minimum area method): Inside the field plot a 1×1-m (1 m^2) first square was marked with four marks so that one of the vertices matched the plot centre. The number of different tree species in the square was counted. Then, the positions of two of the marks were moved so that a rectangle of 2×1-m (2 m^2) was obtained. The occurrence of any tree species different from those identified inside the previous area was counted. This procedure was repeated until no new tree species were observed when the area

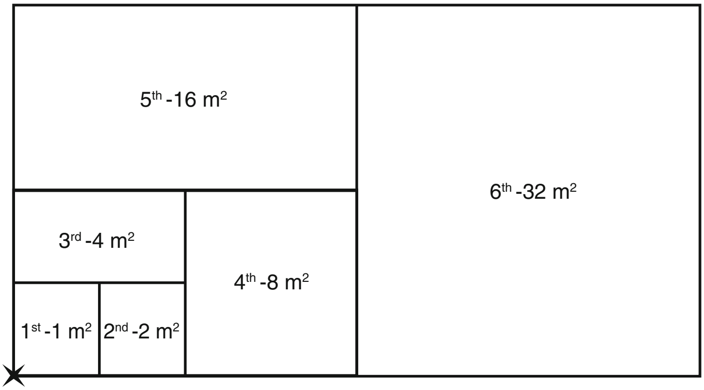

Fig. 28.3 Vegetation richness, minimum area method. The cross sign represents the plot center

was doubled (Fig. 28.3). The total number of species observed and the area of the last rectangle on which a new species was observed were registered.

2. Lichen and moss presence on stems was first assessed in NFI4 (1990–1999). The percentage of trees with lichen and/or moss on their stems was evaluated using the following criteria and classification: High (ML% $\geq$ 50), Medium (25 $\leq$ ML % $<$ 50), Low (5 $\leq$ ML% $<$ 25) and Null (ML% $<$ 5).

28.4 Design of the Present NFI5

28.4.1 Sample Points and Dot Grids

NFI5 was based on a regular 0.5 × 0.5-km dot grid covering the whole country from which other coaser grids with sample dots separated by 2 and 4 km were generated. Figure 28.4 shows the dot grids applied to NFI5: the finer dot grid (0.5 × 0.5-km) was used for photo-interpretation, while the coarser grids defined NFI field sample plots (2 × 2-km on forest land and 4 × 4-km on shrub land). Since the three grids are coincident each NFI field plot (forest or shrub) corresponds to a photo-plot. The NFI plot centre coordinates (coordinate system: Hayford-Gauss military; projection: Gauss-Krüger; ellipsoid: Hayford – international; datum: St. Jorge's Castle Lisbon) were previously defined using GIS software (Tomé et al. 2007e).

28.4.2 Aerial Photography and Photo-interpretation

Photo-interpretation was performed on digital orthophotos with a 0.5 × 0.5-m pixel on the terrain (DGRF 2005b). It is important to stress the innovation of the aerial photographs used in the present NFI when compared with the ones used in the

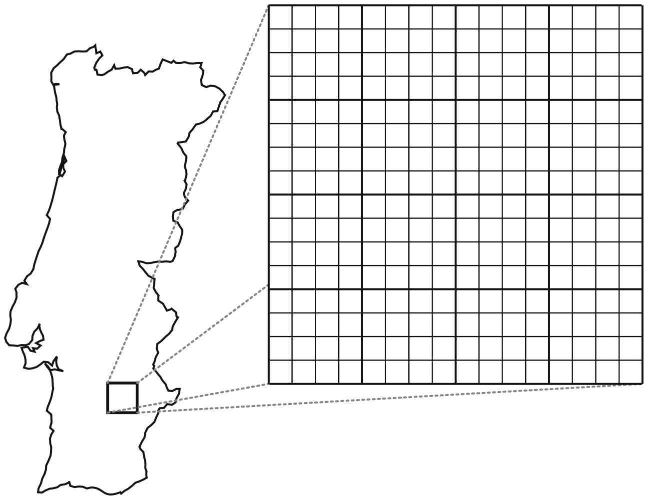

Fig. 28.4 Grids used in NFI5. The thightest grid, 0.5 km per 0.5 km, was used for photo-interpretation; the 2 × 2-km grid was used for NFI forest land field plots and the 4 × 4-km dot grid was used for NFI shrub land field plots

previous one (1 × 1-m pixel). The orthophotos were integrated in a GIS to be visually interpreted. The software also allowed accessing the aerial photographs from 1995 which was extremely useful allowing classification in case of doubt concerning the species, especially in cases of clear cut, burnt areas and young stand areas from 2006.

Simple systematic sampling was used and a 500 × 500-m dot grid was overlaid on top of the orthophoto resulting in 355,737 dots to be visualized on the screen. Each of the dots was considered as a photo-plot and was classified according to a code described in the photo-interpretation manual (DGRF 2005b). The photo-plot classification is the same as the surrounding stratum (in terms of land use and occupation) with an area greater or equal to 5,000 m^2 or with a width greater or equal to 20 m. Photo-plots found on the boundary between two different strata were classified according to the following:

- North/South Boundary – take the classification of the 5,000 m^2 on the western side of the photo-plot
- East/West Boundary – take the classification of the 5,000 m^2 on the northern side of the photo-plot

28.4.3 Selecting NFI Plots for Field Work

The large areas burnt in 2003 and 2005 had major consequences on wood used in industry as raw material and on wood stocks. NFI classic methodologies imply the use of photo-interpretation results as a tool for field work planning. Nevertheless, in this particular case, waiting for photo-interpretation work to be concluded would delay publication of NFI results (Tomé et al. 2007e). Therefore, it was decided to carry on photo-interpretation and field work simultaneously.

The selection of the NFI forest and shrub plots was performed according to the following criteria:

- Forest plots were sampled through simple systematic sampling overlaying the 2 × 2-km grid with the 1995 Eucalyptus Strata Cartography. The remaining dots on the 2 × 2-km grid were overlaid on the Land Use Cartography based on Landsat 5 satellite images from 2004. Through this procedure 11,038 potential forest plots were obtained.
- Shrub plots were sampled through simple systematic sampling overlaying the 4 × 4-km grid with the 1995 Eucalyptus Strata Cartography. Additionally, and similarly to what had been done regarding forest plots, Landsat 5 satellite images from 2004 were overlaid to the 4 × 4-km grid resulting in 1,220 potential shrub plots.

Finally, all dots obtained from the previous procedures were overlaid with the water class from the Land Use Cartography produced based on Landsat 5 satellite images from 2004 so that all dots from the Alqueva dam would be excluded. In total 12,258 field sample plots were obtained: 11,038 classified as forest and 1,220 as shrublands.

Unlike in the previous inventory, field work and aerial photography flights took place at the same time making it impossible for field crews to take the orthophotos with marked plot centre locations. Instead, they were provided with the plot centre coordinates obtained in the GIS software and the respective 1:25,000 scale maps. Field crews were instructed to use global positioning system (GPS) to locate the plot centre. In case of GPS malfunction or of weak signal, plots should be located based on the measurement of azimuth and distances between two identifiable points located both on the scale map and the field as close to the plot centre as possible.

Each of the 12,258 NFI plots was visited and had its stratum classified according to the photo-interpretation manual from NFI5 (DGRF 2005b): 10,344 of those plots were visited, classified and measured, 6,478 in forest (5,264 in forest stands), 2,121 in shrublands, 419 in other wooded lands and 1,326 in other strata. 1,914 plots were considered “inaccessible”. Apart from the plots that had been selected by remote sensing as forest another, 791 plots that were not selected by remote sensing as falling on forest strata were classified as forest by the photo-interpreters and 256 as young stands. For plots whose stratum was classified as forest, other wooded land or shrubland, stand evaluation was carried out with respect to structure, vitality, biodiversity and production. To assess production, each plot underwent a wide set of measurements based on the procedures described in the field manual for NFI 2005–2006 (DGRF 2005a).

Simple fixed-area circular plots were delimitated. All NFI plot areas were 500 m^2 except when the dominant species in the stand was either cork oak or holm oak in which case plot areas were 2,000 m^2. NFI rectangular plots were delimited in sloping terrain areas with soil prepared in terraces. In case the plot was on a recently harvested stand all stumps were measured (DGRF 2005a).

Trees with heights between 50 and 130 cm as well as those taller than 130 cm but with *dbh* less than a threshold of 5.0 or 7.5 cm (5.0 cm for eucalyptus and 7.5 cm for all other species) were counted in an area of 50 m^2 over a cluster of five circular sub-plots with area 10 m^2 distributed in a cross according to the cardinal points. The centre of the central plot matched the centre of the NFI inventory plot, while the centres of the other four plots were 10 m away from the centre of the central plot. The area of each sub-plot was increased to 40 m^2 instead of 10 m^2 for pure or dominant stands of *Quercus suber* and *Quercus ilex* spp. *rotundifolia* (Fig. 28.5). In these sub-plots the presence of natural regeneration below other trees' canopies was also registered as well as the mean height of trees taller than 130 cm (DGRF 2005a).

Plots were delimited using a Vertex hypsometer and its transponder. Regardless of the species, trees were included in the plot if half of the section of the tree or coppice stool at *dbh* height was inside the plot, while trees on the border line of the plot were alternately considered as being part of the plot (DGRF 2005a).

NFI5 was prepared with the intention of transforming NFI plots into permanent plots. For this reason, the plot centres were marked with a metal tube to allow their precise location with a metal detector on the next visit. The azimuths and distances of the three trees closest to the centre of the plot were registered. These trees were numbered and marked with a paint band at eye level to allow easier location in the future. To allow future monitoring of dominant trees and sample trees they were also marked with three and two paint dot marks, respectively (DGRF 2005a).

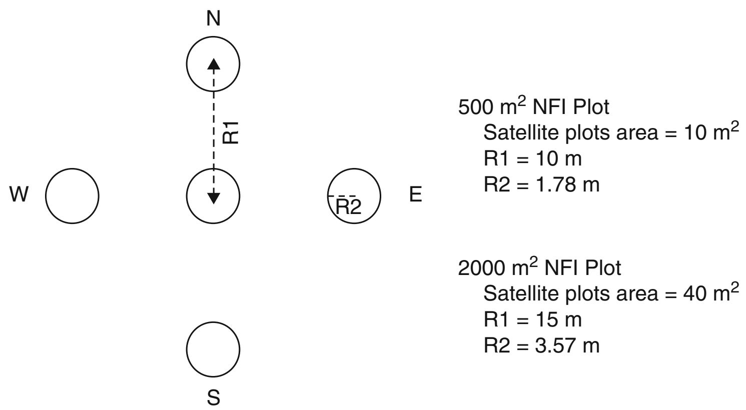

Fig. 28.5 Sampling of small trees: For 500 m^2 NFI plots, the satellite plots area is of 10 m^2 with R1 = 10 m and R2 = 1.78 m, while for 2,000 m^2 NFI plots, the satellite plots area is of 40 m^2 with R1 = 15 m and R2 = 3.57 m

28.4.4 Management, Personnel, Measurement Techniques, Quality Assurance

Even though the Portuguese NFI is DGRF's responsibility, the institution doesn't have the personnel to conduct the NFI work by themselves. As a result, most of the work is done by subcontracted entities for both field work and data processing.

The field equipment used were GPS devices for plot location, Vertex hypsometers for plot delimitation and tree height measurements, callipers for *dbh* measurements and Pocket PC's for storing the collected information.

Software for NFI5 data collection was developed for Pocket PC's in cooperation with CELPA. In order to assure quality of the information, several restrictions were introduced in the software: impeditive restrictions (not allowing filling in any other information while the mistake or missing value was not corrected or filled in) and warnings (informing the field crews that something was wrong).

The fact that photo-interpretation and field work were conducted at the same time allowed using field information to validate photo-interpretation results. Whenever field and photography classifications were different, the photo-plots' classifications were reanalyzed resulting in the correction of some of the previous results. In the same way, a pre-defined number of NFI plots was sampled by region for validation and the results were compared. In some cases the measurements resulting from validation replaced the initial ones. Apart from validation, a preliminary analysis was performed on the data which allowed detecting any incongruence before the NFI information system was implemented on an Access database which allowed storing and organizing the information. Data processing was performed using two different softwares (Access and SAS) by different people so that any differences in the results would be detected, checked and corrected.

28.5 Estimation Techniques

28.5.1 Area Estimates

For each species or species group, the following classification was considered:
(A) Stands, with the following sub-divisions (types of stand, TP):

1. Pure
   (a) Even-aged
   (b) Uneven-aged
2. Mixed dominant
   (a) Even-aged
   (b) Uneven-aged

3. Mixed dominated
   (a) Even-aged
   (b) Uneven-aged
4. Young stands
5. Burnt stands
6. Harvested stands

(B) Disperse trees, with the following sub-divisions:

1. Disperse trees in other stands (includes clumps)
2. Other wooded land

For eucalyptus, another sub-division was considered: planted stands, coppice stands and composed coppice with standards. Thus a three-level hierarchical classification is obtained: (1) species; (2) composition + young, burnt and harvested (evaluation based on the aerial photography); and (3) structure and management regime (evaluation based on the field information). The areas of the different types of stands can be estimated up to level 2 based on photo-interpretation, while the area corresponding to level 3 must be estimated based on the field information. The area corresponding to clumps and disperse trees, needed to obtain an estimate of the total volume, was obtained based on the NFI plots (Tomé et al. 2007e).

28.5.1.1 Estimates Based on Photo-interpretation

The area of a level 2 type of stand was obtained by multiplying the corresponding proportion, obtained based on the photo-interpretation, by the area of the country and the sampling error was estimated based on the qualitative sampling theory (Table 28.1).

As was stated previously, for the level 3 stand types as well as for the disperse trees in other stand types, areas were estimated based on the number of NFI plots which matched the forest strata, in other words by the proportion that this type of stand represents relative to the number of points on the 2 × 2-km grid. This

Table 28.1 Area estimates for a level 2 stand type

Proportion of each stand *TP* and its corresponding standard error:	$p_{TP} = \frac{N_{TP}}{N500}$
	$s_{TP} = \sqrt{\frac{p_{TP} \cdot (1 - p_{TP})}{N500}}$
Area of each stand type *TP* (ha):	$A_{TP} = A \cdot p_{TP}$
Sampling error related to the stand type *TP* estimate:	$Error_{TP} = A \cdot z_{0.025} \cdot s_{TP}$ (ha)
	$Error\%_{TP} = \frac{Error_{TP}}{A_{TP}} \cdot 100$ (%)

N_{TP} = number of points on the stand type (*TP*); $N500$ = 355,764 = total number of points in the 0.5 × 0.5-km grid; A = country area in ha = 8,879,862; $z_{0.025}$ = percentile 97.5% of standard normal distribution.

Table 28.2 Area estimate associated to the level 3 type of stands, species in groves or species spread in other stands, where X represents either the level 3 type of stands or disperse trees

Proportion of X and it's corresponding standard error:	$p_X = \frac{n_X}{N2000}$
	$s_X = \sqrt{\frac{p_X \cdot (1-p_X)}{N2000}}$
Area of X (ha):	$A_X = A \cdot p_X$
Sampling error associated to the area estimate of X:	$Error_X = z_{0.025} \cdot s_X$ (%)
	$Error\%_X = \frac{Error_X}{A_X} \cdot 100$ (%/%)

n_X = number of NFI plots classified as X; $N2000$ = total number of points in the 2 × 2-km grid ($N2000$ = 22,240); A = country area in ha = 8,879,862; $z_{0.025}$ = percentile 97.5% of standard normal distribution.

evaluation is a non-quantifiable error in terms of sampling theory because not all the points on the 2 × 2-km grid have been visited in the field. Some were not visited because they had been classified at start with land use other than forest (although this non-forest classification was proven to be incorrect during the photo-interpretation process), while others were not visited because they were considered to be inaccessible by the field crews. Nevertheless, this error is considered to be small when compared to the sampling error. Thus, for these types of stands the models in Table 28.2 were used.

28.5.1.2 Correction of the Photo-interpretation Estimates Based on the NFI Field Plots

The forest inventory is usually used to verify photo-interpretation by applying correction factors to the photo-interpretation estimates. NFI5 was done simultaneously with the photo-interpretation; consequently aerial photographs were not available for the field crews. For this reason another error had to be considered: the field crews might have not installed the plots in the right place. However, the comparison was still made, and the number of "switches" between the photo-interpretation stratum and the field stratum was determined by the use of a contingency table. The number of points strata_photo × strata_field was obtained after all plots for which the difference between the field coordinates obtained by the field crews and the grid ones were larger than 25 m were excluded. Plots classified as inaccessible on foot were also excluded. The area corresponding to each combination where strata_photo was different than strata_field was determined based on qualitative sampling in a manner similar to the description in Table 28.2, in other words, considering a sampling based on the 2 × 2-km grid. As stated before for the level 2 stand types, this methodology assumes that the classification of the land use as forest or non-forest was correct, which is not entirely accurate. Corrections have been made for all area estimated with a sampling error below 20%. For all other cases, it was considered not to have enough precision to do so.

28.5.1.3 Correction of the Areas of Non-forest Strata in Order to Guarantee the Additivity Property Concerning the NUTS Areas

Given that the methodology used for calculation of the areas was based on the proportions relative to the total number of points in the grid N500, when summing up the area estimates of the different types of stands in a certain NUTS, the value is different than the respective NUTS area. To guarantee the additivity property, the difference was divided for all the non-forest strata proportionally to the strata representativeness in each NUTS.

28.5.2 Volume and Biomass Estimates

Based on the NFI plot information collected at tree level, different variables were estimated which allows characterization of each species and subsequently each stand.

28.5.2.1 Tree Level Variables

For NFI plots, all trees with *dbh* greater than the threshold (5.0 cm for Eucalyptus and 7.5 cm for all other species) had the following variables measured/calculated at tree level: diameter breast height (*dbh*), total height (*h*), total volume and biomass (*w*).

Tree *dbh*

The arithmetical mean of two *dbh* measurements taken perpendicular to each other for all the trees inside the NFI plot was calculated.

For cork oaks it only makes sense to use the underbark diameter since the diameter above bark depends on debarking. NFI5 did not contemplate the measurement of cork thickness (ct), although some field crews, based on their experience in past inventories measured it. For these cases the diameter underbark is given by:

$$du = d - 2\frac{ct}{10} \tag{28.1}$$

where *dbh* and *du* are the diameters with and without cork (cm), respectively and ct represents cork thickness (mm). For all other cases the average cork growth index was estimated (icc) for each county (Table 28.3) assumed to be the same for all trees. Based on this, the cork thickness was estimated using the SUBER model methodology (Tomé 2004), which used the models listed in Table 28.3. Some plots had no debarking year written on the trees. For those a random cork age between 1

Table 28.3 Equations used on cork oak to estimate the diameter underbark whenever there was no cork thickness available

Underbark diameter in virgin trees (*du*)	$du = \beta_0 + \beta_1 d$
Average cork growth index by county (cg_{mean})	$cg_{mean} = \beta_0 + \beta_1 ndprec + \beta_2 ndgeada$
Cork thickness in complete years as a function of the total cork thickness ($ct1_{tc}$)	$ct1_{tc} = \frac{\beta_0+\beta_1 tc1}{tc1} ct_{tc}$
Cork growth in complete rings ($ct1_i$)	$ct1_i = ct1_j e^{\beta_0 \left(\frac{1}{tc1_j^{\beta_1}} - \frac{1}{tc1_i^{\beta_1}}\right)},$
Total cork thickness as a function of cork thickness in complete years (ct_{tc})	$ct_{tc} = \frac{tc1}{\beta_0+\beta_1 tc1} ct1_{tc1}$ where $ctbb_{tc} = \frac{ct_{tc}}{\beta_2}$

d and *du* – trees' *dbh* overbark and under bark, respectively (cm); $ct1_i$ – cumulative cork thickness in complete rings in year i, boiled cork (mm); ct_i – cork thickness (total cork thickness) in year *i*, boiled cork (mm); $ctbb_i$ – cork thickness (total cork thickness) in year *i*, on the tree (mm); $tc1_i$ – number of complete cork rings of (age-1) in year *i*; *ndprec* – number of days with rain; *ndgeada* – number of days with frost.

and 9 was used. Cork thickness is very difficult to measure in virgin trees (trees never debarked before) therefore a model to estimate the diameter underbark was used (Table 28.3).

Total Tree Height (*h*)

Total height was measured for all dominant trees and sub-sample trees. Dominant trees are the 20 thickest ones (at breast height) in one hectare. In mixed stands both the dominant and dominated trees had dominant trees considered. Sub-sample trees are those whose diameters are closer to the central diameter in each *dbh* class. The selection was made by the Pocket PC's software. Trees with sanitary or conformation problems were skipped. In these cases the next tree closer to the central class value in a good condition was selected. Height-*dbh* curves were used to estimate the total height of the remaining trees.

A regional height-*dbh* curve was used for each species (Table 28.4). The models of NFI4 were avoided whenever it was possible, because no description of the data and methodology used to develop them was found.

A small number of height-*dbh* curves had been published for maritime pine (Oliveira 1985; Moreira and Fonseca 2002; DGF 2001). Some of the models are quite simple given the fact that they were mainly used in yield tables (Oliveira, 1985; Moreira and Fonseca 2002). Therefore, a regional height-*dbh* curve was developed using the maritime pine database PBRAVO available at Grupo de Inventariação e Modelação de Recursos Florestais (GIMREF) of Centro de Estudos Florestais (ISA; UTL). The model is published in Tomé et al. (2007c).

For eucalyptus there are several regional height–*dbh* curves (Soares and Tomé 2002; DGF 2001; Tomé et al. 2007a, c). The Tomé et al. (2007a) regional height–*dbh* curves were preferred for application to the entire country because they are based on a wide set of data supported by appropriate methods. These models include a qualitative variable which indicates whether the stand is a planted or

Table 28.4 Regional height-*dbh* curves used

Maritime pine	$h = hdom\left(1 + \left(\beta_0 + \beta_1 \frac{N}{1000}\right)e^{\beta 2hdom}\right)\left(1 - e^{\beta_3 \frac{d}{hdom}}\right)$
Eucalyptus	$h = hdom\, e\left(\left(\beta_0 + \beta_1 hdom + \beta_2 \frac{N}{1000} + \beta_3 dg\right)\left(\frac{1}{d} - \frac{d}{ddom}\right)\right)$
Other oaks	$\ln h = \beta_0 + \beta_1 \ln d + \beta_2 \ln hdom + \beta_3 \ln dg$
Chest nut	$h = \frac{hdom}{1+\beta_0 hdom\left(\frac{1}{d}-\frac{1}{ddom}\right)}$
Holm oak, stone pine, other softwoods and other hardwoods	$h = hdom\left(1 + \beta_0 hdom\ e^{(\beta_1 hdom)}\right)\left(1 - e^{(\beta_2 d/ddom)}\right)$
Cork oak	$h = hdom\ e^{\left(\beta_0+\beta_1\frac{du}{dudom}+\beta_3 hdom\right)\left(\frac{1}{du}-\frac{1}{dudom}\right)}$

d – *dbh* (cm); *dg* – quadratic mean *dbh* (cm); *ddom* – quadratic mean *dbh* of dominant trees (cm); *h* – total height (m); *hdom* – dominant height (m); *N* – Stand density (ha^{-1}), *du* – *dbh* underbark (cm); *dudom* – quadratic mean *dbh* underbark of dominant trees (cm).

Table 28.5 Height-*dbh* curves used for disperse trees

Cork oak	$h = \frac{du}{\beta_0+\beta_1 du}$
All other species	$h = \frac{d}{\beta_0+\beta_1 d}$

d – *dbh* (cm); *du* – *dbh* underbark (cm); *h* – total height (m).

coppice stand. The same set of data was used to fit a model capable of estimating height regardless of rotation because for stands with coppice with standards no information on rotation was collected (Tomé et al. 2007c).

Chestnut height was estimated using the height–*dbh* curve developed by Patrício (2006) and other oaks had their height estimated with the height–*dbh* curve developed by Carvalho (2000) for Pyrenean oak. Height estimates for all other species used the height–*dbh* curves used in the NFI4 (DGF 2001).

For NFI plots in which dominant trees' height was not available (namely, plots in which the tree species appeared as a disperse tree) simple prediction models having *dbh* as the driving variable (Table 28.5) were used (Tomé et al. 2007c).

Total Tree Volume

In the Portuguese NFI, tree stem volume corresponds to the volume of stem wood over bark above ground (including stump, except for maritime pine) to the top of the tree. Tree stem volume was estimated for all living trees using the models in Table 28.5. For maritime pine, the volume by the following three categories was estimated:

Class A-Logs with top diameter greater than 20 cm and longer than 2 m
Class B-Logs with top diameter between 12 and 20 cm or top diameter greater than 20 cm, but shorter than 2 m
Class C-Logs with top diameter between 6 and 12 cm
Top of the tree (diameter below 6 cm)

Table 28.6 Volume equations

Eucalyptus, maritime pine and other softwoods	$v = \beta_0 \left(\frac{d}{100}\right)^{\beta_1} h^{\beta_2}$
Cork oak	$vu_{7.5} = \beta_0 du^{\beta_2}$
Holm oak	$v_{7.5} = \beta_0 d^{\beta_2}$
Other oaks and other hardwoods	$v_{2.5} = \frac{\beta_0}{1000} (d^2 h)^{\beta_1}$
Chestnut and Acacia spp.	$v = \beta_0 d^2 h$
Stone pine	$v = \beta_0 d^{\beta_1} h^{\beta_2}$

d – *dbh* (cm); h – total height (m); v – stem volume with stump over bark (m^3); du – *dbh* under bark (cm).
For other oaks v (dm^3) represents stem volume with stump over bark with a top diameter equal to 2.5 cm.
For maritime pine v represents the total stem volume without stump over bark (m^3); For holm and cork oak the stem volume as well as the branches volume up to a diameter over bark of 7.5 cm ($v_{7.5}$) and of 7.5 cm ($vu_{7.5}$), respectively, were considered.

Table 28.7 Volume ratio equations for maritime pine and eucalyptus

Maritime pine	$vu\_st = \beta_0 d^{\beta_1} h^{\beta_2}$
Eucalyptus	$vu\_st = \beta_0 \left(\frac{d}{100}\right)^{\beta_1} h^{\beta_2}$
Maritime pine and eucalyptus	$Pvudi = \frac{vudi\_st}{vu\_st} = e^{-\beta_0 \frac{d_i^{\beta 1}}{d^{\beta_2}}}$
Maritime pine	$d_i = d\left[-\beta_0\left(\frac{h_i}{h} - 1\right) + \beta_1\left(\frac{h_i^2}{h} - 1\right)\right]^{0.5}$

d – *dbh* (cm); h – total height (m); *vu_st* – stem volume underbark without stump (m^3); d_i – top diameter (cm) measured at height h_i (m); *vudi_st* – volume underbark without stump up to the top diameter d_i (m^3); *Pvudi_st* – proportion of the volume underbark without stump up to the top diameter d_i.

Volumes for cork oak and holm oak were estimated using models developed by Paulo and Tomé (2006); all other oaks had their volume estimated with models published by Carvalho (2000). The volumes of chestnuts and *Acacia* spp. were estimated using models published by Patricio (2006). For species such as maritime pine, stone pine and other softwooded species, volume models were developed using appropriate methods (Tomé et al. 2007d); similarly for eucalyptus (Tomé et al. 2007b).

The merchantable volume of eucalyptus was estimated to a top diameter of 6 cm (Tomé et al. 2007b) and to 5 cm for maritime pine (Falcão 1994). The ratio volume models used for both these species are found in the Table 28.7.

Tree Biomass

Total tree biomass includes above-ground biomass (*wa*) and root biomass (*wr*). Above-ground biomass includes the biomass of the following tree elements: stem (*ws*), wood (*ww*), bark (*wb*), branches (*wbr*) and leaves (*wl*). Above-ground biomass was estimated for all the living trees on the plot using the models in Tables 28.8–28.12.

The only models available in Portugal for root biomass have been developed for maritime pine at tree level (Tomé et al. 2007d) and for eucalyptus at stand level (Soares and Tomé 2004). Other softwoods had their root biomass estimated with the same model used for maritime pine. The models developed for cork oak and holm oak by Montero et al. (2005) in Spain have been used, and his model for Pyrenean oak was applied to all other hardwood species.

Table 28.8 Biomass functions for eucalyptus, maritime pine and other softwoods

Stem (w_s), bark (w_b) and wood (w_w),	$w_i = \beta_0 d^{\beta_1} h^{\beta_2}$ $(i = s, b, w)$
Branches (w_{br}) and needles or leaves (w_l)	$w_i = \beta_0 d^{\beta_1} \left(\frac{h}{d}\right)^{\beta_2}$ $(i = br, l)$
Total above-ground (w_a)	$w_a = w_s + w_{br} + w_l$ where $w_s = w_w + w_b$
Roots (w_r)	$w_r = \beta_0 w_a$

d – *dbh* (cm); *h* – total height (m); w_i – trees' biomass component *i* (kg) where the above-ground components for eucalyptus are w_w, w_b, w_{br} and w_l, while for pine are w_s, w_{br} and w_l.

Table 28.9 Biomass functions for cork oak

Wood from the stem and branches (*wwbr*1), virgin cork – trees with mature cork (*wbv*1), branches (*wbr*2) and leaves (*wl*)	$w_i = \beta_0 cu^{\beta_1}$ $(i = wbr1, bv, br, l)$
Virgin cork – trees with virgin cork (*wbv*2) and roots (*wr*)	$w_i = \beta_0 du^{\beta_1}$ $(I = bv, r)$
Mature cork (*wba*)	Estimated with the equations from the SUBER model
Total above-ground (*wa*)	$w_a = w_w + w_b + w_c$

du – *dbh* underbark (cm); *cu* – perimeter underbark measured at breast height (cm); w_i – biomass of component *i* (kg); w_{a} – trees' total above-ground biomass (kg), where the total biomass of bark/cork $w_b = w_{ba} + w_{bv}$ (and w_{bv} can be either w_{bv1} or w_{bv2}).

Table 28.10 Biomass functions for holm oak, evergreen oaks and other hardwoods

Stem wood (w_w), bark (w_b), crown (w_c) and roots (w_r), wood (w_w) and crown (w_c)	$w_i = \beta_0 d^{\beta_1}$ $(i = s, br, r)$ or $(i = w, b, c, r)$ for holm oak
Total above-ground (w_a)	$w_a = w_s + w_{br}$ or $w_a = w_w + w_b + w_c$ for holm oak

d – *dbh* (cm); w_i – biomass of component *i* (kg); w_a – trees' total above-ground biomass (kg).

Table 28.11 Biomass functions for stone pine

Stem (w_w) and bark (w_b)	$w_i = \beta_0 c^{\beta_1} h^{\beta_2}$ $(i = w, b)$
Branches (w_{br})	$w_{br} = \beta_0 c^{\beta_1}$
Leaves (w_l)	$w_l = \beta_0 c^{\beta_1} \left(\frac{h}{d}\right)^{\beta_2}$
Roots (w_r)	$w_r = \beta_0 d^{\beta_1}$
Total above-ground (w_a)	$w_a = w_w + w_b + w_{br} + w_l$

c – stem perimeter at 1,30 m (m); *h* – total height (m); w_i – biomass of element *i* (kg); w_a – trees' total above-ground biomass (kg).

Table 28.12 Biomass functions for chestnut

Stem (w_w)	$w_w = \beta_0 d^{\beta_1} h^{\beta_2}$
Bark (w_b) and roots (w_r)	$w_i = \beta_0 d^{\beta_1}$ (i = b, r)
Branches (w_{br})	$w_{br} = \beta_0 d^2 h$
Total above-ground (w_a)	$w_a = w_w + w_b + w_{br}$

d – *dbh* (m); *h* – total height (m); w_i – biomass of tree element *i* (kg); w_a – trees' total above-ground biomass (kg).

Biomass models for the above-ground parts of eucalyptus, maritime pine, stone pine and other softwoods were developed as part of NFI5 (Tomé et al. 2007d). On the other hand, the existing models by Patricio (2006) and Paulo and Tomé (2003) were used for chestnut and holm oak, respectively. Cork oak is the most complex species, having a wide set of above-ground biomass estimates to be accounted for (Paulo and Tomé 2006; Tomé et al. 2004; Almeida and Tomé 2008). Above-ground biomass for other *Quercus* spp. was estimated based on the models developed by Carvalho (2000).

28.5.2.2 Stand Level Variables

Based on tree level calculations and/or estimates, stand level variables such as stand density (*N*), stand basal area (*G*), stand volume (*V*), dominant height (*hdom*), site index (*S*), quadratic mean *dbh* (*dg*) and quadratic mean *dbh* of the dominant trees (*dgdom*) were calculated/estimated per plot and species. The variables are defined as follows:

- Stand density is defined as the number of trees with *dbh* greater than the threshold per hectare.
- Stand basal area is estimated by adding the sectional areas at *dbh* height of all the trees on the NFI plots and reporting it on a per hectare basis.
- Stand total volume is estimated as the sum of volumes for all the trees on the NFI plot and reported on a per hectare basis.
- Dominant height is obtained by arithmetically averaging the total heights of the dominant trees of the dominant and dominated species on the NFI plot. In a mixed stand of dominant pine and dominated eucalyptus (NFI plot area = 500 m^2), the five largest diameter pine trees and the five largest diameter eucalyptus trees are used. Dominant height was only considered for the dominant and the dominated species.
- Quadratic mean *dbh* (dg) is defined as the quadratic mean of the *dbh* of all trees with *dbh* greater than the threshold.
- Quadratic mean *dbh* of the dominant trees (dgdom) is the quadratic mean of the *dbh* of all dominant trees on the plot.
- Site index provides information on the productive potential of the stand and is defined as the dominant stand height at a specified standard age. Standard age

Table 28.13 Site index equations

Maritime pine, eucalyptus and other softwoods	$S = A\left(\frac{hdom}{A}\right)^{\left(\frac{t}{t_p}\right)^n}$
Chestnut, Acacia spp., holm oak and cork oak	$S = \frac{A}{1-\left(1-\frac{A}{hdom}\right)\left(\frac{t}{t_p}\right)^n}$
Pyrenean oak	$S = hdom_d\left(\frac{1-e^{nt_p}}{1-e^{nt_d}}\right)^k + 1.30$

S – site index (m); *hdom* – dominant height (m); $hdom_d$ – dominant height above *dbh* level; *t* – age (years); t_p – standard age (years); t_d – age at *d* level; *d* – *dbh* (cm).

varies according to the species, but it is usually close to rotation age. Site index models for eucalyptus were developed by Tomé et al. (2001). For site index estimates on maritime pine, stone pine and other softwoods, existing models were used (Tomé 2001). On the other hand, for chestnut and *Acacia* spp., estimates were obtained using the model developed by Patrício (2006). Cork oak and holm oak site index estimates were estimated using the models of González et al. (2005), while those for Pyrenean oak and *Quercus* spp. used the models developed by Carvalho (2000). The different site index models can be found in Table 28.13.

28.5.3 Drain Statistics Estimation

Drain estimates are not directly provided by the NFI, but are obtained from national statistics.

28.6 Current and Future Prospective

Some decisions have already been taken, such as transforming the plots established in 2005 NFI into permanent plots. In 2008, 25% of the plots measured during NFI5, were re-measured, and another 25% in each of the following 3 years so that in 4 year's time, all plots from NFI5 will have been re-measured. Each year, data processing will combine the information from the plots measured in the current year with the information from the other 75% of the plots which will have been updated using growth and yield models.

Apart from all types of information gathered during NFI5, plans have been made to collect information on soil and dead wood (logs and snags) in the next NFI. Acquisition of new aerial photography for the whole country has also been planned.

Based on the NFI5 field data, new models have been already developed, and work is underway to improve existing models and to develop new models, if necessary.

28.7 Options for Estimates Based on Reference Definitions

It is possible to obtain some estimates based on the reference definitions whether they match the national definition or not. Table 28.14 shows types of information that can be estimated based upon the reference definition and the types that can only be obtained based on the national definition.

28.8 The Influence of COST Action E43 and Related Projects

The main objectives of COST Action E43 are to increase cooperation and interaction in the fields of scientific and technological research at the European level. This initiative makes it possible for multiple national entities, institutes, universities and industries to work together on a wide range of research and development activities (COST Action E43 2009).

In the last decades, the role of forests and forestry has become broader. The scope of the NFI's has also broadened, and new variables for assessment have been

Table 28.14 The availability of estimates based on national definitions (ND) and reference definitions (RD)

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	Area estimates by forest type are based on the aerial photography
Growing stock volume	Yes	Yes	NFI	Using models
Increment of growing stock volume	Yes	No		There is no permanent grid of NFI plots, therefore increment can not be calculated based on two consecutive NFI measurements. Volume increment can be estimated with simulators
Above- and below-ground biomass	Yes	Yes	NFI	Using models
Dead wood	Yes	No	NFI	Dead wood only comprises the standing dead wood, no lying dead wood is accounted for in the Portuguese NFI
Litter	Yes	–	NFI	
Soil	No	–	–	There is no soil information collected in the Portuguese NFI
Afforestation, reforestation, deforestation (Kyoto 3.3)	Yes	Yes	SNIERPA	Can be derived from NFI data combined with cartography produced by IGE
Naturalness of forest	No	–	–	–
Forest type	Yes	No	NFI	Can be derived from NFI data
Occurrence and abundance of vegetation species	Yes	Yes	NFI	–

introduced. New harmonized information is often required, and as new technologies for assessment arise, work ends up being conducted independently by different institutes. The need for new harmonized data and for harmonized data collection and processing methodologies emerged from international conventions and policy processes such as the Kyoto Protocol which addresses climate change and the MCPFE for which severe problems have been reported in the harmonization of some definitions and in the implementation of the harmonized definitions (Metla 2009).

COST Action E43 aimed at improving and harmonizing the existing national forest resource inventories in Europe by supporting new inventories in such a way that they would meet both national requirements for forest information as well as the need for harmonized, up-to-date and transparent forest information at European and international level; promoting the use of scientifically sound and validated methods in forest inventory designs, data collection and data analysis and provide input knowledge to future forest research activities; and promoting contacts for sharing experiences and new ideas in order to ensure the continuous improvement of the NFIs.

Such an ambitious project could not move forward without interacting with similar research projects. For this reason COST Actions such as E4 (Forest Reserves Research Network) and E27 (Protected Forest Areas in Europe) have provided valuable information for planning the work in this Action. On the other hand, there are and were other Actions such as E21 (Contributing of Forests and Forestry to Mitigate Greenhouse Effect) which require quality input data from forest inventories and therefore can be based on the outputs of this Action. COST Action E43 also supports the UNECE, Forest Focus and MCPFE, activities, especially Vienna Resolution 4 and 5, where there is a strong reference to improve and harmonize existing forest assessment and monitoring systems (Metla 2009).

For all these reasons, the target audience for the outcome of COST Action E43 is wide. It goes from organizations, such as FAO, and processes such as MCPFE and the Intergovernmental Panel on Climate Change (IPCC) that use and compile forest resources information; passing by NFI users such as policy makers, industries and research organizations. The dissemination of the results to the end-users is of extreme importance. The findings presented in conferences and seminars have been published and will be published in the coming articles. The users may also find information on the website of COST Action E43 (Metla 2009). COST Action E43 will also serve as link and contact point to non-European NFI's and European countries that did not participate in this Action.

Projects of this type can be extremely useful at national level. For countries such as Portugal that are planning future inventories, consulting COST Action E43's publications will allow the official entity responsible for this task to adopt the reference definitions and the methodologies that that have been defined as a result of the cooperative work of many experts from the different countries engaged in COST Action E43. This is equally useful to support the outlining of research projects and the scientific studies to be undertaken.

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Chapter 29
The Republic of Korea

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29.1 Development of the National Forest Inventory of Korea

Forest inventories in Korea began in the early 1960s with the cooperation of the United Nations Development Program (UNDP) and the Food and Agriculture Organization of the United Nations (FAO). Thereafter, several inventory projects were conducted, mainly for purposes of management planning for national forests and rehabilitation of denuded forest land. The use of aerial photography and statistical sampling techniques were introduced through the collaborative program of UNDP and FAO and became the basis of scientific forest inventories in Korea. At the end of the UNDP/FAO mission, the organization and staff came under the control of the Korea Forest Service (KFS) which established the Forest Resource Survey Institute (FRSI) in 1971. This was a cornerstone for national forest inventories in Korea (Korea Forest Service 2005).

Based on experiences gained from the projects, the FRSI initiated the first National Forest Inventory (NFI) together with a forest soil survey in 1972, and the NFI has since been conducted four times on a regular basis: NFI1 (1972–1975), NFI2 (1978–1981), NFI3 (1986–1992), and NFI4 (1996–2005). NFI5 (2006–2010) is ongoing using a new inventory system and implementing framework.

Until NFI4, the main NFI objectives were to collect information on forest resources and to produce national forest statistics for forest policy decision making. With the advent of new sustainable forest management paradigm in 1990s, the NFI drew attention for its role and importance in the forestry statistics sector. Moreover, increasing demands for credible forest information from international processes and conventions such as sustainable forest management and the United Nations

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Framework Convention on Climate Change (UNFCCC) forced us to change the inventory system.

In late 1990s, NFIs in many countries began to improve by changing from periodic to annual inventory systems as a means of continuously monitoring forest resources and ecosystems. This international tendency became a major factor that led us to the annual inventory system.

In 2001, a pilot research project was launched to improve the NFI design to satisfy the national and international demands for reliable forest resources information. The project recommended introduction of the annual inventory system for monitoring and assessing changes in forest resources and ecosystems over time. Based on this recommendation, the Forest Resource Establishment and Management Act mandated that the KFS conduct an NFI on a 5-year cycle.

From NFI5 (2006–2010), the inventory program has improved by changing from periodic to annual inventories. The new NFI design focuses on assessing and monitoring the extent and state of forest resources in an accurate and timely manner. The transition has required conceptual and technical changes in the inventory program which now includes the following core elements: annual inventories, the entire grid measured in five years, systematic layout of 4,000 permanent sample plots, a new sample plot design, a re-measurement strategy, and a collaborative implementation framework.

29.2 The Uses and Users of the Results

The NFI is the only and primary source of nationwide forest information and traditionally consists of two major components which provide two kinds of forest information: growing stock data generated from plot measurement, and forest area data obtained from a forest type map at a scale of 1:25,000. The map provides detailed stand information on forest type, species, diameter class, age class, and crown density obtained from interpretation of aerial photographs. Both kinds of data are integrated for generating national forestry statistics.

NFI data are widely used by public and private environment-related organizations. One of the main users is the KFS which publishes the Statistical Yearbook of Forestry every year based on NFI data. In addition, local authorities use NFI data for forest management planning. The Ministry of Environment uses the forest type map together with other auxiliary data to assess the degree of forest naturalness. The Ministry of Land, Transportation and Maritime Affairs uses stand information from the forest type map as basic data to guide decisions regarding conversion of forest land to other uses. Private organizations and companies use NFI data for forest management and land use planning. In addition, NFI data generated by the newly improved inventory system are expected to play an important role in international reporting to the FAO Global Forest Resources Assessment (FRA) and the greenhouse gas (GHG) inventory under UNFCCC by providing a wide range of carbon, biomass and biodiversity data.

Table 29.1a Basic area estimates for 2005

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a]
Forest land	6,394	64	1.0 ha minimum area, 30% crown cover, including temporarily unstocked forest land	n.a.[b]
Total land area	9,965	100	–	–[c]

[a]Standard error.
[b]Not available.
[c]Assumed to be error free.

Table 29.1b Basic volume estimates for 2005

Quantity	Estimate	Description	SE[a]
Growing stock net volume on forest land (million cubic metre)	506.38	Living trees with *dbh* $\geq$ 6 cm, over bark volume	n.a.[b]
Growing stock net volume per hectare on forest land (m^3/ha)	79.2	–	n.a.[b]

[a]Standard error.
[b]Not available.

29.3 Current Estimates

Numerous variables are observed and measured on plots: tree species, diameter at breast height (*dbh*), tree height, tree growth, soil, tree mortality, tree damage, and management activities. The variables include also ecological data not previously collected to address information needs for national reporting to international processes and conventions. The basic area and volume estimates for year 2005 are given in Tables 29.1a and b.

The definition of forest land in Table 29.1a was used in the previous NFIs until 2005. The new definition was adopted in the NFI5 (2006–2010) and was based on the FRA2005 definition of forest (FAO 2004).

29.4 Sampling Design

Previous NFIs used temporary plots until 2005. This approach could not provide the temporal set of inventory data necessary to assess and monitor forest ecosystem changes over time. Based on the experience and knowledge gained from previous inventories, we adopted a new sampling design and a new plot configuration that are more suitable for the annual inventory system. However, based on the results of a research project on annual inventories, we maintained the sampling intensity of the most recent previous inventory.

29.4.1 Sample Plots

The inventory population is the total land of Korea. The first phase of the sampling design is based on a stratification of potential sample points into forest and non-forest plots using a 4 × 4 km grid superimposed on a digital orthophoto map for all of Korea. Each grid point is examined to decide whether it is located on forest or non-forest land. Using this approach, approximately 4,000 sample plots have been systematically distributed all over the forest land (Fig. 29.1). The sampling design for NFI5 adopted permanent sample plots for continuous monitoring of forest resources and ecosystem. The sample plots are divided into five panels with one panel measured annually in each of five consecutive years. Each panel will be re-measured every 5 years. In the second sampling phase, approximately 1,000 of the total permanent sample plots are systematically sub-sampled. More intensive measurement is conducted in these plots, including vegetation and soil carbon surveys (Korea Forest Research Institute 2008).

The field plot consists of four circular sub-plots. The centre of sub-plot 1 is located at the plot centre; the centres of sub-plots 2, 3, and 4 are located at distances of 50 m from the plot centre at azimuths of 360°, 120°, and 240°, respectively. Each sub-plot is tri-areal plot, consisting of three different plots: a sapling plot of 0.003 ha with 3.1 m radius, a basic tree plot of 0.04 ha with 11.3 m radius, and a large tree plot of 0.04 ha consisting of the annulus formed as the portion of a 16.0 m radius circle outside the 11.3 m radius basic tree plot. The centre sub-plot only contains six microplots, three vegetation plots and three soil carbon plots, each with areas of 1 m^2. The centres of the microplots are located at distances of 10 and 17 m from the plot centre, respectively (Fig. 29.2). These micro plots occur only in the 1,000 permanent sample plots that are systematically sub-sampled from the total permanent sample plots. Variables for which plot observations and measurements are collected were discussed in the field manual (Korea Forest Research Institute 2008).

29.5 Management

29.5.1 Organization and Personnel

The NFI is a collaborative project among three agencies; KFS, Korea Forest Research Institute (KFRI), and the Forest Inventory Center (FIC) under the National Forestry Cooperatives Federation (NFCF). KFS is responsible for project coordination and budgeting; KFRI is primarily responsible for project management and research and development of methods; and FIC is responsible for the field survey. FIC employs approximately 30 field crews that conduct field plot measurements on an annual contractual basis. A field team consists of three persons and is intended to measure at least one plot per day. The staff of other agencies involved in the NFI is given in Table 29.2.

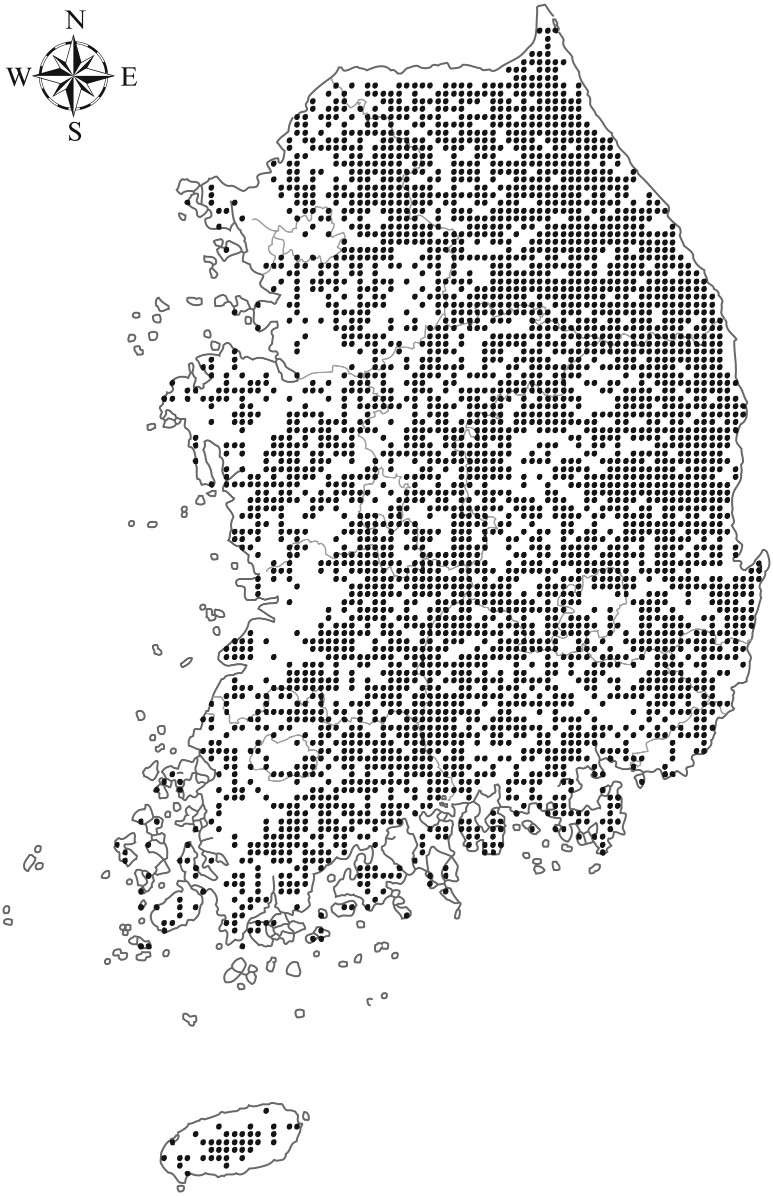

Fig. 29.1 NFI sampling design

29.5.2 Quality Assurance

The quality assurance program includes various checking and supervising activities such as documentation of methods, training programs, checks of tally sheets and

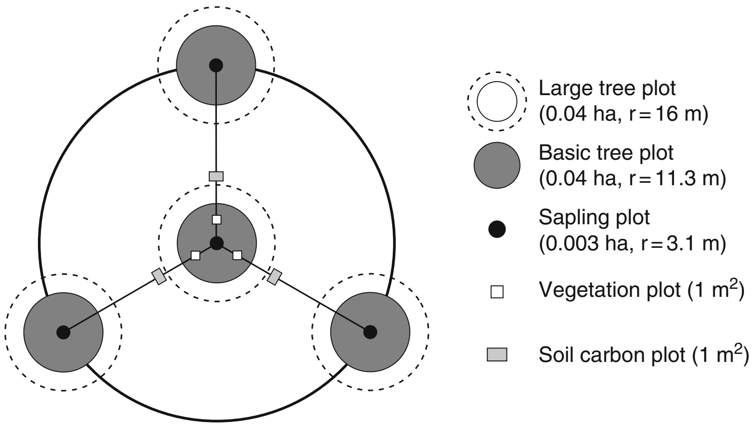

Fig. 29.2 Field plot configuration

Table 29.2 Staff of agencies involved in NFI

Agencies involved	Staff
Information and Statistics Division, Korea Forest Service (KFS)	4
Forest Resources Information Division, Korea Forest Research Institute (KFRI)	11
Forest Inventory Center (FIC), National Forestry Cooperatives Federation (NFCF)	30
Total	45

data quality. KFRI staff participate in the measurement of at least 40 plots (5% of the total plots) every year to supervise plot measurement and to provide on-the-job training. FIC also has its own cross-checking program among field teams. In addition, on a contractual basis, independent inspection teams re-measure 3% of the total plots to evaluate plot data quality as well as overall project management.

29.6 Future Prospects

NFI5 has been conducted for 3 years with the improved design. At this early stage, the first priority is given to properly establishing permanent sample plots in the field for future re-measurement, and to establishing a base for continuous monitoring and assessment of forest resources and ecosystem change over time. Each year each panel's data are stored in the NFI Database Management System and tentatively analyzed to estimate quantities such as forest area, volume, and volume by species. However, a detailed data analysis procedure has not been developed yet. An urgent task is to develop statistical estimation procedures suitable for the new annual inventory system; for example, how to estimate volume per cluster plot, and how to combine data for different panels. The NFI program has been enhanced by changing from a periodic to annual system from NFI5 (2006–2010). The enhanced NFI is expected to provide accurate and timely forest information at the national level and to satisfy increasing international reporting requirements.

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Chapter 30
Romania

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30.1 Development of Romania's National Forest Inventory

The main reason for realizing a national forest inventory was the high interest in wood resources information in Romania due to the development of the forest industries by the end of 1950s.

Starting in 1948, a forest management planning system was implemented over the entire Romanian forestry fund and the tradition at that time was to realize the stand level national inventory by aggregating stand inventories originally designed for management planning purposes. Indeed, all Romanian forests became public properties in 1948 and started to be unitarily managed by state. Based on the information contained by the forest management plans, national inventories of the forestry fund were conducted in 1965, 1973, 1980 and 1984.

An inventory system based on permanent sample plots was investigated between 1983 and 1989. This system was implemented in 1990 over the entire forestry fund and was combined with the national forest monitoring system.

A National Forest Inventory (NFI) was initiated in 2006, which is designed to cover all Romania's forest vegetation, meaning the forestry fund, the woodlands outside of the forestry fund and trees outside forests. The Romanian Forest Research and Management Institute is responsible for the NFI design and implementation, field measurements, as well as results calculation and publication. The Romanian NFI is inspired from different NFI systems that are currently in use in different European countries. Its characteristics were adapted to the size and the landscape conditions of Romania. Nowadays, NFIs are required to provide information far beyond the simple forest mensuration. The new NFI was therefore conceived from the beginning to enable the measurement on a systematic grid of

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all the information that are required for, for example, carbon reporting under Kyoto Protocol and forest biodiversty.

A pilot inventory has been conducted in 2007 and 2008 in order to verify the feasibility of the methods developed, adapt them when necessary and ensure a proper inter-calibration of the field crews.

30.2 The Use of the NFI Information

The demand for accurate national-level forest statistics is very high nowadays, as the last full inventory was done over 20 years ago, and forest users from both the public and private sectors are in great need of data on the current forests state. The NFI information will be used to set up the national forest policy, which will be expressed in forest legislation and national forest programs for sustainable forest management. It would also be used in decision-making processes concerning the development of the forest industry, and to provide forest resource information for national and international statistics reporting (Forest Resources Assessment of the Food and Agriculture Organization of the United Nations (FAO) and the Ministerial Conference on the Protection of Forests in Europe) and to provide with information on forest health and damage, biodiversity and carbon pools.

30.3 Current Definitions

For forest land and other wooded land, both the national definition and the COST Action E43 reference definitions are used. The reference definitions are near FAO (2004) definitions (Table 30.1). The NFI assessments cover all land classes including area estimates for all these land classes. In most cases, both the reference definition, given by COST Action E43, and national definition (Marin et al. 2006; Marin 2007) are applied.

The other basic quantities to be assessed by NFI using both national and reference definitions are (Table 30.2):

- Forest land, Other wooded land (OWL) and Other land
- Volume of growing stock on Forest and OWL

Table 30.1 The definition for forest land and other wooded land in the Romanian NFI

Quantity	Definition
Forest land (reference definition, applied parallel with national definition)	10% crown cover with minimum height of trees of 5 m at maturity in situ, minimum width 20 m
Other wooded land (reference definition, applied parallel with national definition)	Less than 10% crown cover with minimum height of trees of 5 m at maturity in situ, minimum width 20 m

Table 30.2 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current Rumanian NFI

Estimate	ND	RD	Responsible
Forest area	Yes	Yes	NFI
Growing stock volume	Yes	Yes	NFI
Above- and below-ground biomass	Yes	Yes	NFI, models
Dead wood	Yes	Yes	NFI
Litter	Yes	Yes	NFI, models
Soil	Yes	Yes	NFI, models
Afforestation	Yes	Yes	NFI, statistics
Deforestation			
Reforestation (Kyoto 3.3)			
Naturalness of forest	Yes	Yes	NFI
Forest type	Yes	Yes	NFI
Occurrence and abundance of vegetation species	Yes	Yes	NFI

- Volume of growing stock per hectare on Forest and OWL
- Annual increment of growing stock of trees on Forest and OWL
- Annual increment of growing stock of trees per hectare on Forest and OWL
- Annual drain on forest and OWL
- Annual drain per hectare on Forest and OWL
- Volume of dead wood
- Information about carbon pools such as above-ground biomass, dead wood, litter, soil organic matter
- Forest roads

30.4 Sampling Design

The Romanian NFI is designed as a continuous forest inventory with a 5-year inventory cycle. It is based on systematic sampling, combines repeated measurements of permanent plots with measurements of temporary plots and is a two-phased NFI (aerial photos and field forest measurements and assessment). The Romanian NFI covers the entire country territory and it is based on a 4 × 4-km grid (Fig. 30.1). The grid density is greater in plain areas (2 × 2 km) because of a very low forest cover. The plots are established using the grid as shown in Fig. 30.2 (Marin et al. 2006).

In order to increase the efficiency of the field work, the measurements are performed on clusters with four sample plots located at the corners of a 250 × 250-m square. The geographical reference point of that cluster is located in the south-west corner of the 4 × 4 (2 × 2)-km grid (Fig. 30.3). The field forest inventory would comprise at the end of the 5-year cycle about 24,000 permanent and 5,000 temporary sample plots. Temporary sample plots would be systematically selected.

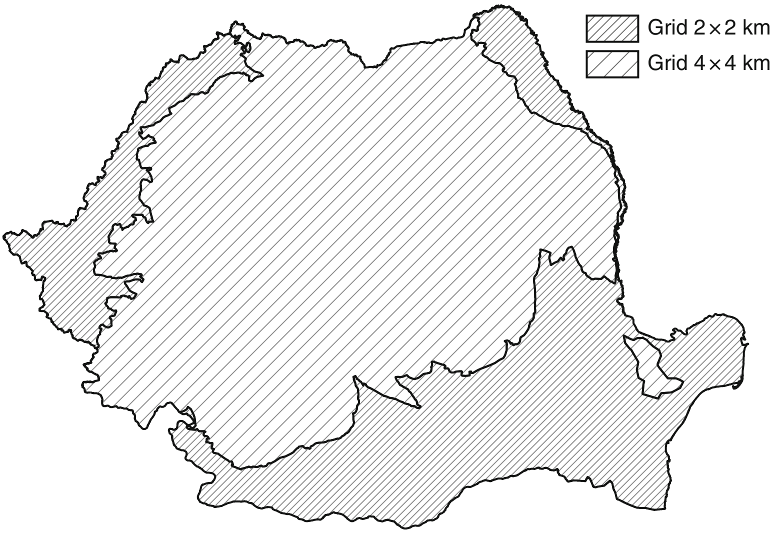


Fig. 30.1 Map of Romanian placement of the NFI 4 × 4 km and 2 × 2 km grids

A systematic grid of 500 × 500 m covering the entire country territory is used to determine land use (and land use change) categories on orthophotograps.

Each sample plot contains several circles (Fig. 30.4), as follows:

1. Two concentric circles located at 10 m on east and west side of the sample plot centre for regeneration survey:
   a. Two circles of 1.00 m radius for trees with a height between 10 and 50 cm
   b. Two circles of 1.78 m radius for trees taller than 50 cm and with a diameter at breast height (*dbh*) less than 56 m
2. Three concentric circles located at sample plot centre:
   a. A circle of 7.98 m radius for measurement of sample trees with $56 \leq dbh \leq 285$ mm, lying deadwood and ground vegetation
   b. A circle of 12.62 m radius for measurement of sample trees with $dbh > 285$ mm
   c. A circle of 25 m radius for description of forest site, forest type, soil characteristics and forest edges

The set of measurements performed on each of these sub-plots was designed to not only estimate the forest resource and its growth, but also to enable accurate reporting of the carbon pools. Therefore, apart from the classical trees biometric measurements, litter and soil characteristics are described and soil samples are taken. The inventory protocol should enable the estimation of mineral and organic soil layers in forests and changes in soil organic carbon.

Because the NFI is the first systematic national inventory after a long period, the estimation of forest growth would rely on dendrochronological measurements.

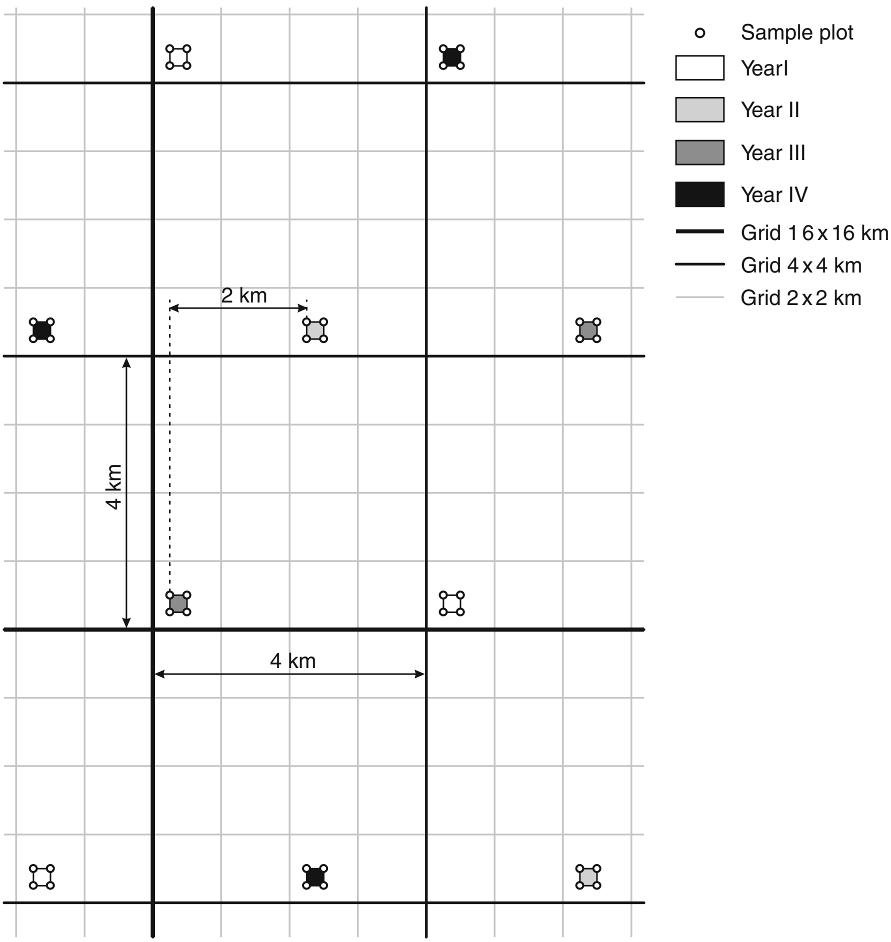


Fig. 30.2 Years of NFI field data collection

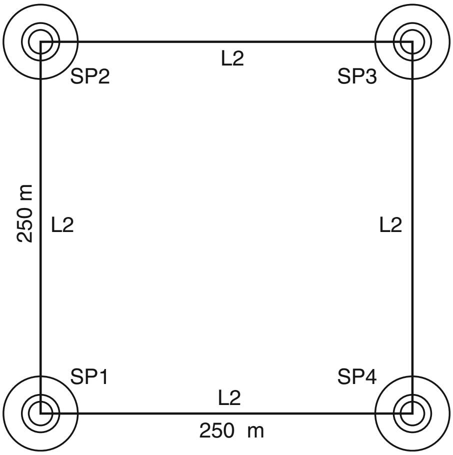
Fields crews therefore takes increment cores from three to six trees in order to accurately estimate trees age and to compute their growth over the last 5 years.

30.5 Management

About 6,000 permanent plots and 1,250 temporary plots are measured each year covering the entire country. There are currently 18 field crews with 3 people per field crew. One crew is devoted to the control of field measurements (Marin 2007).

Another 16 people are working on NFI photointerpretation, logistics, data-base, dendrochronology and soil chemical analysis.

Fig. 30.3 Structure of a cluster: four field sample plots per grid nod



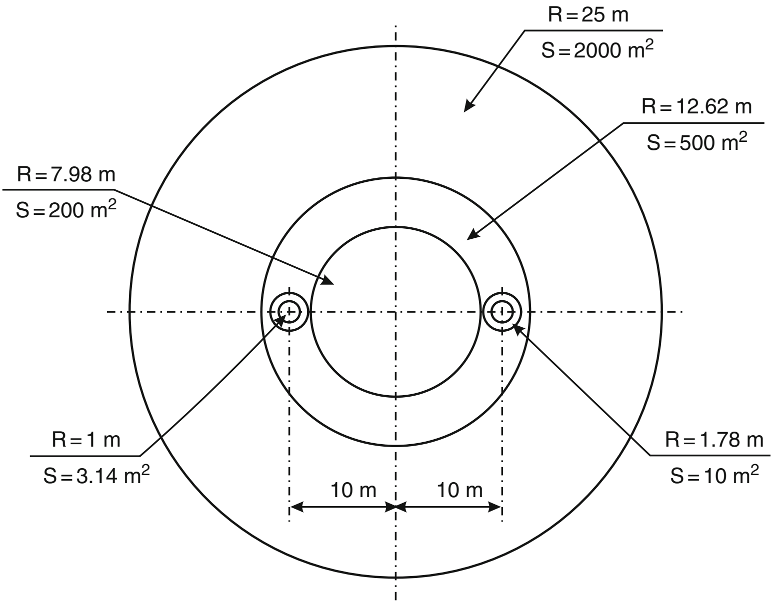


Fig. 30.4 Layout of the terrestrial sample plot components. Each circle represents a different sampling zone with specific measurement and measurement rules (refer to the text for more details). Radius and surfaces are provided for each

The field equipment was selected to meet the requirements of precision and efficiency and enable the measurement of all tree characteristics on the sample plots. Field crews are therefore equipped with electronic devices such as field computers, global positioning system receivers (GPS) and Vertex IV. A special computer program was developed at the Forest Research and Management Institute that permits recording of all measured data directly on computers and to feed the databases.

There are three ways of controlling data quality. The most efficient is very good training of the field crews and inter-calibration tests. A training course of two weeks is organized each year. Another way is to use correlations, restriction and logical relations implemented in field data collection software and to control the data collected by field crews using specialized software. The third way is to check the field work by performing re-measurements of a proportion of field plots by other crews.

30.6 Estimation Techniques

The estimation of the forest area is based on the total country land area and inland water bodies, which are known or assumed to be error-free, and the proportion of points from the 500 × 500-m NFI grid that are on forest.

The volume estimation is based on national-wide species-specific equations, with *dbh* and height as input variables. These equations have a high accuracy and their parameters for 43 main tree species are available. For the coniferous species, the equations refer only to the stem volume, without branches. The height is measured for each sample tree.

The total drain estimates in Romania are based at the moment only on the annual statistical reports made by the forest districts and forest industry companies. The measurement in NFI permanent and temporary sample plots will be used for drain estimation in the future.

30.7 Current and Future Prospects

The Romanian multi-purpose NFI is based on a systematic sampling scheme. A pilot inventory has been performed to validate the different hypotheses and options taken to adapt the protocol to the high variety of situations faced in the field, and to test the feasibility of the program. Much remains to be done and final results cannot be expected before 2010. Romania is offering a great diversity of landscapes, most of the forest is located on mountains, often in remote zones hard to access. But the protocol and the equipment recently acquired are designed to support an inventory that can provide all the data required for a detailed reporting and precise estimates of the forest resource: the inventory is not focusing on the forest composition and volume only but would also provide with direct estimates of carbon pools and biodiversity, of the accessibility, of the ownership, of its state, etc. Care was indeed taken to ensure that the NFI information complies with the good practice guidelines recommended by the United Nations Framework Convention on Climate Change and for assessing the biological diversity of forest.

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Chapter 31
Russian Federation

O.N. Solontsov

31.1 Development of the Russian National Forest Inventory

Before the admission of Forest Code in 2007 (Russian Federation 2007a), the Russian Federation used a system for national or territorial forest assessment based on aggregated data from forest management plans which were updated every 10–15 years. Forest management plans were updated 3–4 times on average within that period, although in some regions they had been updated as many as 12 times. These data were used to prepare strategic forest management plans.

In 2007, the term National Forest Inventory (NFI) was established within the Forest Code as the new system for assessing qualitative and quantitative forest characteristics and forest development. In the same year, the basic methodology for NFI Russia was prepared as "National Forest Inventory Guidelines". Preparation of the guidelines took into account not the only current state legislation (Russian Federation 2007b) but also international NFI experiences in Europe and North America.

31.2 The Use and Users of the Results

Preliminary NFI results are presented annually to the national bodies responsible for forest management, protection and reproduction, as well to the organization conducting national forest inspections. The data are used for strategic planning and decision making at the country level.

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E. Tomppo et al. (eds.), *National Forest Inventories*,
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31.2.1 General Provisions

The aims of the NFI are:

- To assess the status of forest and their qualitative and quantitative characteristics
- To detect and record changes in the forest status resulting from adverse impacts as well as their causes
- To evaluate forest management and protection activities, their compliance with the Forest Management Plan for the Russian Federation regions, the Forest Management Regulation (for forest parks), and the Forest Development Plan (for leased forest areas)
- To summarize the collected data and to submit summarized results on an annual basis to the public authorities responsible for forest management, protection and renewal decision making and to the public authorities responsible for state forest inspections

To comply with these aims, intermediate objectives are necessary:

- To provide objective information for the forest policy, forest planning and decision making processes
- To provide an objective stock assessment and its change for timber and non-timber resources on regional, forest vegetation zones and country levels
- To provide information about total growing stock change and forest increment for defined time periods
- To provide information about the state of the forest, forest ecological variability, the influence of external factors to the forest structure, including carbon pool balance
- To provide an assessment of forest biodiversity
- To provide information about adherence to forecasted aims per region of the Russian Federation

31.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

Emission reporting under the United Nation's Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol is the responsibility of the Federal Service for Hydrometeorology and Environmental Monitoring (ROSGIDROMET). To date, NFI data has not been used for UNFCCC and Kyoto reporting, because the data collection is in the beginning of the first cycle. Nonetheless, the data collected as part of NFI Russia could be used for other purposes such as constructing region-specific biomass expansion factors for individual tree species.

31.2.3 The Role of the NFI in Assessing the Biodiversity

The Russian NFI program aims at providing information useful for biodiversity assessment. For this purpose, the first Russian NFI cycle includes many indicators related to species richness, ground vegetation, forest structure and description of deadwood biomass. In addition, the NFI includes direct field evaluation of selected biodiversity indicators for standing trees including species composition, species richness, species distribution and dimensions variability.

31.3 Sampling Design and Methodology

NFI Russia aims to assess the forest on forest land. Data about forest area are gathered from existing forest management planning documents and official reporting as well as information needed for distribution/delineation of the forest area among defined strata. Stratified sampling and estimation are used to obtain estimates of forest parameters. Stratification is used to reduce the total number of sample plots necessary to achieve the desired precision by grouping forest stands into more homogeneous strata with the result that the variability of growing stock observations within strata is less than in the general population. Stratification is based on stand characteristics of parcels measured in the course of forest management planning. Stratification is based on the following core indicators:

- Groups of tree species (dominant tree species)
- Age groups
- Forest site types (groups)
- Altitudinal belts in mountainous terrain

Field data collection methods were developed in cooperation between the Federal Forest Agency of Russia and the Institute of Forest Ecosystem Research Limited (IFER) in Czech Republic and were based on experiences gained during the NFI pilot experiment conducted in 2007. This methodology is described in two documents (Russian Federation 2007c, 2009a, b), "Methodology of Field Data Collection" and "NFI Russia: Step-by-step manual for fieldwork". The handbook "Methodology of Field Data Collection" includes five appendices:

1. List of NFI regions and Forest enterprises of Russia
2. List of plant species (trees, shrubs, herbs, etc.) for NFI Russia
3. Structure of Field-Map project
4. Working steps for preparation and execution of fieldwork
5. NFI Russia standard forms (used for manual data collection without field computer)

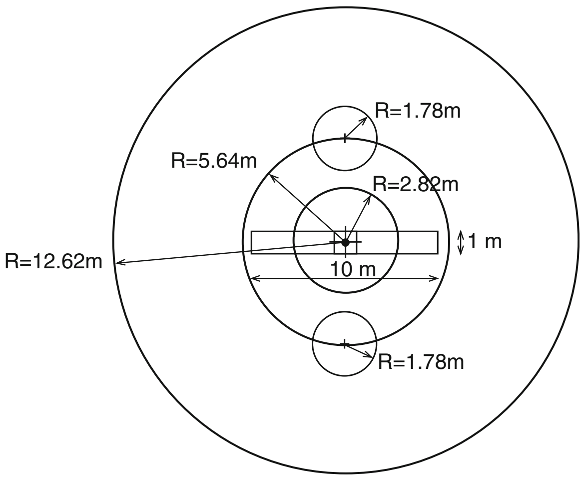

Fig. 31.1 Design of NFI Russia sample plot

31.3.1 Sample Plots

Inventory plot:

- Single circular plot (Fig. 31.1).
- In total there are approximately 150,000 plots located on forest land.
- Approximately 120 primary (field) variables per plot.
- Permanent plots with tree positions mapped.
- Plot area is 500 m^2 with three concentric circles:
  - Trees with *dbh* $\geq$ 6 cm are measured on a circular plot with radius 2.82 m (25 m^2).
  - Trees with *dbh* $\geq$ 12 cm are measured on a circular plot with radius 5.64 m (100 m^2).
  - Trees with *dbh* $\geq$ 20 cm are measured on a circular plot with radius 12.62 m (500 m^2).
- Two additional smaller circular regeneration plots with radius of 1.78 m (10 m^2) are established 5.64 m to the north and south for trees with height $\geq$20 cm and *dbh* $\geq$ 59 mm.
- Ground vegetation is described for a rectangular sub-plot 1 $\times$ 10-m (10 m^2) located at the center of the plot.
- Number of trees with measured heights varies according to species proportions on the plot. Selection of the samples is done automatically by an inbuilt algorithm based on measured *dbh* and species information.
  - Five sample trees are measured for height if the species basal area proportion is 0.5 or greater.

  - Three sample trees are measured for height if the species basal area proportion is between 0.2 and 0.5.
  - One sample tree is measures for height if the species basal area proportion is less than 0.2.

- Forest regeneration is assessed by counting trees of particular species and height classes.
- Dead woody debris lying on the ground is measured for length and mid-diameter of all dead logs on the plot with minimum diameter of 6 cm at the smaller end. In addition coverage of dead branches and smaller debris is also measured.
- Number and size of stumps is recorded for stumps with diameter $\geq$12 cm.
- Several variables describing growing conditions, ecosystem structure etc. are recorded.
- Stand and tree damage is recorded.
- Several attributes regarding soil and humus characteristics are collected on each sample plot.

31.4 Management

31.4.1 Management and Personnel

The NFI is conducted by the Federal Forest Agency directly thorough its territorial bodies or subordinated organizations. Roslesinforg was responsible for conducting the NFI Russia programme in the period 2007–2008. Roslesinforg has three territorial branches and 20 subordinate local offices with approximately 3,600 permanent staff personnel. Of these, more than 500 people are directly involved in NFI Russia. More then 17,000 plots were established in the field during the 2007–2008 period.

31.4.2 Measurement Technology

Field data collection is based on the Field-Map, a technological tool for collecting field data using electronic measurement devices. The technology includes the Field-Map software which was developed by IFER. The following electronic measurement devices were used in the first NFI cycle:

- Field Computer DNS Tactical Systems Armor X10 or TS Computers M840
- MapStar – an instrument for measuring absolute horizontal angles (compass)
- Forest Pro – laser rangefinder designed for measuring distances and vertical angles

- GPS Garmin for providing geographic coordinates
- Mechanical caliper for measuring tree diameters

31.4.3 Quality Assurance

The initial training of employees participating in the NFI was conducted prior to the first NFI cycle. Every leader of a field team passed an examination on NFI methodology and working processes. Re-training and verification of NFI workers is conducted annually. Technology used for field data collection incorporates comprehensive data checks. Data entry and logical relations within the database are checked directly in the field in course of data collection (Russian Federation 2007a). In addition the data collection is checked by specialized groups of field workers. Quality assurance has three levels:

1. Field data checks performed by an independent company (0.7%).
2. Field data checks conducted by the Federal Forest Agency branch office (1%).
3. Internal data checks conducted by Roslesinforg (4.5%).

Altogether approximately 6.2% of the inventory plots were verified in 2008. There are at least two field checks for each field team planned for 2009.

31.5 Current Status and Future Perspective

The following results were achieved in 2008:

- The NFI methodology was tuned and tested
- The software for data preparation, data collection and data processing was tested and appropriate qualification in mastering those programs was reached
- The field teams were fully equipped with up-to date hardware technology (GPS, field computers, laser rangefinders and inclinometers, digital compasses, cameras and other instruments)
- More than 12,000 inventory plots were measured in the field
- Field checks were conducted with satisfactory results

There are several tasks yet to be achieved in the following years:

- To improve/update NFI methodology
- To comply with all NFI targets as described above
- To improve current NFI techniques and software for data processing
- To make the best use of the NFI results in forest management and forest policy

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Chapter 32
Slovak Republic

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32.1 Slovakia's National Forest Inventory

The Ministry of Agriculture of the Slovak Republic, in its resolution No. 3473/2004-710 of 1 July 2004, decided to implement a National Inventory and Forest Monitoring (NIFM) program. The main objective of NIFM in Slovakia is an inventory system that will provide objective and complete information on the state and development of forest ecosystems components at the regional and national levels for selected time intervals.

32.2 The Use and Users of the Results

32.2.1 General Use

NIFM information will serve as a basis for decision making, planning, management activities of respective institutions and directive authorities in the forest and related sectors, mainly in the wood-processing industry and in environmental protection. Implementation of the first NIFM cycle addresses the needs of the previously mentioned sectors, trends in international forest monitoring, and other commitments resulting from Slovakia's membership in the European Union.

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32.2.2 The Use of NIFM in UNFCCC and Kyoto Reporting

Slovakian reporting concerning Land Use, Land-Use Change and Forestry (LULUCF) of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol is not based on NIFM information because the first NIFM cycle was only conducted during 2005 and 2006. The National Forest Centre (NFC) released the first aggregated results in 2007, and a single inventory cycle does not provide sufficient data to estimate forest carbon stock change. Nevertheless, the Slovakian NIFM system was designed to provide the necessary information for estimating and reporting the carbon stock change in the five carbon pools under UNFCCC. The Slovakian NIFM will also provide usable information on above- and below-ground biomass, dead wood, litter, soils and soil carbon. NIFM can also serve as a vital source of information on land areas, particularly land use changes. The latter information is required for accurate estimates of afforestation,reforestation and deforestation (ARD) activities under Article 3.3 of the Kyoto Protocol.

32.2.3 The Role of NIFM in Assessing the Status of Biodiversity

The need for information on non-productive forest functions has increased substantially with recent interest and emphasis on the environmental effects of climate change, sustainable management of forest resources, and environmental policies focusing on the maintenance of biodiversity and natural conditions. In addition to the traditional NIFM variables such as stand and tree age, tree species composition, diameter distributions, growing stock volume, the number of trees, and soil and site variables, additional groups of variables have been introduced for purposes of assessing the status of forest biodiversity. Table 32.1. gives an overview on the biodiversity related assessments carried out by the NIFM. All presented variables are assigned to one of three classes according to their relevance in terms of forest biodiversity.

32.3 Current Estimates

Estimates and standard errors of land classes, growing stock and dead wood based on data from 2005 and 2006 are presented in Tables 32.2a and b.

32.4 Sampling Design

Several inventory sampling designs were discussed (Šmelko et al. 2004) with respect to the objective of 2 years of field work (2005–2006). A 4 × 4-km sampling grid with 500 m^2 sample plots representing 1,600 ha was selected as optimal given

Table 32.1 Forest biodiversity assessments in the NIFM

Biodiversity component	Assessed variable		Relevance
Composition	Species	Tree species	High
		Number of herb species	Medium
		Number of moss species	Low
		Number of lichen species	Low
		Number of fungi species	Low
		Star species	Low
		Red listed species	Medium
		Introduced species	High
			Medium
Structure	Horizontal structure	Number of layers	High
		Diameter	High
		Age	High
	Vertical structure	Number of layers	High
		Height	High
	Area	Forest area	High
		Plantation area	Low
		Managed area	Medium
	Fragmentation	Forest edges	High
Function	Damages	Wind	High
		Snow	Medium
		Browsing	Low
		Pests	Medium
		Insects	Medium
		Nutrition	Medium
		Hydrology	Medium
Genetics	Regeneration		High
	Disturbance		High
	Species occurrence/autochthony		Medium

Table 32.2a Basic area estimates for the years 2005–2006

Quantity		Estimate (1,000 ha)	Share (%)	Description	SE[a]	
					Absolute	Percent
Forest land	State	1,153	23.5	Forest is land spanning more than 0.3 ha with trees taller than 5 m and a canopy cover of more than 20%, or trees able to reach these thresholds in situ	18	3.2
	Non-state	748	15.2		14	4.7
	Sum	1,901	38.8		22	1.1
Other land with tree cover		273	5.6		9	3.7
Total forest		2,174	44.3		23	1.0
Total land area		4,905	100.0		–[b]	–[b]

[a]Corresponds 68% one-sided confidence interval.
[b]Assumed to be error free.

Table 32.2b Basic volume estimates for the years 2005–2006

Quantity			Estimate	Description	SE[a]	
					Absolute	Percent
Growing stock (million cubic metre)	Forest land	State	332.9	Growing stock is the volume of living and standing trees including stem volumes from the stump height with minimum *dbh*, top diameter and branch diameter 7 cm under bark	n.a.[b]	3.6
		Non-state	205.0		n.a.[b]	4.8
		Sum	537.9		11.3	2.2
		Other land with tree cover	36.5		2.6	8.4
		Total	574.4		12.1	2.2
Growing stock per hectare (m^3/ha)	Forest land		283.5		5.5	1.9
	Other land with tree cover		132.5		8.9	7.5
	Total		264.5		5.1	1.9
Volume of dead wood (million cubic metre)	Forest land	Standing dead wood	12.9	Standing dead wood is the volume of dead and standing trees with the *dbh* 7 cm including stem volumes from the stump height. Lying dead wood is the volume of stems with minimum diameter 7 cm and with length 1 m	1.0	8.0
		Stumps	10.7		0.9	6.1
		Lying dead wood	37.0		2.3	6.3
		Thin dead wood	16.6		1.0	5.6
		Sum	77.2		2.4	3.0
	Other land with tree cover	Standing dead wood	0.7		0.2	23.3
		Stumps	0.6		0.2	27.3
		Lying dead wood	1.7		0.3	19.5
		Thin dead wood	1.8		0.3	15.4
		Sum	4.7		0.4	8.7
	Total	Standing dead wood	13.5		1.0	7.7
		Stumps	11.2		0.9	5.9
		Lying dead wood	38.7		2.3	6.1
		Thin dead wood	18.5		1.0	5.2
		Sum	81.9		2.4	2.7

[a]Correspond 68% one-sided confidence interval.
[b]Not available.

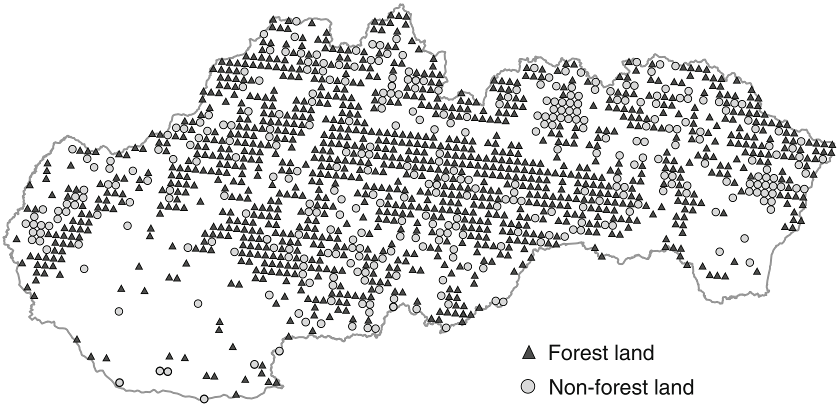

Fig. 32.1 Sampling grid of Slovakia's NFIM Network of inventory plots

the available financial sources and required accuracy accepted by the Steering Committee of the inventory. Accepted accuracies were estimates of the forest area at the national level with error of ±2.2%, estimates of growing stock volume per hectare with error of ±1.8%, and estimates of total growing stock volume with error of ±2.7%, all with 68% reliability. Modifications of the sampling design that would have reduced errors by 0.50–0.25 would require more dense grids and would increase costs by factors of 4–8.

The NFI methodology is based on a combination of ground-photo methods and a systematic allocation of sample plots over the entire country (Fig. 32.1).

32.4.1 Sample Plots

For the terrestrial inventory, which is the basis of the entire survey, four kinds of sample plots are used (Fig. 32.2):

A – a fixed area circular plot with a radius of 12.62 m for the assessment of site, stand and ecological variables, and for the inventory of lying dead wood and stumps

B – concentric circular plots with radii of 3 and 12.62 m for observation and measurement of attributes of trees with diameter at breast height (*dbh*) between 7 and 12 cm, and $dbh \geq 12$ cm, respectively

C – a variable radius plot for small trees with $dbh < 7$ cm, its diameter (r = 1.0 or 1.41 or 2.0 m) is chosen according to density of individuals on the concrete plot

D – extended constant circle with radius 25.0 m for the inventory of forest borders, roads and water resources

Plot sizes were selected to accommodate the characteristics of the observed and measured variables including more than 100 attributes and variables.

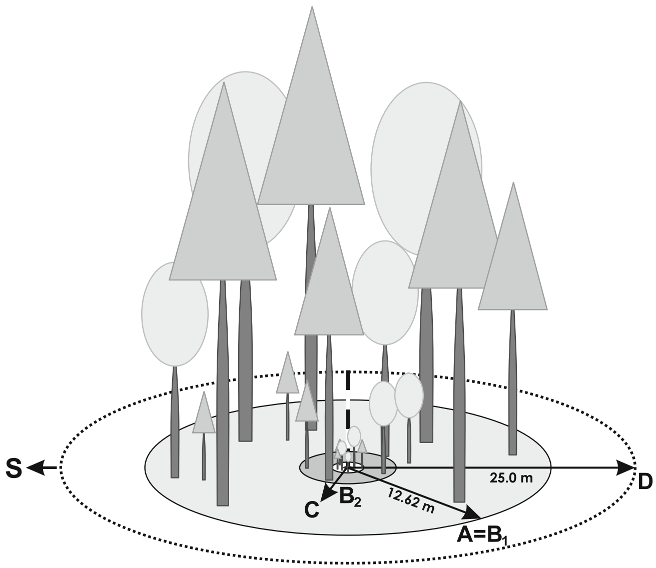

Fig. 32.2 Scheme of terrestrial sample plots

A photo interpretation was carried out using a 2 × 2-km grid superimosed on orthophotographs of Slovakia. Photo plots were 2,500 m^2 in area and were used mainly for identification of forest and non-forest lands. The total number of photo plots was 12,268. Other stand variables such as tree species composition, age or development stage were also interpreted from aerial photos but were not used in NIFM because the resolution of the available orthophotomap (Geodis-Eurosense 2002 Ortofotomapa © Geodis Slovakia, s. r. o. (2002–2003) was not able to produce information compatible with information obtained from the terrestrial inventory.

Interpretation of orthophotos for the sample plots on the 4 × 4-km terrestrial inventory grid was used for orientation and navigation in the field. In accordance with NFI methods, field inventories were conducted for all plots whose photo interpretations were not definitively non-forest, were uncertain as to whether they belong to the category 'Non-forest' (in accordance with the methodology) and were within Slovakia.

32.4.2 Management, Personnel, Measurement Techniques, Quality Assurance

The Forest Research Institute (FRI) in Zvolen was charged with developing the methodology and implementing the national inventory in cooperation with other institutes of the National Forest Centre, specifically, Lesoprojekt – the Institute for

Forest Management Planning (IFMP) and the Institute of Forest Resources and Information. In 2004, a Methodical and Technical Board for NIFM was established at the FRI Zvolen – Directive Centre of NIFM. The Board consisted of specialists in forestry and ecology from all relevant institutions in Slovakia. Necessary instruments and equipment were purchased, and the methodology was prepared and verified. Because of limited time and financial capacity, the entire NIFM project was simultaneously implemented as a pilot project. In other countries, methodological preparation is usually done at least 2–3 years in advance and then followed by operational implementation.

Before field work, all workers attended a 1-week training course. Field sampling and data collection were performed according to uniform and detailed working procedures (Šmelko et al. 2005) that were discussed and approved by the Board for the Methodology and Technique of NIFM. Each year five inventory groups, each with three members (foresters from IFMP – Lesoprojekt and FRI), carried out the field work. In 2005, one working group from the private mensurational office EuroForest Ltd. also participated. Data collection was supported by modern computer technology, and FieldMap was used for the establishment of inventory plots, mapping, obtaining and recording data. A control group, consisting of the members of the Control Centre of NIFM, coordinated and directed the professional side of the field work, checked approximately 10% of established inventory plots, provided consultations and evaluated problematic inventory plots.

At the end of each year, the field work was assessed at a common final meeting of all interested parties. Working group performance exceeded quality standards. The average assessment mark was 2.1 (very good) on a scale of 1–5 where 1 was excellent and 5 unacceptable. Only two checked inventory plots were assessed as unsatisfactory; they were re-established. The assessment of data on the time necessary to conduct individual work provides valuable information for repeated cycles of NIFM. Table 32.3 presents a summary of field work.

32.5 Data Processing

Proper attention was paid to data processing methods during the entire implementation of the inventory. Theoretical problems were solved; estimation procedures corresponding to the sampling design were investigated; and the required biometric models and algorithms for mathematical-statistical calculations were derived and verified in the course of the inventory. Data processing included the three interlinked components described in Sections 32.5.1–32.5.3.

32.5.1 Data Checking

The aim was preparation, checking and completion of the entire database, particularly checking data completeness, numerical and logical accuracy and interrelations

Table 32.3 Basic information on inventory plots

Quantity	Year											
	2005				2006				2005 and 2006			
	Number of plots	Percent	Control	Percent	Number of plots	Percent	Control	Percent	Number of plots	Percent	Control	Percent
Forest land	642	82.8	60	9.3	519	73.0	45	8.7	1,161	78.1	105	9.0
Other land with tree cover	103	13.3	17	16.5	158	22.2	28	17.7	261	17.6	45	17.2
Non-forest and outside Slovak Republic[a]	30	3.9	5	16.7	34	4.8	4	11.8	64	4.3	9	14.1
Total	775	100.0	82	10.6	711	100.0	77	10.8	1,486	100.0	159	10.7
Number of observations												
Increment cores	340				1,242				1,582			
Humus samples	2,198				1,947				4,145			
Soil samples	1,480				1,243				2,823			

[a]'Non-forest' and 'outside Slovak Republic' is the number of inventory plots excluded because the more accurate field evaluation indicated the criteria for 'Forest' were not satisfied in accordance with the NIFM methodology; these inventory plots did not have clear/unambiguous localizations in the territory of Slovak Republic. In total, 1,486 inventory plots were established of which 64 were evaluated as 'Non-forest' and 'outside Slovak Republic'.

of variables and attributes. Checking was based on algorithms specially prepared for this purpose.

32.5.2 Volume Models

Most data for individual trees or whole inventory plots are of primary character. In addition, for further processing derived data were necessary of which the following are most important:

a. Estimation of tree heights and lengths of tree crowns (Šmelko et al. 2007) based on a sample of NIFM observations and measurements. The advantages are fourfold: a reduction in the number of field measurements by approximately half with resulting cost savings, data on tree heights and crown lengths for each tree separately which is important for a new progressive approach called one-tree monitoring, prediction of growth processes using growth simulators, and replacement of measurements for leaning trees using a method that eliminates relatively large systematic errors.
b. Volume models for main and related tree species used to estimate tree volume (v) based on measured diameter at breast height (dbh) and height of trees (h). Volume models using domestic data (Petráš and Pajtík 1991) were constructed for five volume components: (1) large wood under bark which is the official component for estimates of growing stock of the forests in Slovakia; (2) large wood over bark as is most frequently used in the European Union; (3) stem under bark; (4) stem over bark; and (5) tree volume over bark which is important for needs such as balance of carbon supplies in above-ground dendromass. These models may be used not only for trees with $dbh > 7$ cm but also for stem under bark, stem over bark, and volume of tree over bark for trees with a dbh in the interval 0.1–7.0 cm measured on the sample plots C for small trees (Figure 32.2). The latter application for estimating small wood is a new objective of the national inventory.
c. The calculation of assortments (qualitative classes of round timber) was made for every living tree with $dbh \geq 12.0$ cm using models for domestic tree assortment tables (Petráš and Nociar 1991; Mecko et al. 1996) as a function of observed dbh, height h, and stem quality classes A–C. The results are estimates of volume for trees classified into quality classes of logs I, II, IIIA, IIIB, V (including IV) and VI in m^3 of large wood under bark.
d. Contrary to international traditions, deadwood was quantified in NIFM in a way that permitted estimation of all volume components in m^3 with bark and aggregation of the estimated components.

   – The volume of standing dead wood was estimated using volume models for living trees.
   – Special regression models were constructed for stem volume using diameter at upper cutting area of stem D and height of stem H as inputs.

–Volume of large lying wood (diameter $\geq$7 cm at the smaller end) was estimated using the measured diameters d_1 and d_2 over bark at both ends and the length L of each piece on inventory plots or sub-plots using Smalian's formula.
– For the volume of small lying wood (diameter <7 cm) an original method was developed whereby the volume of densely stacked small wood (in m^3) per square metre of the area is obtained from the model as a function of its estimated mean diameter d_s and it is multiplied by the inventory plot area, coverage of small wood and tree species proportion.

e. Estimation of tree growth area for trees belonging to different storeys. In NIFM, inventory plots with portions in age classes, growth stages or forest categories were divided into sub-plots for both horizontal and vertical levels. Tree growth areas were estimated using regression models constructed using data from the entire NIFM database. For trees with heights <1.3 m, models were based on heights, whereas for trees with heights $\geq$1.3 m, the models were based on diameters.

32.5.3 Up-scaling

Estimates based on a sample of inventory plots have a random or probabilistic character. Each estimate is only one of many possible values that might be obtained if the inventory with the same design were repeated several times but with the sampling grid shifted. Up-scaling means to estimate quantities for the area inventoried in such a way that confidence intervals at the selected levels (68% or 95%) are provided.

The size of the confidence interval depends directly on the variability of observations or measurements for the particular variable and indirectly on the sample size or density of the sampling grid. Several approaches for the estimation of parameters were used depending on the inventory sampling design and characteristics of variables such as quantitative or qualitative, tree or plot, fixed or variable area plot, and number of trees per plot.

For most parameters, the following approaches were used (order of formulas – sampling characteristic and its mean error, absolute and relative):

(a) Relative proportion of forest category $p_{(FOREST)}$ (forest coverage) and its standard error $S_{p(FOREST)}$

$$p_{(FOREST)} = \frac{\sum_{i=1}^{n} A_{i(LES)}}{\sum_{i=1}^{n} A_{i(LES+NELES)}} \qquad (32.1)$$

$$\mathrm{S_{p(FOREST)}} = \pm\sqrt{\frac{p_{LES}.(1 - p_{LES})}{n}} \tag{32.2}$$

$$\mathrm{S_{p(FOREST)}}\% = \frac{S_{p(LES)}}{p_{(LES)}}.100 \tag{32.3}$$

Explanatory notes: Les – Forest; Neles – Non-forest,

$A_{i(LES)}$ = forest area on plot i

$A_{i(LES+NELES)}$ = area of plot i

(b) Area of the forest of A category $A_{(FOREST)}$ (ha)

$$\mathrm{A_{(FOREST)}} = \mathrm{A_{(U)}} * \mathrm{p_{(FOREST)}} \tag{32.4}$$

$$\mathrm{S_{A(FOREST)}} = \mathrm{A_{(U)}} * \mathrm{S_{p(FOREST)}} \tag{32.5}$$

$$\mathrm{S_{A(FOREST)}}\% = \frac{S_{A(LES)}}{A_{(LES)}}100 = \mathrm{S_{p(FOREST)}}\% \tag{32.6}$$

Explanatory notes: Les – Forest

(c) Mean value (average) of quantitative stand parameter Y ('Ratio of Means' method), e. g. average standing volume per 1 ha

$$\bar{Y}_{ha} = \frac{\bar{Y}}{\bar{\bar{X}}} = \frac{\sum_{j=1}^{n} Y_j}{\sum_{j=1}^{n} X_j} \tag{32.7}$$

$$S_{\bar{Y}(ha)} = \sqrt{\frac{\sum_{j=1}^{n} (Y_j - \bar{Y}_{ha}.X_j)^2}{n.(n-1).\bar{X}^2}} \tag{32.8}$$

$$S_{\bar{Y}ha}\% = \frac{S_{\bar{Y}ha}}{\bar{Y}_{ha}}100 \tag{32.9}$$

(d) Total of quantitative parameter Y, e.g. total standing volume on the area of the territory A_U

$$Y = A_U.\bar{Y}_{ha} \tag{32.10}$$

$$S_Y = \sqrt{A^2.S_{\bar{Y}}^2 + \bar{\bar{Y}}^2.S_A^2} \tag{32.11}$$

$$S_Y\% = \sqrt{S_A\%^2 + S_{\bar{Y}}\%^2} \tag{32.12}$$

(e) Relative proportion of qualitative attribute *a* related to inventory plot (sub-plot-storey combination) with the area X_{aj}, e. g. growth stage

$$p_a = \frac{\sum_{j=1}^{n} X_{aj}}{\sum_{j=1}^{n} X_j} \tag{32.13}$$

$$S_{pa} = \sqrt{\frac{p_a.(1 - p_a)}{n}} \tag{32.14}$$

$$S_{pa}\% = \frac{S_{pa}}{p_a} 100 \tag{32.15}$$

Legend: *A* – area of territory, *X* – area of inventory plot, sub-plot, storey, *n* – number of sampling units, *j* – order of sampling units, *S%* – standard deviations
Notes:

1. The mentioned mean errors represent a theoretical limit where the actual error is less than the limit probability 0.68. For a probability of 0.95, this limit is about twice as large.
2. Formulas for mean error of the proportion S_p are valid only if $n > 40$ and p_a is in the range 0.3–0.7, the binomial distribution may be approximated by a Gaussian distribution, and confidence interval (error band) is symmetrical. Otherwise, the Fisher transformation from p_a to the parameter (is introduced, and the sampling proportion p_a and the lower and upper limits of the confidence interval, p_1 and p_2 respectively, will be non-symmetrical.

Post-stratification is a technique for increasing the precision of estimates by combining inventory plots into homogenous groups called strata (Cochran 1977). The result is less variability within strata and greater overall precision. This technique was used in NIFM for estimation of means of parameters related to area using age, growth stages and tree species to construct strata.

Data with respect to inventory plots were processed separately for each stratum $h = 1, 2, \ldots, L$ according to the algorithm given above as to (c). Resultant 'stratified' estimates for all strata were calculated according to these relations:

$$\bar{Y}_{ha(strat)} = \sum_{h=1}^{L} W_h.\bar{Y}_{ha(h)} \tag{32.16}$$

$$S_{\bar{Y}ha(strat)} = \sqrt{\sum_{h=1}^{L} W_h^2.S_{\bar{y}ha(h)}^2} \tag{32.17}$$

$$W_h = \frac{\sum_{j=1}^{n(h)} X_{j(h)}}{\sum_{j=1}^{n} X_j} \tag{32.18}$$

where: Y – mean quantitative value, X_j – total area of inventory plots $X_{j(h)}$ – area of respective stratum, W_h – areal proportion of respective stratum.

32.6 Structure of Outputs

Inventory results may be obtained to satisfy the particular requirements and needs of users and customers. A limiting factor is the accuracy of estimates. The density of the 4 × 4-km sampling grid permits sufficiently precise and usable estimates from NIFM only at the national level and for main forest categories, age classes, growth stages, and groups of tree species. At the regional level, particularly for regions with low forest coverage, the possibilities are limited. Only estimates of regional totals separately for coniferous or broadleaved tree species can be considered. Based on sampling theory, the error associated with estimates for smaller parts of the forest increases as the proportion of the total decreases. With the NIFM sampling design, the errors for 20%, 15% and 5% of the forest increase by factors of 2, 3, and 5, respectively.

32.7 Information System

The NIFM Information system is temporarily operated on local personal computers during data processing, whereas the basic data obtained from FieldMap is stored at the central MFC server. Measured geographical data are stored in shape files separately according to measured characteristics in a logically formed address structure. After data processing, a uniform storage facility of all data will be formed as part of a forestry information system (IS Forestry). Geographical data will be stored together with attributes and descriptive data in a single geo-database with an exactly defined scheme that will enable updating and processing of subsequent partial outputs. At the same time this solution will enable problem-free conversion into a format necessary for the next NIFM cycle. The stored data will be available for various categories of users (e.g. researchers, state authorities) according to the rules agreed in advance. Our aim is to make selected aggregated and analytical data in the form of dynamic maps available via the Internet for specialists as well as the general public.

32.8 Conclusions

On the basis of the assessment of the inventory operation and preliminary NIFM results, seven conclusions may be stated:

- To implement the first cycle of NIFM, a new sampling method was developed for the national inventory and future permanent monitoring of all forests of Slovakia; the method is adapted to domestic conditions and is comparable to other European designs, although it has several original elements.
- Preparation and implementation of NIFM was in accordance with approved procedures and all planned work was completely accomplished at a good quality level.
- The established permanent 4 × 4-km grid of inventory plots will be used for repeated measurements. The grid may be intensified or varied to accommodate monitoring of the development of forest ecosystems (using a combination of permanent and single inventory plots, more intensive use of remote sensing, information technology, etc.).
- NIFM 2005–2006 produced very valuable and vast data on all components of forest ecosystems in Slovakia. Variables were intentionally chosen to be useful for multifunctional purposes, for future research projects or for obtaining information about forests and forest ecosystems.
- Estimates from NIFM 2005–2006 correspond relatively well with the framework of accuracy presupposed in decision making about the task assignment.
- Preliminary estimates of forest area, tree species proportions, distribution of altitudinal vegetation zones are in accordance with total data of forest management plan (to 31 December 2005). The 22.7% greater volume of growing stock of large wood under bark estimated by the national inventory is attributed to different measurement methods (exact tree measurements on sample plots during NIFM versus mostly mensurational estimation for management plans), to lower diameter threshold for *dbh* (7 versus 8 cm), to measuring coppice-with-standards (not only main stand) and to differences in observed age structures. Greater differences were observed for inventories in other countries; for example in Austria the difference was nearly +40% and in the Czech Republic the difference was +33%. For Germany, results from the NFI and forest management cannot be compared because the methods have different aims and purposes.
- The importance of the national forest inventory will increase after the subsequent cycles (interval 10 or 7 years) when trends for all parameters may be estimated at both the national and regional levels.

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Chapter 33
Slovenia

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33.1 Development of Forest Inventories in Slovenia

For some time Slovenia obtained information on it's nation's forests by compiling data originally gathered for forest management planning needs. Traditionally, that data was obtained by sampling selected parts of forest management units (purposive sampling) and also by visual assessments of all the stands in the units (Hladnik and Hocevar 1989).

A large stride toward statistically-based large-scale forest inventorying was made in 1985, when the country joined the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) under the United Nations Economic Commission for Europe (UNECE) (UNECE 1979) and began monitoring forest health and forest ecosystem condition. Similar to the proposal of ICP Forests (UNECE 2006), the inventory design was based on cluster sampling, wherein each cluster consisted of four 6-tree sample plots (Prodan 1968). Although the plots (and the method itself) were considered suitable for gathering especially qualitative data (forest and tree health conditions), already the first inventory provided also information on forest sites, growing stock and increment (Solar et al. 1987; Levanic 1990).

In following years the design was supplemented with angle count plots (Kovac et al. 1995) that significantly reduced the variability of mean values of sampling units and made spatial estimates more robust. Accordingly, as well as reporting to the Convention on Long-range Transboundary Air Pollution (CLRTAP) (UNECE 1979), these estimates were also used for the reporting (Hocevar et al. 1999) to the Temporal and Boreal Forest Resources Assessment (TBFRA 2000) conducted by UNECE and the Food and Agriculture Organization of the United Nations (FAO).

Regardless of the many contributions of the inventory design it was decided that, after analyzing how representative the plots were for possible future needs, before the

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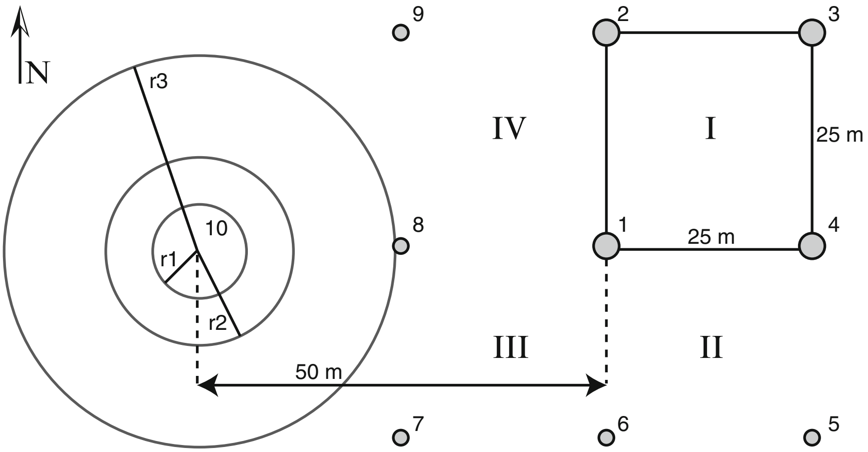

Fig. 33.1 Sampling design launched in 2000

2000 survey got underway, further improvements would not make it more efficient and would not guarantee more trustworthy information in the long-run. Consequently, to ensure representative sampling units and to allow for detecting changes over time, hidden concentric permanent sample plots (CPSP) were introduced and established as the main sampling units (Kovac et al. 2000) (Fig. 33.1). Since this modification, all the measurable variables have been recorded on these plots.

Although the 6-tree sample plots seemed unnecessary after introducing the CPSP linking the two inventory systems, they have been still in use; namely they assisted in bridging the gaps between the old and the new time series and will assist in inferring the health status of the population of trees that were selected at the beginning of monitoring.

The sampling designs were created in a way that allowed the use of inventorying system on the grids of variable densities (e.g. 4 × 4 km, 8 × 8 km, 16 × 16 km) and to measure variables over different time-spans.

In parallel with the large-scale Forest and Forest Ecosystem Condition Survey (FECS), Slovenia put into operation the inventory system at the level of forest management units, primarily used by forest management planning. The Rules on Forest Management and Silvicultural Plans (Official Journal of the Republic of Slovenia, nr. 5/1998 with fulfilments) replaced purposive sampling with the control sampling method (Schmid-Haas 1983; Hocevar 1990, 1991) that has since been used in all managed forest lands regardless of ownership. Accordingly, until the end of the 2007, more than 100,000 uniformly distributed CPSP have been established on grids with plot distances ranging between 250 × 250 m and 500 × 500 m, and measured for the first time. Due to continuous forest inventorying, sampling has just entered its second repetition (Table 33.1).

To summarize, within the last 20 years Slovenia has developed a rather complex system of hierarchical forest inventorying, making it possible to monitor the

Table 33.1 Data collection in Slovenia

Year	Grid density (km × km)	Number of clusters/plots	Content	Method + remark
1985	4 × 4	M6 (1207)[a]	M6: forest health/ defoliation, growing stock	Cluster of four 6-tree sample plots (Solar et al. 1987)
1987	4 × 4 16 × 16[b]	M6 (1041)[a] F/D (85)	M6: characteristic of stand/site, forest health/defoliation, growing stock	Cluster of four 6-;tree sample plots (Solar et al. 1987; Kalan 1989)
1988	16 × 16 16 × 16[b]	M6 (64) F/D (78)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots (Solar et al. 1989; Kalan 1989)
1989	16 × 16 16 × 16[b]	M6 (97)[c] F/D (84)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots
1990	16 × 16 16 × 16[b]	M6 (26)[d] F/D (72)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots
1991	4 × 4 16 × 16[b]	M6 (549) F/D (86)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots (Solar et al. 1991; Kalan 1989)
1993	16 × 16	M6 (34)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots (Bogataj et al. 1993)
1994	16 × 16 16 × 16	M6 (34) S (7)	M6: forest health/ defoliation S: site characteristic, soil samples	Cluster of four 6-tree sample plots (Kovac et al. 1995)
1995	4 × 4 16 × 16	M6 (712) S (36)	M6: characteristic of stand/site, forest health/defoliation, growing stock, Angle count plot: basal area	Cluster of four 6-tree sample plots + angle count plots (Kovac et al. 1995);
	16 × 16	F/D (39)	S: site characteristic, soil samples	
1996–1999	16 × 16	M6 (43)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots (Kovac et al. 1995)
2000	4 × 4	M6 (709)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots and 1 CPSP (Kovac et al. 2000)
	4 × 4	CPSP (617)	CPSP: characteristic of stand/site, forest health/defoliation, growing stock, dead wood, biodiversity	
2001–2004	16 × 16	M6 (42)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots
2005	16 × 16	M6 (44)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots and 1 CPSP

(*continued*)

Table 33.1 (continued)

Year	Grid density (km × km)	Number of clusters/plots	Content	Method + remark
	16 × 16	CPSP (39)	CPSP: forest health/ defoliation	S: test survey
	16 × 16	S (1)	S: site characteristic, soil samples	
2006	16 × 16	M6 (45)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots and 1 CPSP
	16 × 16	CPSP (40)	S: site characteristic, soil samples	
	16 × 16	S (44)		BioSoil-soil and BioSoil-biodiversity methodology
2007	4 × 4	M6 (612)	M6: forest health/ defoliation	Cluster of two (4 on 16 × 16 grid) 6-tree sample plots and 1 CPSP (Kovac et al. 2007 ; Urbancic et al. 2007)
	4 × 4	CSPS (778)	CSPS: characteristic of stand/site, forest health/defoliation, growing stock, forest functions, biodiversity	S: only plots which were not included in 16 × 16 km survey
	8 × 8	S (150)	S: site characteristic, soil samples	
2008	16 × 16	M6 (44)	M6: forest health/ defoliation	Cluster of four 6-tree sample plots (Kovac et al. 2007)

CPSP – concentric permanent sample plot; M6 – six tree method plot; S – soil survey; F/D – foliar and deposition survey.

[a]On additional clusters of 6−tree sample plots outside basic grid (16 × 16 km) forest health/ defoliation was assessed in more polluted areas.

[b]16 × 16-km bio-indication network (not exactly the same as 16 × 16 km).

[c]Some randomly selected clusters of four 6−tree sample plots from 4 × 4 km grid were additionally assessed.

[d]Only some randomly selected clusters of four 6−tree sample plots from 16 × 16-km grid were. additionally assessed.

conditions of the nation's forest lands and forest ecosystems at various scales. The integrity of the system along with the most relevant features are shown in Table 33.1 and Fig. 33.2, respectively.

33.2 The Use and Users of the 2007 FECS Results

33.2.1 General Use and the Use of the 2007 FECS Data for National Reporting

The 2000 Forest and Forest Ecosystem Condition Survey (FECS) gathered valuable data and information about the nation's forests and forest ecosystems. The Slovenian

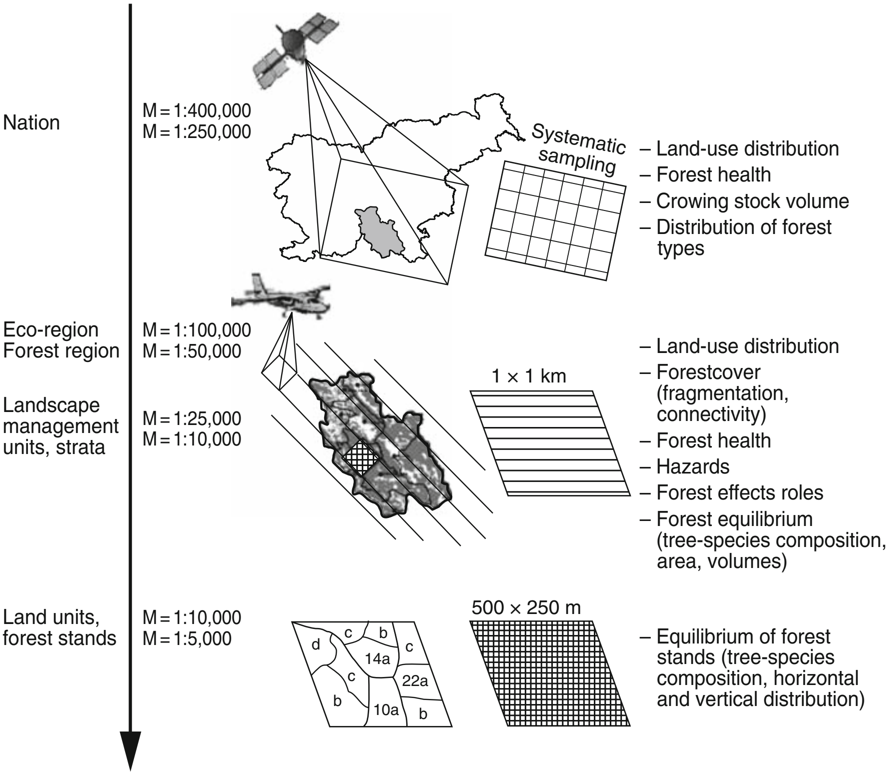

Fig. 33.2 Scheme of Slovenia's integrated inventorying system (Hocevar et al. 1996)

Forestry Institute (SFI) used the surveys in research and in international and national reporting to the CLRTAP, the Slovenian Environmental Agency and the Statistical Institute of the Republic of Slovenia. The Ministry of Agriculture, Forestry and Food of the Republic of Slovenia (MAFF) used them for international reporting such as to the Global Forest Resources Assessment 2005 (FRA 2005; FAO 2006) and to the Ministerial Conference on the Protection of Forests in Europe (MCPFE) in 2006 (MCPFE 2002, 2003), whilst other national and international institutions used them for research.

Since its launch, the aim of FECS has been to provide essential and trustworthy information on forests and forest ecosystems conditions. Because of the high costs of sampling, all the FECS's have been deliberately designed for multiple uses. As such they collect information on forest health, forest vegetation, mineral nutrition, forest soils, forest resources, forest diversity and forest functions.

Besides forest science and practice, much of the information has been needed by the Government to shape forest and environmental policy and to report to national and international institutions (UNECE/FAO 2000; FAO 2006; MCPFE 2002, 2003; UNFCCC). Furthermore, other governmental agencies, such as the Environmental Agency of the Republic of Slovenia and the Statistical Institute of the Republic of Slovenia have employed the data in national reporting.

33.2.2 The Use of 2007 FECS Data in UNFCCC Including Kyoto Reporting

By ratifying the Kyoto Protocol, Slovenia committed itself to reducing greenhouse gas emissions by 8% in the first commitment period 2008–2012 compared to the base years 1986 (for CO_2, CH_4 and N_2O gases) and 1995 (for F-gases), respectively. Notwithstanding the existence and potential of the inventory system at the forest management unit level, it has been suggested that only the FECS could be used for the Kyoto Protocol reporting, as it fully meets the methodological requirements provided by the Good Practice Guidance of the Intergovernmental Panel on Climate Change (IPCC 2003) of the third tier, which Slovenia has also accepted. In addition to the above suggestion, it has also been said that the execution of the 2007 FECS would have been justified only if the inventorying had been repeated periodically.

33.2.3 The Role of 2007 FECS in Assessing the Status of Biodiversity

Although the 2007 FECS has provided data, of which some is relevant for assessing biodiversity (e.g. stand structures, tree species compositions, regeneration, origin of stands, naturalness, area under management regime in protected forests, the amount and composition of deadwood), the derived information should be used with caution as much is of limited value and does not fully comply with statistical methodologies. For instance, some preliminary investigations (Kovac 2008) have shown that only the biodiversity of large-sized forest complexes and forest types could be monitored successfully, while the biodiversity of the Natura 2000 habitat types, which are much more fragmented and small-sized, should be surveyed with much denser grids (Hladnik 2008).

33.3 Current Estimates

The basic area estimates are given in Table 33.2a and volume estimates together with the mean basal estimate in Table 33.2b. The term "forest" is defined by the Law on Forests of Slovenia (Official Journal of the Republic of Slovenia, nr. 30/1993). Article two states:

Table 33.2a Basic area estimates from 2007

Quantity	Estimate (1,000 ha)	Share (%)	SE[a] (1,000 ha)
Forest land (reference definition)	1,181	58.6	n.a.[b]
Total land area	2,027	100	–[c]

[a]Standard error.
[b]Not available.
[c]Assumed to be error free.

Table 33.2b Basic volume estimates from 2007

Quantity	Estimate	SE[a]	SE (%)[b]
Growing stock volume Million cubic metre	407.1	17.6	4.3
m^3/ha	326.4	1	4.3
Annual increment of growing stock Million	10.8	0.7	6.5
m^3/ha	8.7	0.6	6.9
Deadwood volume Million cubic metre	23.2	3.9	16.8
m^3/ha	18.6	3.1	16.7
Basal area per hectare m^2/ha	35.8	1.2	3.4

[a]Standard error in units of volume.
[b]Standard error in percent.

1. Forest is:
   (a) A plot of land overgrown with forest trees in the form of stands, which can reach a height of at least 5 m and sized to at least 0.25 ha
   (b) A plot of agricultural land in transition to forest land sized to at least 0.25 ha that has not been used for agriculture for the last 20 years and is overgrown with forest trees which can reach a height of at least 5 m and their crown cover should be at least 75%
   (c) Riverside forest corridors and windbreaks sized to at least 0.25 ha, if their widths are at least one tree-height
2. The term "other wooded land" refers to all stands sized to at least 0.25 ha that cannot be identified as forest within the meaning of this law but have been overgrown with forest trees or other forest vegetation and have not been used for agriculture for the last 20 years. The term other wooded land also comprises game pens and the forest corridors under power lines sized to at least 0.25 ha.
3. The forest infrastructure apportioned to individual plots is an integral part of the forest.
4. The following are not "forest" or "other wooded land" within the meaning of this law: individual forest trees, groups of forest trees of area less than 0.25 ha, avenues, parks and plantations of forest trees.
5. The provisions of this law and rules issued on the basis hereof shall also apply to forest trees which grow outside forests insofar as they are specifically defined.

Definitions for tree stem volume, growing stock and deadwood are given in the Section 33.5.

33.4 National Forest Inventory – the 2007 FECS

33.4.1 Legal Framework

Although the FECS was put into operation two decades ago, the term “National Forest Inventory” has never been mentioned in the national forest legislation. This situation is due to the fact that forest management planning, unlike in the majority of European countries, is operated across all the nation’s forest lands and collects necessary data on the plots, belonging to much denser grids. Instead, the Slovene forest legislation (Rules on Forest Protection, Official Journal of the Republic of Slovenia, nr. 92/2000 with fulfilments) introduced the term FECS. The rules explicitly dictate that the inventorying is to be carried out annually on the 16 × 16-km grid and periodically (5–10 years) on the 4 × 4-km grid. In comparison to the periodic inventories, annual inventories are less intense and collect only the limited amount of data needed for early warnings (for example for increasing defoliation and gradation of pests).

Along with the general objectives of the FECS, the 2007 survey aimed to provide accurate and trustworthy information on the carbon stock and the growing stock volume to fulfil reporting requirements for the Kyoto Protocol. Because reporting was to be in line with the requirements of the third tier, the most relevant requirements are assured as follows:

- The list of necessary variables was defined in collaboration with forest science (forest inventorying, forest planning and management, growth and yield, and forest ecology) data users and policy makers.
- The SFI designed a manual for data gathering in the field (Kovac et al. 2007). The manual addresses all variables and provides sound protocols along with the schemes. All the protocols were tested in 2006 on the 16 × 16-km grid and were, in the case of ambiguity, corrected before being put into operation.
- The quality assurance and quality control were assured by training field-crews and by revisiting 5% of clusters. Algorithms, implementing the logical controls were developed and used after the data storage.
- The protocols for correcting erroneous data have been developed to assure the consistency of corrections and to review previous data sets.
- The methods for computation of estimates have been developed in a scientific way. To ensure their state of the art, all of them have been compared with internationally recognised methodologies.

In addition to the Kyoto Protocol reporting requirements, the design of the 2007 FECS also took into account many recommendations provided by the IPCC (2003), COST Action E43, FAO (2006) and MCPFE (2002, 2003).

In short, the main features of the 2007 FECS were

- Sampling design: open clusters consisting of one CPSP and 6-tree sample plots
- Sampling grid: 4 × 4-km, 778 clusters

- Field work: executed between July and August 2007
- Field crews: three field crews, provided by the SFI, were responsible for inventorying on the 16 × 16-km grid and for the control check of 5% of all plots, 35 field crews, provided by Forest Service of Slovenia (FSS), were responsible for inventorying on the 4 × 4-km grid
- Field crew consisted of one leader (university forestry engineer) and one assistant (student)

33.4.2 The 2007 FECS Design

The 2007 FECS statistical design is in principle the same as the design in 2000. The only modification was the introduction of an inner circle in the CPSP that permitted assessment of growing stock volume for trees with a diameter at breast height (*dbh*) between 0 and the 10 cm threshold. The most relevant information on all four concentric plots is presented in Table 33.3.

The sample clusters were located as in the previous inventory. As shown in Fig. 33.3 the main sampling unit CPSP defined whether a cluster, consisting of CPSP and the remaining two or four 6-tree sample plots, was installed. All the CPSPs, regularly positioned 50 m westward from the intersections of sampling grid coordinates could only be identified by knowing their geographical coordinates. Neither plots, nor trees were visually marked (with numbers, letters or other signs), to ensure regular (unbiased) forest management practice and the representativeness of data and results.

As noted earlier, the measurement methods were tested in 2006 on 40 sample plots (16 × 16-km sampling grid). The testing was necessary to assure that the measurement procedures were unambiguous and to assess the costs of inventorying.

Table 33.3 Critical values for assessing living and dead wood on CPSP in the 2007 FECS

Plots	$CPSP_1$	$CPSP_2$	$CPSP_3$	$CPSP_4$
Radius (R) of the plots [m][a]	3.09	7.98	13.82	25.23
Area (P) of the plots [m^2]	30	200	600	2,000
Characteristics of stand and site	Area of 2,000 m^2			
Standing living trees	$dbh > 0$ cm $h \geq 1.3$ m	$dbh \geq 10$ cm	$dbh \geq 30$ cm	
Standing dead trees	$dbh \geq 10$ cm		$dbh \geq 30$ cm	
Lying dead trees	$dbh \geq 10$ cm		$dbh \geq 30$ cm	
Stumps	d $\geq$ 10 cm $h \geq 20$ cm			
Snags	d $\geq$ 10 cm $h \geq 50$ cm		d $\geq$ 30 cm $h \geq 50$ cm	
Coarse woody debris – woody parts of trees (branches, parts of stem, etc.)	d $\geq$ 10 cm l $\geq$ 50 cm		d $\geq$ 30 cm l $\geq$ 50 cm	

[a]Reduction of plot area due to terrain slope should be considered when defining radius of the plots.

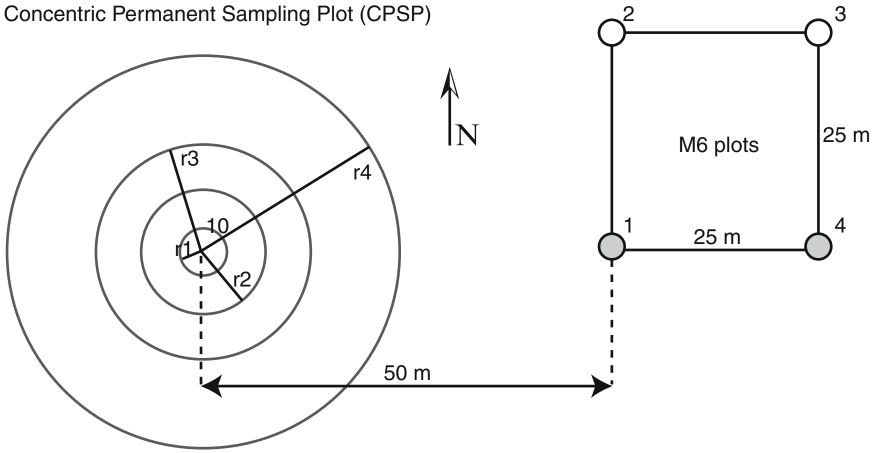

Fig. 33.3 Scheme of a cluster: on 16 × 16-km grid: CPSP + all four 6-tree sample plots; on 4 × 4-km grid: CPSP + two 6-tree sample plots numbers 1 and 4

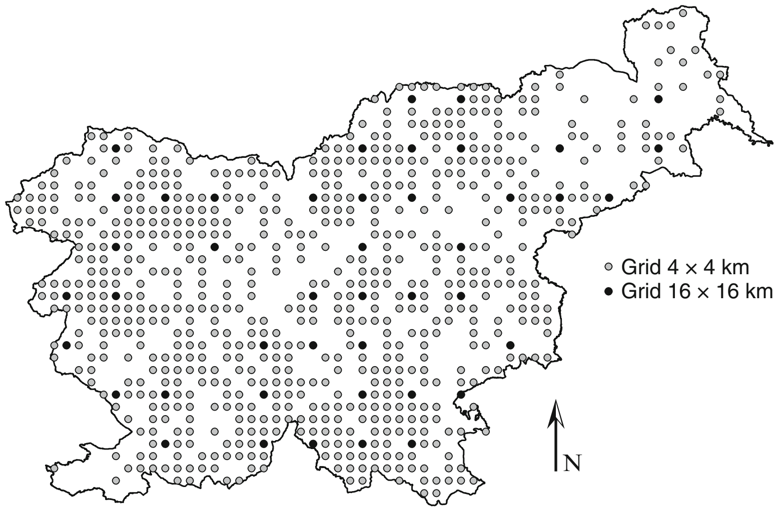

Fig. 33.4 Arrangement of clusters in the 2007 FECS sampling grid

The 2007 FECS encompassed measurements and assessments on the 778 clusters of the 4 × 4-km sampling grid (see Fig. 33.4). To reduce the costs of field work, the likely locations of clusters were inspected on satellite and digital orthophoto images prior to the field inventorying. That step was necessary because of day-to-day land use changes and because of forest cover expansion into the abandoned farmlands that Slovenia has been experiencing for more than a decade.

33.4.2.1 Field Work

Each cluster fulfils the following activities:

- CPSP: detailed description of the site and stand (type of management, ownership, vertical and horizontal composition, suitability of forest functions, etc.)
- CPSP: determination, assessment and measurement of tree features (tree species, social status (height class), defoliation, injuries, diameter/circumference at breast height, distance and azimuth from the centre of a plot to every measurable tree, height and age of the three dominant (widest) trees, status of a tree (regarding to the type of growing stock/biomass, e.g. living, dead, standing, lying), tree status code – present in both assessments (in the years 2000 and 2007), cut down/felling, dead, etc.)
- CPSP: assessment and measurements of deadwood (type of dead wood, dimensions e.g. diameter, length/height, tree species, decay class)
- M6 plot: tree species, social status, defoliation, injuries, etc.

33.4.2.2 Deadwood Assessment

Dead trees (lying and standing) are measured regardless of the presence or the absence of bark. A dead tree is considered a tree only if branches are still present on the trunk. If branches are no longer part of the trunk, the object is defined as a large wooden piece. If a lying dead wood piece crosses the plot boundary (see Fig 33.5, example 5), only the part inside the plot is taken into consideration in which case length (l) and mean diameter (d) are measured. All threshold values that must be considered are shown in Table 33.3.

A lying dead tree is chosen for measurements only if its *dbh* lies inside the plot and if its *dbh* is larger or equals 30 cm (see Fig 33.5, examples 1–3).

A stump is selected for measurement if its centre (see Fig 33.5, example 6) lies within the critical plot radius. If the stump is not symmetrical in height and basal area, its mean dimensions, namely mean height (h) and mean diameter (d), should be computed by taking account of adjacent values (e.g. upper and lower height of stumps of different shapes or of stumps on slopes; largest and smallest diameter of stumps with irregular basal area). If a stump is pulled out from the soil with roots, or if the roots are visible, only the part without roots should be measured.

33.4.2.3 Activities, Personnel, Data Management

The execution of the 2007 FECS encompassed activities such as management, preparation of field manual and forms, organization of the training course, field inventorying, field control, data input and quality control, data analysis and reporting. With the exception of field inventorying that was strongly supported by the FSS

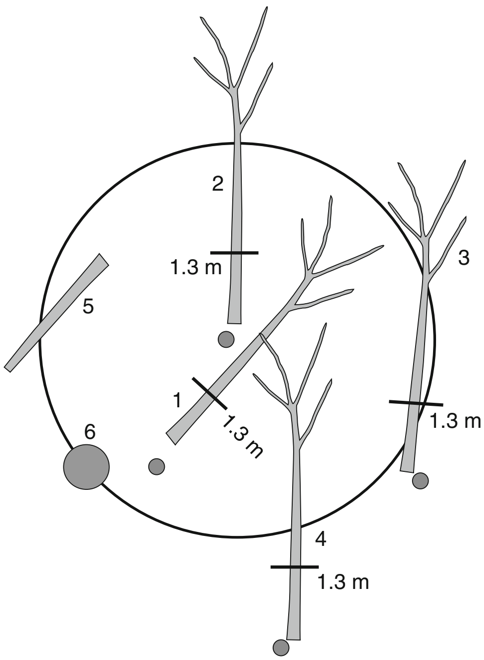

Fig. 33.5 Examples of lying dead trees and stumps

the SFI carried out all the remaining activities. In total, 90 people were involved in the FECS; 20 from the SFI and 70 from the FSS.

In comparison to the field inventorying the data management was the second most demanding task. The data gathered in the field was entered into the computer manually and after that logically controlled. The queries, the formulas for the computation of raw and derived data as well as some estimates, have been programmed in the SQL and C++ languages. The open programmable environment allows making queries, databases, tables and more simple analyses. However, more complex analyses need to be conducted in the geographic information system (GIS), e.g. ArcGIS, IDRISI and PCI Geomatics, or statistical, e.g. S-Plus or statistical software environments.

33.4.2.4 Quality Assurance

All field crews engaged in inventorying attended the training course on assessment and measurement protocols and practical work. Immediately after the course, at the beginning of the actual field work, all the field crews were visited by SFI staff who worked with them for a day. The aim of these visits was to ensure the proper understanding of all procedures and to clarify continuing misunderstandings of the protocols.

At the end of inventorying SFI crews revisited 40 clusters (or at least 5% of all plots) and evaluated the quality of field work.

33.4.2.5 Collected Variables

Table 33.4 shows the variables collected in the 2007 FECS. The majority was selected to fulfil the demands of the Rules on Forest Protection (Official Journal of the Republic of Slovenia, nr. 92/2000), while the rest of them to support the Government and research institutions in international and national reporting to MCPFE, FRA, Kyoto Protocol, UNFCCC, CLRTAP, national agencies and institutes. Prior to the test in 2006, the list of variables was defined in collaboration with SFI, FSS, MAFF and Biotechnical Faculty, Department of Forestry and Renewable Forest Resources. All the variables were fully harmonized with the international recommendations such as the ones of COST Action E43, MCPFE (2002, 2003) and FAO (2006).

33.5 Estimation Techniques

33.5.1 Area Estimation

Because of the sampling methodology, exact area estimation is not part of the FECS. Instead, the map of actual agriculture and forest land use (MAFF 2002) which was finished in 2002 and since then subject to updating, is being used whenever this information is needed. The map was produced through vectorization of the digital orthophoto images (reference year 1997).

33.5.2 Volume Estimation

For the estimation of the volumes of individual trees, Slovenia has traditionally used the modified French Tariffs (Cokl 1957, 1959). The tariffs, having been derived for uneven-aged (rapid tariffs), even-aged (slow tariffs) and stands of intermediate form (intermediate tariffs), take account of the tree species and the quality of sites. The tariff functions also provide the volumes of stems along with the stump and bark and the volumes of all branches with the diameters larger than 7 cm.

Because the tariff class of each tree species is normally determined at the level of forest compartment, the procedure requires only computing the volumes of individual trees. Nevertheless, if the tariff class is unknown or if it needs to be changed, the determination of the tariff class is inevitable.

Table 33.4 Variables of the 2007 FECS

Variable group	Variable	Contributes to MCPFE criteria and indicators
1. Forest sites and stands	General information	1.1 Forest area
	Location of sample plot's centre (Gauss-Krüger coordinates from global positioning system (GPS))	4.2 Regeneration
	Ownership	4.3 Naturalness
	Administrative unit (e.g. forest region, management unit, compartment)	4.9 Protected forests
	Site conditions	
	Shape of micro-relief (e.g. flat, the top, slope, etc.)	
	Exposition (in degrees)	
	Parent rock group (mixed, carbonate, non-carbonate)	
	Rockiness (in % of rock cover)	
	Slope (in degrees)	
	Phytosociological association	
	Stand conditions	
	Forest edge (the proportion of forest on a plot)	
	Vertical forest composition (regular selection forest, quasi-selection forest, evenly-aged, unevenly-aged, coppice, bushy forest, other)	
	Developmental stage of a stand (young growth, pole stand (I and II), younger old growth, old growth, undefined)	
	Stand mixture (pure conifers, conifers with broadleaves, broadleaves with conifers, pure broadleaves)	
	Form of stand mixture (individual occurrence, occurrence in patches, . . .)	
	Canopy closure (dense, normal, tender, patchy, fragmented)	
	Regeneration	
	Origin of a stand (natural, artificial, combined)	
	Class of tariffs	
	Forest characteristics (primary forests, modified natural, semi-natural)	
	Forest type	
	Homogeneous of stand	
	Forest management	
	Availability for wood supply	
	Age of dominant trees	
	Height of dominant trees	
2. Forest health	Tree	2.1 Deposition of air pollutants
	Defoliation (in %)	2.3 Defoliation
	Type of defoliation	2.4 Forest damage
	Yellowness	

(*continued*)

Table 33.4 (continued)

Variable group	Variable	Contributes to MCPFE criteria and indicators
	Type of yellowness	
	Occurrence of dead branches (e.g. dead twigs only, dead branches, dead parts of the crown, dead top, other combinations)	
	Occurrence of leaf and needle injuries (diseases, insects, abiotic damages, other)	
	Overall defoliation due to known causes	
	Easily determined stem injuries (e.g. cancer, fungi, bark-beetles, other primary insects, wildlife, lightening, forest fire, windfall, snowfall, sleet, frost, avalanches, rock fall, harvesting, recreation, vandalism, etc.)	
	Freshness of injuries (e.g. fresh unhealed, old unhealed, old healed, . . .)	
	Occurrence of lichens and surface covered by lichens by Crustose, Foliose and Fructicose group	
3. Soil and plant nutrition	Soil	2.2 Soil condition
	Horizon	
	Depth	
	Moisture	
	Consistency	
	Structure	
	Texture	
	Soil type	
	Humus type	
4. Growth and yield	Growing stock (tree with *dbh* $\geq$ 10 cm)	1.2 Growing stock
	Tree species (determination)	1.3 Age structure and/or diameter distribution
	Azimuth of a tree (in degrees from the centre of a plot)	
	Distance from the centre of a plot (in m)	1.4 Carbon stock
	dbh ($\geq$ 10 cm)	3.1 Increment and felling
	Code (history of a tree; e.g. no change, cut, ingrowth, etc.)	
	Social position (Kraft's scale)	4.1 Tree species composition
	Length of broken part of tree top	4.4 Introduced tree species
	Growing stock of thinner trees (*dbh* <10 cm)	4.8 Threatened forest species
	Tree species (determination)	
	dbh (<10 cm)	
	Tree height class	
	Number of trees	
5. Biodiversity (woody debris, plant richness)	Occurrence of wooden plants (count)	4.5 Deadwood
	Dead wood biomass	
	Type of biomass (dead standing tree, downed dead tree, stump, snag, coarse woody debris)	
	Tree species (determination)	

(*continued*)

Table 33.4 (continued)

Variable group	Variable	Contributes to MCPFE criteria and indicators
	dbh (for trees) Diameter and height (length) for stump, snag and coarse woody debris) Decomposition rate (presence of bark and hardness of wood)	
6. Potentials of sites for providing forest effects/roles	Enquiry about forest functions and roles Presence of Rock fall Sabre-shaped stump Erosion (water) Avalanche Landslides Forest fires Hydrological function Recreation function Anthills Pasture in forest Garbage dump Heaps of stones Wild animals Fruitful tree species Hunting objects Non wood products Similarity to natural forests Richness of stand structures The need for maintaining the stand in the present form The degree of stand preservation with regard to potential vegetation, Accumulation of dead wood biomass	3.3 Non-wood goods 3.4 Services 3.5 Forests under management plans 5.1 Protective forests – soil, water and other ecosystem functions 5.2 Protective forests – infrastructure and managed natural resources

Criteria C 1: Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles; C 2: Maintenance of Forest Ecosystem Health and Vitality; C 3: Maintenance and Encouragement of Productive Functions of Forests (Wood and Non-Wood); C 4: Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems; C 5: Maintenance and Appropriate enhancement of Protective Functions in Forest Management (notably soil and water); C 6: Maintenance of other socioeconomic functions and conditions.
Unclassified: 3.2 Roundwood; 4.6 Genetic resources; 4.7 Landscape pattern; 6.1 Forest holdings; 6.2 Contribution of forest sector to gross domestic product (GDP).

33.5.3 Computation of the Tree Volume

The volumes of trees are calculated by choosing the appropriate tariff equation (type, class) with the *dbh* as the independent variable. Tariff type (equation) and class (coefficient) are both defined with the tariff code selection. A tariff code (01–20

Table 33.5 Tariff coefficients

Tariff's Class										
From 1 to 10	1	2	3	4	5	6	7	8	9	10
v_{45}	1.143	1.200	1.263	1.326	1.396	1.466	1.543	1.620	1.706	1.791
From 11 to 20	11	12	13	14	15	16	17	18	19	20
v_{45}	1.885	1.979	2.084	2.188	2.303	2.418	2.546	2.673	2.814	2.954

uneven-aged stands; 21–40 stands of intermediate forms; 41–60 evenly-aged stands), determined at the level of forest compartment for eight different tree species groups (T_1–T_8) and stored in the database must be assigned to every single tree. All in all three different tariff types (four equations) and 20 tariff classes with different coefficients (v_{45}) are needed (Table 33.5):

- Uneven-aged stand/forest (German 'plenterwald'), rapid Algan's P tariffs (for tariff codes 1–20)

$$v = \frac{v_{45}}{1400} * (dbh - 5) * (dbh - 10) = \frac{v_{45}}{1400} * \left(dbh^2 - 15 * dbh + 50\right) \tag{33.1}$$

and for trees which *dbh* is thinner than 25 cm:

$$v = \frac{v_{45}}{1400} * \left(-226.33 + 38.575 * dbh - 1.9237 * dbh^2 + 0.04876 * dbh^3\right) \tag{33.2}$$

- Uneven-aged stand/forest, intermediate Cokl's V tariffs (for tariff codes 21–40)

$$\begin{aligned} v &= \frac{v_{45}}{1600} * (dbh - 2.5) * (dbh - 7.5) \\ &= \frac{v_{45}}{1600} * \left(dbh^2 - 10 * dbh + 18.75\right) \end{aligned} \tag{33.3}$$

- Even-aged stand/forest, slow Schaeffer's E tariffs (for tariff codes 41–60)

$$v = \frac{v_{45}}{1800} * dbh * (dbh - 5) = \frac{v_{45}}{1800} * \left(dbh^2 - 5 * dbh\right) \tag{33.4}$$

Determination of a tariff class (Cokl 1957, 1959):

- After determining the type of stand it is first necessary to determine the *dbh* class wherein the growing stock volume of a stand is halved. Practically that can be done by counting 20% of trees with the largest *dbh* in unevenly-aged stands, 25% of trees in the stands of intermediate form and 30% of trees in evenly-aged stands.
- Having determined the adequate *dbh* class, the average tree height may be assessed from the tabular data or by tree height measurements of the selected trees in the stand.

- As soon as the mean tree height is known, the tariff class may be determined in one-way tables, compiled for stand type and tree species.

Volume of a tree with *dbh* $<$ 10 cm is calculated with the mathematical equation for cone.

$$V = G*\frac{h}{3} = \left(\pi*dbh^2*\frac{h}{12}\right) \quad (33.5)$$

33.5.4 Growing Stock Volume Estimation

The calculation of growing stock volume per sample plot is as follows:

- The growing stock volume per hectare is obtained by adding the values of volume per hectare
- The volume (m^3) of every tree is multiplied by the correspondent area factor (FP). This calculus helps obtain the volume of an individual tree per hectare (m^3/ha)
- Area factors (FP) are as follows:
  - FP_1 = 333.3; for the trees under the measurement threshold with *dbh* ranging between 0 and 9.9 cm
  - FP_2 = 50; for trees with *dbh* ranging between 10 and 29.9 cm
  - FP_3 = 16.7; for trees with *dbh* equal or larger than 30 cm
  - FP_4 = 5; for dead standing trees (code 2) with *dbh* equal or larger than 30 cm

The estimate of the growing stock volume per hectare is calculated as an average of plot level volumes and the total volume estimate for forest land as a product of the estimates of volume per hectare and the estimate of the forest land area.

33.5.5 Deadwood Volume for an Individual Tree

The choice of the method (tariff or Huber's equation) depends on the type of deadwood. In the case of:

- Trees (standing dead tree, lying dead tree) the volume calculation is the same as in the case of the living tree (tariff equations, see above),
- Stumps, snags and coarse woody debris, the volumes are calculated on the basis of its diameter (D) and height/length (H/L) by using the Huber's equation – volume of cylinder

$$V = G*H \text{ or } L = \left(\pi*D^2*H \text{ or } \frac{L}{4}\right) \quad (33.6)$$

33.5.6 Deadwood Volume Estimation

The calculation of deadwood growing stock volume per sample plot is as follows:

- The dead wood growing stock volume per hectare is obtained by adding the values of volume per hectare.
- The volume (m^3) of every piece of deadwood is multiplied by the corresponding area factor (FP) according different types of dead wood, to calculate volume of dead wood per hectare (m^3/ha).
- Area factors (FP) are calculated on the basis of the sample plots areas (P) and dead wood types:
  - Tree (standing dead tree, lying dead tree), if *dbh* is:
    - From 10 to 29.9 cm: FP_2 is 50,
    - Equal to or greater than 30 cm: FP_4 is 5.
  - Stump: FP_2 is 50,
  - Snag, if diameter (D) is:
    - From 10 to 29.9 cm: FP_2 is 50.
    - Equal to or greater than 30 cm: FP_4 is 5.
  - Coarse woody debris, if diameter (D) is:
    - From 10 to 29.9 cm: FP_2 is 50.
    - Equal to or bigger than 30 cm: FP_4 is 5.

33.5.7 Growth and Drain Estimation

The growth (gross growth including ingrowth) is estimated by the following formula provided by Kaufmann (2001):

$$G_{gi} = V_{s2} - V_{s1} + CM_{1.5} - CM_1 + I = V_{sc2} - V_{sc1} + I \quad (33.7)$$

where

V_{s1} – Volume of the survivor trees in the first inventory
V_{s2} – Volume of the survivor trees in the second inventory
V_{sc1} – Volume of the survivor and the cut trees in the first inventory
V_{sc2} – Volume of the survivor and the cut trees in the second inventory
CM_1 – Volume of the cut and mortality trees in the first inventory
$CM_{1.5}$ – Volume of the cut and mortality trees including their growth up to half of the inventory interval
I – Volume of the trees ingrown over the calliper threshold of 10 cm

Although wood harvesting is usually bound to larger concentrations of wood, the FECS database seems to be a trustworthy information source for the estimation of drain at national level. To ensure unbiased forestry management on the CPSP's, all the plots are hidden and all the trees growing on them are unmarked. The drain is estimated as volume of the cut and mortality trees including their growth up to half of the inventory interval.

The estimate presented in Table 33.2b has been derived on the basis of the 2000 and 2007 FECS data.

33.6 Current and Future Prospects

In concert with national legislation FECS provides the data for many topics and thus may be used by various end-users responsible for national and international reporting, for shaping policies, for research and for developing forest practices. The current content of the FECS makes it possible to report to the conventions such as CLRTAP and UNFCCC, to MCPFE and to FRA. Additionally FECS fully supports the Government in implementing the European Union (EU) and national legislation and in shaping national forest and environmental policies. In turn it assists science in its research activities and forest practice in setting goals and objectives.

As far as future is concerned, FECS is expected to become part of the Forest Law that would guarantee more stable conditions needed in the inventory research and implementation. In the view of potential end-users and already expressed needs, the future FECS will have to cover even more topics than presently. Of essential importance seem to be the data on existing and potential natural hazards, on sustainability of forest functions, etc.

The design itself will also have to be improved. If the existing permanent sample plots become unrepresentative, it will be necessary to improve the design by adding temporary plots. Also remote sensing techniques, currently not part of FECS, will be used to aid the FECS.

33.7 COST Action E43 Effects on the 2007 FECS

COST Action E43 has confirmed that the decision of Slovene science in 1985 to develop and launch a statistically grounded large-scale forest inventorying was correct. Although the intentions at the beginning were not great, the later improvements made the FECS very promising and thus it has turned to one of the most important national databases. COST Action E43 has significantly affected the contents of the 2007 FECS. Firstly, it has made it possible to exchange knowledge and experiences inevitable in such projects. Secondly, it has brought together scientists who, since then, have been able to work hand-in-hand. Thirdly, it has produced the most-up-to-date list of variables along with the measurement protocols that can be subject to large-scale monitoring. Lastly, it has shown ways how to unify independently developed inventory systems into entities and make them more efficient.

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Chapter 34
Spain

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34.1 Development of Spain's National Forest Inventory

The first National Forest Inventory (NFI) (Primer Inventario Forestal Nacional, NFI1) was conducted between 1965–1974. The main motivations for that inventory were the need to (1) provide forest data for statistics and politics at regional and national level, and (2) to estimate the forest growing stock, forest areas, and increments as a guide for establishing new forest enterprises. NFI1 covered all the national forest area. The assessment units were the 50 Spanish provinces which have a mean surface area of 1 million hectare and with a total of 50.6 million hectare for all of Spain. Each year of the inventory, five provinces were sampled using the following methodology in each province:

- Stratified double sampling design with allocation of the field plots to minimize the variance of volume estimates.
- Estimation of forest areas by assessing the forest/non-forest status of points at the intersections of a systematic sampling grid, overlaid on aerial photographs of 1:30,000 scale.
- All plots were temporary.
- Selection of trees on sample plots using the angle count method (Bitterlich 1948).
- Three representative standing trees per plot were measured to obtain data for construction of volume and increment models.

The final results of NFI1 were reported in fifty provincial and three national publications.

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The second NFI (Segundo Inventario Forestal Nacional, NFI2), was conducted from 1986–1995. The assessment unit was also the province. Each year, five provinces were sampled using a methodology with the following main characteristics:

- Forest areas and strata were identified from the existing agriculture and land use map.
- Field plots were located at the intersections of a 1 × 1-km Universal Transverse Mercator (UTM) grid. The sampling intensity was greatly reduced in poorly productive forest areas and Quercus spp. coppice areas.
- Distances and azimuths from the plot centres to trees and diameters at breast height (dbh), heights and six different tree shapes were registered (e.g. pollard tree, bifurcation at a height of more than 4 m, etc.). The objective of this last variable is to classify trees from the same species into homogenous groups and to use different equations for each of those groups in order to obtain more precise tree volume estimates.
- Field plots were marked as permanent.
- Four circular concentric plots of radius 5, 10, 15 and 25 m were used to measure trees of different *dbh*s
- Four representative standing sub-sample trees per the whole plot (four concentric plots) were measured for length and width of the crown, bark thickness, diameter increment for the last 10 years and upper diameter at a height of 4 m.

The third National Forest Inventory (Tercer Inventario Forestal Nacional, NFI3), started in 1997 with the field work ending in 2007, and covered all forests in all ownership groups. The main methodological characteristics are similar to those of the NFI2 with the following differences:

- Stratification was 'a posteriori' and land cover classification and forest area estimation were based on digital maps and ortho-images.
- Unlike in the NFI2, no additional tree measurements were performed regarding length and width of the crown, bark thickness, diameter increment or upper diameters.
- Sub-sample trees were not measured.
- A new improved methodology for biodiversity estimation was developed and used for some provinces. This new methodology has been applied since 2005 with 15 provinces having been inventoried.

Fifty provincial booklets which included forest resource maps reported the results of this inventory. The fourth NFI (Cuarto Inventario Forestal Nacional, NFI4) began in 2008. A summary of the Spanish NFIs is given in Table 34.1.

Table 34.1 The national forest inventories in Spain

Inventory	Years	Stratification	Sampling method and field plots	Number of plots
NFI1	1965–1974	Grid over photographs	Optimal allocation of plots; temporary plots	65,000
NFI2	1986–1995	Grid over maps	Systematic 1 × 1-km grid; permanent plots	84,203
NFI3	1997–2007	Grid over digital maps	Same systematic grid as NFI2; permanent plots	95,327

34.2 The Use and Users of the Results

34.2.1 General Use

The information generated by the Spanish NFI has been used in forest management planning at the regional and national levels, including decisions on forest industry investments. It has also provided data for national and international statistics such as the Forest Resources Assessment of the Food and Agriculture Organization of the United Nations (FAO) and the Ministerial Conference on the Protection of Forests in Europe (MCPFE). It also produces information on biodiversity, carbon pools and carbon pool changes for the Land Use, Land-Use Change and Forestry (LULUCF) reports of the United Nations Framework Convention on Climate Change (UNFCCC).

34.2.2 The Use of NFI Data in UNFCCC Including Kyoto Reporting

Since the mid-1990s, the Spanish NFI has been the main source of information for greenhouse gas reporting for LULUCF of the UNFCCC. It will also play an important role in reporting LULUCF activities under Articles 3.3 and 3.4 of the Kyoto Protocol (always referring to the forest part). Currently, the land-use categories reported by Spain are consistent with the IPCC Guidelines (IPCC 2003). Area estimates for forest land-use categories are based on NFI data. IPCC land-use categories are defined on the basis of national land classes. The NFI is the main information source for the carbon pool changes in above-ground and below-ground biomass, dead wood, litter and soil organic matter. For litter and soil NFI data are applied together with models and flux measurements. CO_2 removals associated with sequestration by forests are reported for both Forest Land and Land converted to Forest Land but not for other land uses. The two NFI variables used for UNFCCC, LULUCF and Kyoto Protocol reporting are estimated area and estimated biomass volume.

For LULUCF and Kyoto Protocol reporting, estimates are based on the NFI2 and NFI3:

- NFI2. ICONA second NFI (1986–1995). ICONA – National Institute for Nature Conservation. Spanish Ministry of Agriculture, Food and Fisheries.
- NFI3. DGB: third NFI (1997–2007). Directorate General for Biodiversity (DGB), Spanish Ministry of Environment.
- The National Inventory Report (NIR) for 1990–2005 (UNFCCC 2007).

34.2.3 The Role of NFI in Assessing the Status of Biodiversity

An improved and updated methodology for assessing biodiversity using permanent sample plots has been incorporated into the Spanish NFI. As a result, additional groups of variables have been introduced to the NFI of which the most important are:

1. Ground cover, including bare soil, rocks, herbaceous plants, flooded areas, etc.
2. Species, decay class, volume and appearance of dead wood by the following classes:
   (a) Standing dead trees with $dbh \geq 7.5$ cm
   (b) Fallen dead trees with $dbh \geq 7.5$ cm
   (c) Standing and fallen dead trees with 2.5 cm $< dbh <$ 7.5 cm
   (d) Fallen branches with diameters ≥ 7.5 cm at the thinnest end
   (e) Stumps
   (f) Branch accumulations
3. Cover and the occurrence of ground vegetation
4. Endangered or threatened woody plant species
5. Additional measurements to determine forest structure indices such as Clark and Evans (1954) or Ripley (1977) index
6. Epiphytic lichens inventory based on ICP Forests methodology (Stofer et al. 2003)
7. Micro sites as nests or cavities in stems; animal traces and burrows

34.2.4 Research Applications of Data from Permanent Plots

Using data from repeated measurements at the same plots, studies have been conducted for the purpose of constructing growth models. In the Mediterranean (Murcia), models have been constructed for *Pinus halepensis* Mill.; in the Center plateau (Madrid), models have been constructed for *Pinus sylvestris* L.; and in the Northeast, models have been constructed for other main species.

A computer program 'BASIFOR' has been developed to identify and select plots with particular attributes such as minimal basal area of some species or pre-determined number of trees per hectare.

Loss of biomass and biodiversity due to forest fires can be estimated by comparing data on inventory plots where fires occurred between two successive occasions.

34.3 Current Estimates

Estimates based on NFI2 (1986–1995) are given in Tables 34.2a. and b. The given definitions are formulated on the basis of the work of COST Action E43 although they might deviate from COST Action E43 definitions. National inventories have been designed using specific cartography. The minimum forest patch size depends on the resolution of this cartography which is 2.5 ha in the map used for the actual NFI (although the minimum area considered for forests definition is 0.5 ha).

Table 34.2a Basic area estimates for years 1986–1995 (NFI2)

Quantity	Estimate (1,000 ha)	Share (%)	Description	SE[a]
Closed forest land (national definition)	10,626	21.2	Crown cover ≥20 % with minimum height of trees of 5 m at maturity in situ	n.a.[b]
Open forest land (national definition)	2,883	5.8	Crown cover between 10% and 20%	n.a.[b]
Very open forest land (national definition)	395	0.8	Crown cover between 5% and 10%	n.a.[b]
Forest land[c,d]	13,905	27.8	Closed forest, Open forest and Very open forest	n.a.[b]
Other wooded land (national definition)	12,079	24.1	Crown cover <5%	n.a.[b]
Forestry land	25,984	51.9	Forest land and Other wooded land	n.a.[b]
Other land (reference definition)	24,071	48.1	Land that is not classified as forest or Other wooded land	n.a.[b]
Total land area	50,596	100.0		–[e]

[a]Standard error.
[b]Not available.
[c]Includes 1,486,000 ha of productive forests with priority of wood and cork production.
[d]The forest area in UNFCCC LULUCF reporting amounts to 15,956,000 ha (referred to 1995).
[e]Assumed to be error free.

Table 34.2b Basic volume estimates for years 1986–1995 (NFI2) if not given otherwise

Quantity		Estimate	Description	SE[a] (%)
Growing stock volume on forest land		594.2	Stem volume overbark from above stump to the top diameter of 7.5 cm	<1
Million cubic metre m^3/ha		42.7		
Annual increment of growing stock on forest land		30.1	Increment of survivor trees, ingrowth trees and cut trees between the NFI2 and NFI3	n.a.[b]
Million cubic metre per year m^3/ha per year		2.2		
Annual drain (average 2001–2005) on forest land Million cubic metre	Firewood	16.5		n.a.[b]
	Commercial bole	2.2		
	Sum	18.7		
Annual drain per hectare on forest land m^3/ha per year	Firewood	1.2		n.a.[b]
	Commercial bole	0.2		
	Sum	1.3		
Dead wood volume Million cubic metre		n.a.[b]		n.a.[b]

[a]Standard error.
[b]Not available.

34.3.1 Notes on the Definitions

Clarifications of the land use definitions used for UNFCCC LULUCF reporting:

Forest: the Conference of the Parties held in Marrakech in 2001 (COP7), within the UNFCCC, in its Decision 11/CP.7 on LULUCF, within its Appendix, defined

‘Forest’ as an ‘area of land of at least 0.05–1.0 hectare with tree crown cover (or equivalent stocking level) of more than 10%–30% where the trees have the potential to reach a minimum height of 2–5 metres at maturity in situ’. A forest may consist either of closed forest formations where trees of varying heights and undergrowth cover a high proportion of the ground or open forest with clearings. Young natural stands and all plantations which have yet to reach a crown density of 10–30% or a tree height of 2–5 m are also included under forest, as are areas normally forming part of the forest area but are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest.

For Spain and for UNFCCC reporting the tree crown cover was selected 10% whilst for the Kyoto Protocol it was 20%. These thresholds have been taken from the NFI.

In Spain, a distinction is made between Croplands and Grasslands. The latter areas are defined as vegetation type dominated by pasture as its main use, and are distinguished from forests by having a tree crown cover of less than that used in the definition of forest. Abandoned, non-reforested agricultural lands are included. The areas and sequestered amount of carbon of the categories ‘forest land remaining forest land’, ‘cropland converted to forest land’, and ‘grassland converted to forest land’ are given in Table 34.3.

Table 34.3 Areas and carbon sequestration for the years 1990–2005

Year	Forest land remaining forest land		Cropland converted to forest land		Grassland converted to forest land		Total	
	Area (1,000 ha)	Carbon (1,000 t)	Area (1,000 ha)	Carbon (1,000 t)	Area (1,000 ha)	Carbon (1,000 t)	Area (1,000 ha)	Carbon (1,000 t)
1990	15,956	7,300	0	0	219	4,362	16,175	11,663
1991	15,956	7,300	0	0	438	4,552	16,394	11,853
1992	15,956	7,300	0	0	656	4,742	16,613	12,042
1993	15,956	7,300	0	0	875	4,932	16,832	12,232
1994	15,956	7,300	37	421	1,057	4,351	17,051	12,072
1995	15,956	7,300	126	1,002	1,187	3,730	17,270	12,032
1996	15,956	7,300	215	1,007	1,317	3,903	17,488	12,210
1997	15,956	7,300	299	948	1,452	4,005	17,707	12,253
1998	15,956	7,300	394	1,082	1,575	3,724	17,926	12,106
1999	15,956	7,300	459	734	1,729	4,488	18,145	12,523
2000	15,956	7,300	498	434	1,909	5,486	18,364	13,220
2001	15,956	7,300	524	296	2,102	5,530	18,583	13,127
2002	15,956	7,300	550	292	2,295	5,587	18,801	13,179
2003	15,956	7,300	572	250	2,492	5,931	19,020	13,481
2004	15,956	7,300	572	0	2,711	6,763	19,239	14,063
2005	15,956	7,300	625	601	2,876	5,647	19,458	13,548

34.4 Sampling Design

Spain is divided into 50 provinces, and each province has its own independent forest inventory.

Sample plots have been established at the intersections of a 1 × 1-km UTM grid, in the forest, open forest and very open forest areas (Tale 34.2a, Fig. 34.1). In very open forest areas and in some *Quercus* spp. coppice forest areas, the sampling intensity has been drastically reduced. A single field plot in those areas represents 400–800 ha, whereas plots on forest land and open forest land represent 100 ha.

The estimated relative 95% confidence limits for the estimates of growing stock volume generally vary between 5% and 10%. The error is calculated using a stratified estimator based on systematic sampling and a posteriori stratification.

Sampling at the forest edge:

When a plot is partially in a land use different from forest, or in a forest type different from the one indicated on the maps, the plot centre is moved so that the entire 25-m radius plot falls within the stand type indicated on the map.

34.4.1 Sample Plots

Permanent plots are established systematically at the intersections of a 1 × 1-km UTM grid. All plots are permanently marked by burying a metallic tube at plot centres. The azimuth and distance from an easily identifiable reference point to the plot are recorded for navigation purposes. Field plots consist of four circular concentric fixed areas with radii of 5, 10, 15 and 25 m. On the 25-m radius concentric circle, trees with $dbh \geq 42.5$ cm are measured; on the 15-m radius concentric circle, trees with $dbh \geq 22.5$ cm are measured; on the 10-m radius concentric circle, trees with $dbh \geq 12.5$ cm are measured; and on 5-m radius concentric circle, all trees with $dbh \geq 7.5$ cm are measured and trees with $2.5 \geq dbh \geq 7.5$ cm are counted (Fig. 34.2). Azimuth and distance from plot centre to sample trees are recorded. Slope correction is made by measuring the slope to the tally tree and calculating its distance over ground distance. Additional field data observed and measured on the

Fig. 34.1 Sampling density: 1 × 1-km grid on forest areas and very open forest areas

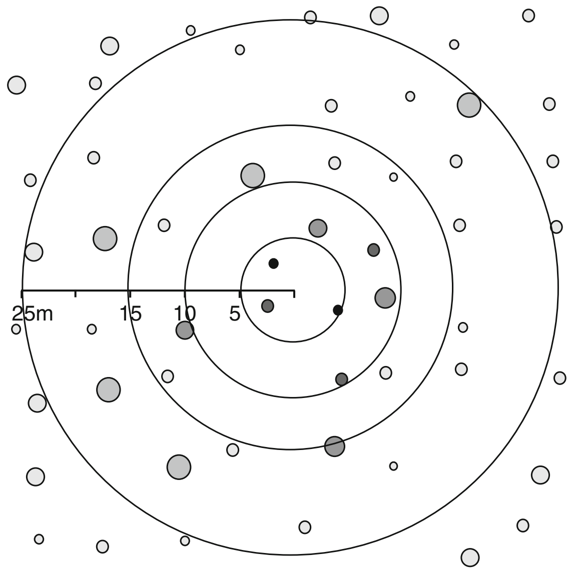

Fig. 34.2 A sample plot as used in NFI3

concentric sample plots include plot identification, forest type, tree mensuration, sample tree data, brush, erosion factors and tree damages.

34.4.2 Management

34.4.2.1 Personnel and Equipment

The organization responsible for the Spanish NFI is the Forest Inventory Service (Servicio de Inventario Forestal) of the 'Subdirección del Inventario del Patrimonio Natural y la Biodiversidad' belonging to the 'Ministerio de Medio Ambiente y Medio Rural y Marino'. Field data collection, data processing and inventory reporting are done by the government affiliated agency 'TRAGSATEC' which is under the management and control of the previously mentioned 'Forest Inventory Service'. Twenty-five field crews, each consisting of a forest technician and two workers, are continuously collecting field data all year long. The field crews are led by a forest engineer and five forest technicians.

34.4.2.2 Measurement Techniques

Orthophotographs are used to locate field plots using a superimposed 1 × 1-km UTM grid. Mirror stereoscopes are used for photo interpretation. In the field, pocket stereoscopes, global positioning system (GPS) receivers and metal detectors are used. Field computers were used for data capture in the NFI3, and distances and heights are measured with electronic devices.

34.4.2.3 Quality Assurance

Quality control checks of field work are conducted shortly after field crews have assessed plots. Check crews visit a 5% random sample of the field plots a second time. The check crews are well trained and experienced in field work and photo interpretation. Plot locations and all attributes are assessed a second time independently from the assessment of the regular field crews. The only data recorded by the regular field crews that are available to the check crews is plot location. The regular field crews have no advance knowledge of the plots that will be checked. The data are checked in the field computers using logical checks, and further manual and computer checks are made at the main office.

34.5 Estimation Techniques

34.5.1 Area Estimation

The strata are formed following sampling by grouping polygons of the ‘Forest type map (MFE)’, (scale 1:50,000). The principal stratification factors are generally main species, cover, origin and forest types and sometimes ownership types. Geographical context such as islands are also considered. Once strata have been defined, their areas are estimated using a geographic information system (GIS). Each plot is assigned to an appropriate stratum. Areas of classes defined on the basis of ownership, protection, and altitude categories are also estimated using GIS.

34.5.2 Volume Estimation

The stem volume of a tree in the Spanish NFI is defined as the volume of the bole over bark from above the stump to the stem top of a tree (diameter <7.5 cm). The volume of growing stock of trees includes the stem volumes of all living trees of all species with minimum *dbh* of 7.5 cm. Deadwood is measured for volume estimation including all dead trees by decay classes.

Mean values per strata and sampling errors:

Designating by y_{ij} the growing stock variables (number of trees, basal area, over bark volume, under bark volume, and annual volume increment and fire wood volume) in stratum i and plot j, mean values per hectare are estimated as,

$$\bar{y}_i = \sum_{j=1}^{n_i} y_{ij}/n_i \tag{34.1}$$

where n_i is the number of plots included in stratum i.

The variance estimator is,

$$s_i^2 = \sum_{j=1}^{n_i} \left(\bar{y}_i - y_{ij}\right)^2 / (n_i - 1) \tag{34.2}$$

and the relative confidence interval of the estimate y_i is,

$$e_i = \pm t\, 100 \frac{s_i}{\bar{y}_i \sqrt{n_i}} \tag{34.3}$$

where t is the Student t-value for a confidence level of 0.95, with $n_i - 1$ degrees of freedom.

Estimation of mean provincial values:

The estimate of the mean value per hectare for a province, y, of variable, y, is,

$$\bar{y} = \sum_{i=1}^{k} p_i \bar{y}_i \tag{34.4}$$

where k is the number of strata, and p_i is the ratio (A_i/A) of the area A_i of stratum i to the total forested area, A. The relative sampling error e of the estimate, y, is calculated as,

$$e = t \frac{\left(\sum_{i=1}^{k} p_i^2 s_i^2 / n_i\right)^{1/2}}{\bar{y}} \tag{34.5}$$

The relative confidence interval for variables y for the strata and total forested area are given in the second Spanish NFI publication.

Estimation of total values:

The values of the variables for the different strata are obtained as

$$Y_i = A_i \bar{y}_i \tag{34.6}$$

and the total value as

$$Y = \sum_{i=1}^{k} A_i \bar{y}_i = \sum_{i=1}^{k} Y_i \tag{34.7}$$

Estimation of total values by area attributes:

Denoting by A_{ij} the area of strata i for attribute j and by $\bar{y}_i$ the mean value per hectare of variable y in stratum i, the total values y_j are estimated as

$$y_j = \sum_{i=1}^{k} A_{ij}\bar{y}_i \qquad (34.8)$$

where k is the number of strata and

$$\sum_{i=1}^{k} A_{ij} = A \qquad (34.9)$$

and A is the total forested area of the province.

34.5.3 Increment Estimation

Volume increment in the Spanish NFI is defined as the increase in tree stem volume over bark from above the stump to the stem top of the tree (stem top diameter <7.5 cm).

In remeasured permanent plots, volume increment is estimated using data from the two most recent inventories (NFI2 and NFI3). The volume of each tree is calculated, using the NFI volume equations and classified, into three different categories:

- Survivor trees (appearing at the beginning and at the end of the cycle)
- Ingrown trees (trees appearing just at the end of the cycle)
- Cut trees (dead or removed trees, measured at the beginning of the period but disappeared at the end of it)

Annual volume increment on each plot is then calculated as an addition of these tree increment volume categories over 10 years (inventory cycle). The used methodology can be consulted in Martin (1982).

In other cases (NFI1 and NFI2), when plots where not permanent, for each province and each species tree annual volume increment was estimated using different models (data from NFI2). These models are equations that relate individual volume increment and tree variables like *dbh*, height and volume.

Stratum annual volume increment is calculated using the *dbh* distribution.

34.5.4 Drain Statistics Estimation

The visible silvicultural treatments in the sample plot are registered. Percentages p_{ij} of silvicultural treatments by stratum are reported as p_{ij} , the percentages of the area of strata i with treatments of type j. These percentages are calculated as,

$$p_{ij} = 100(n_{ij}/n_i)\%, \tag{34.10}$$

where n_{ij} is the number of plots in stratum i with silvicultural treatments of type j, and n_i is the total number of plots in stratum i.

The percentage p_j of total plots with silvicultural treatment of type j is,

$$p_j = \sum_{j=1}^{k} p_{ij} A_i / A, \tag{34.11}$$

where k is the number of strata, A_i is the area of stratum i, and A is the total forested area.

34.5.5 Specific Estimation Questions Related to LULUCF Reporting

Biomass Estimation

The merchantable volume used for obtaining biomass estimates is taken from the NFI reports for each province. This table contains, among other data, the merchantable volume with bark in cubic metre per hectare, stratum and species. Using data from both NFI2 and NFI3, volume per hectare and per species are obtained for each province. The product of these volumes and the Biomass Expansion Factors, (BEFD), give the annual estimate of biomass above ground (Montero et al. 2005, CREAF 2004).

The method applied by Spain for estimation of carbon stock change in living biomass is the IPCC stock change method which is based on estimates from successive inventories, and carbon loss in tree biomass is estimated using annual statistics.

Data for reforested agricultural areas are obtained from the statistics of the Ministry of Agriculture, Food and Fisheries (MAPA).

Area Estimation

Because the second and third cycles of the NFI (NFI2 and NFI3) used different land use maps, a linear interpolation by regions has been made to avoid changes in area estimates resulting from use of different NFI data. Areas for NFI2 are compiled in the 'Mapa de usos y aprovechamientos' MAPA, while areas for NFI3 have been compiled from the Spanish Forest digital Map (MFE50).

34.6 Options for Harmonized Reporting

The status of harmonization of the Spanish NFI is presented in Table 34.4.

Table 34.4 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current Spanish NFI

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI and forest types map (MFE)	–
Volume of growing stock	Yes	Yes	NFI	
Volume increment of growing stock	Yes	Yes	NFI	–
Above- and below-ground biomass	Yes	Yes	NFI, models	–
Dead wood	Yes	Yes	NFI	–
Litter	Yes	–	NFI	–
Soil	Yes	–	National Erosion Inventory (INES)	–
Afforestation, deforestation, reforestation (Kyoto 3.3)	Yes	Yes	National Forest Statistics	–
Naturalness of forest	Yes	–	NFI	
Forest type	No	No		Can be derived from NFI data and MFE data
Occurrence and abundance of vegetation Species	Yes	–	Map (MFE) NFI	–

34.7 Current and Future Prospects

NFI4 started in 2008 and the Spanish forestry digital map is being used at a 1:25,000 scale. The inventory cycle length will possibly be five years for the nine humid Atlantic climate provinces and 10 years elsewhere.

A revision or development of new volume and increment models has been proposed. An intensive investigation of biomass models (above-ground and below-ground biomass) is underway. These species specific models could be applied in the next NFI.

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Chapter 35
Sweden

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35.1 Development of Sweden's National Forest Inventory

The Swedish National Forest Inventory (NFI) began in the 1920s and was based on the experiences from a pilot inventory in 1911. At this time there was great concern about the status of Sweden's forests. The main questions concerned decreasing growing stock and the lack of regeneration after selective logging operations. The first inventory was carried out county by county during the period 1923–1929.

The sampling design of the first NFI was a strip survey with a strip width of 10 m. The distance between the lines (strips) varied from 1 km in southern Sweden to 20 km in the northernmost part. All trees above 15 cm at breast height within the strip were callipered and sample trees were taken in different proportions for different diameter classes. In the second inventory, 1938–1952, the distance between the strips was reduced to 1–10 km over the country. The strip survey was also combined with a sample plot survey using plots of different sizes and shapes. This inventory was also performed county-wise (Table 35.1).

The third NFI, 1953–1962, involved two major changes in the sample design (Matérn 1960). First, the whole country was sampled each year with 10% of the total sample intensity each year. The country was divided into five regions with decreasing sampling intensity towards the north of the country. Secondly, a big change was the transition to plot sampling. Plots were organised into clusters, one cluster comprising one day's work (Fig. 35.1). The following inventories, 1963–1972 and 1973–1982, did not entail any major changes in the sampling design. Instead the development was on data capture and compilation methods using punch cards and computers.

In 1983, permanent plot cluster were introduced in the NFI. No major changes were made in the sampling design, except that about half of the clusters were made

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Table 35.1 The NFIs in Sweden

Inventory	Years	Method	Design
NFI1	1923–1929	Strip survey sampling	County wise
NFI2	1938–1952	Strip survey sampling combined with plots	County wise
NFI3	1953–1962	Cluster sampling with temporary plots	Whole country annually
NFI4	1963–1972	Cluster sampling with temporary plots	Whole country annually
NFI5	1973–1982	Cluster sampling with temporary plots	Whole country annually
NFI6	1983–1992	Cluster sampling, temporary and permanent plots	Whole country annually
NFI7	1993–2002	Cluster sampling, temporary and permanent plots	Whole country annually
NFI8	2003–	Cluster sampling, temporary and permanent plots	Whole country annually

permanent and that half-day clusters were introduced in the southernmost region. The permanent clusters were made smaller and with fewer plots than the temporary clusters (Fig. 35.1). Handheld field computers were used for data recording. The permanent clusters were laid out during 1983–1987 with about 20% to be measured each year. The re-measurement interval was planned to be five years and the first re-measurement was carried out 1988–1992. Due to economic constraints the interval could not be kept during the 1990s, but was re-established in 2003.

The eighth NFI began in 2003 and ends in 2012. A major revision of the inventory design and the scope of the inventory is made before every new inventory period. However, if important new information is needed, changes are made during the inventory cycle.

Although there are always minor changes in the sampling design between the inventory cycles, the major changes during the last decades concern the content of the inventory. The scope of the NFI has been steadily growing since the start in 1923 and especially since 1983. At this time ecological and environmental considerations were introduced through a detailed site inventory (vegetation and soil sampling on permanent plots). In the 1990s, biodiversity issues and the new concept of sustainable forestry (amended forestry act and forestry practises) as well as the questions of carbon sequestration introduced new NFI components that are still in development.

Remote sensing techniques are used as secondary sources of information for the inventory. Satellite images together with road maps are used to construct a field map used for orientation and facilitating the field work. Previously, aerial photographs were used for this purpose. Areas at high altitudes above the conifer limit (timberline) are assessed using maps and aerial photographs.

For about a decade the intent was to incorporate satellite remote sensing as a part of the standard inventory program. Initially the idea was to apply the Finnish approach and produce maps and estimates using the k-NN method. Lately, the

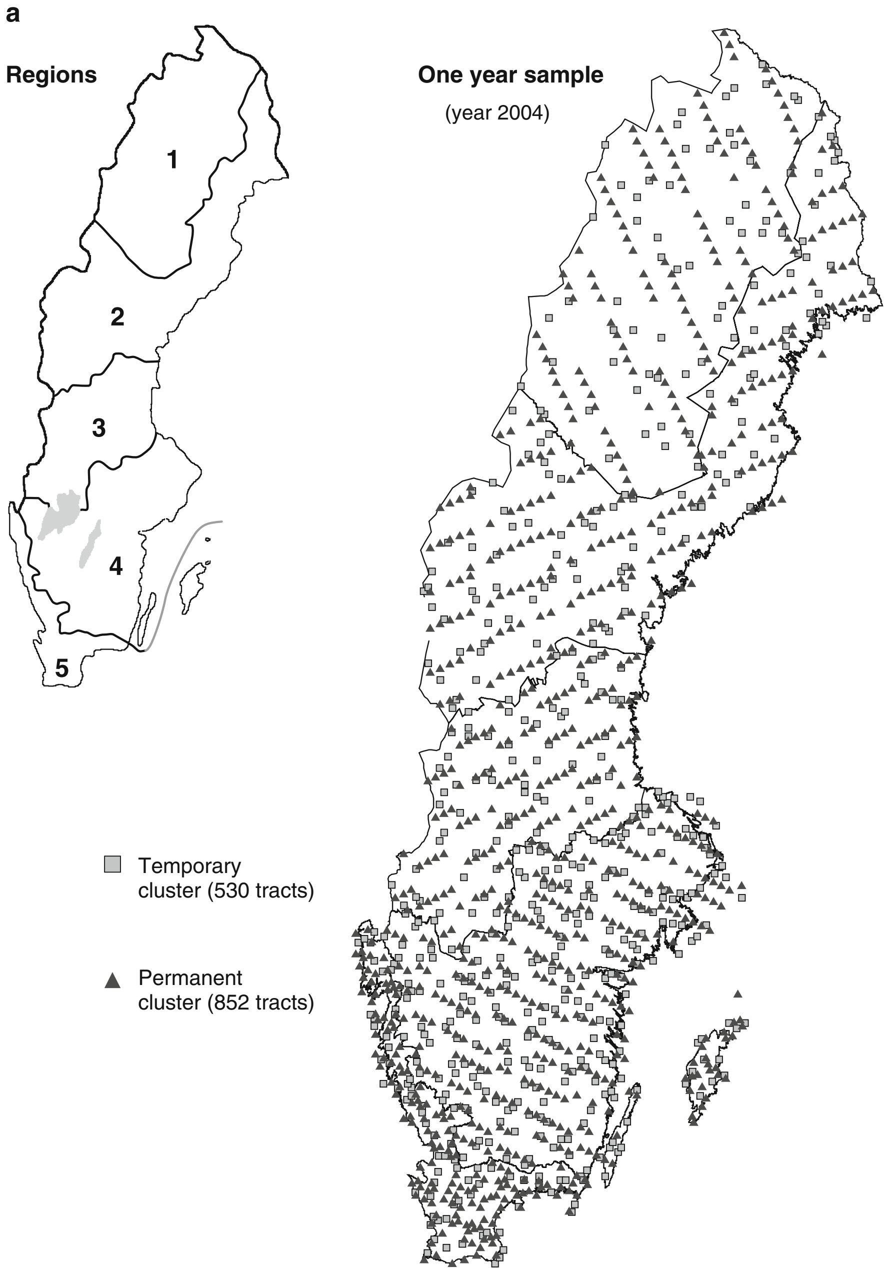

Fig. 35.1 (continued)

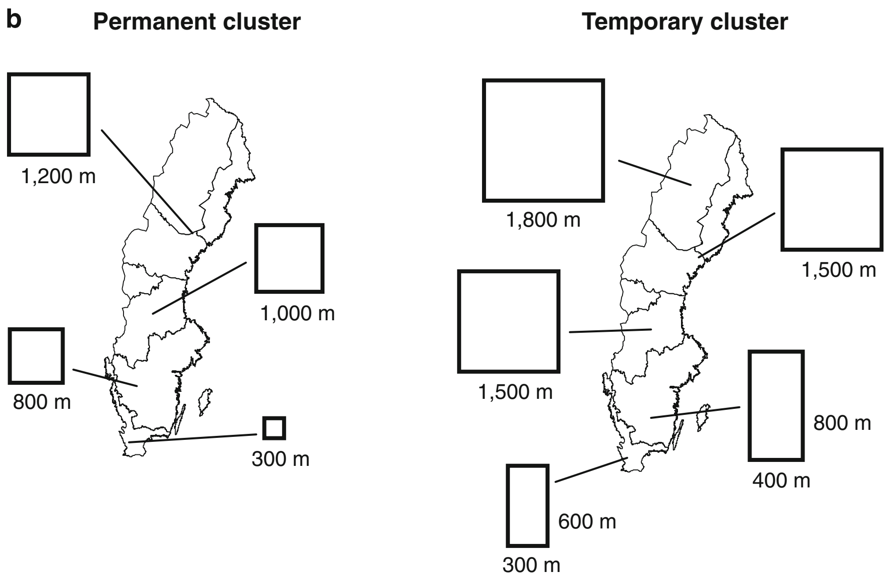

Fig. 35.1 Regional division and size variation for permanent and temporary clusters

intent has changed to developing routines for producing estimates based on the principle of post-stratification. Since 2004, post-stratified estimates have been calculated on a routine basis in the Swedish NFI, mainly for improving local level estimates (areas on the order of 10,000–100,000 ha). As in many other countries, Swedish NFI data are combined with remote sensing to produce wall-to-wall maps of Swedish forests (e.g. Nilsson et al. 2003 and Reese et al. 2003). These have been created at 5-year intervals starting in 2000.

The first NFIs were run by special forest committees. Since 1946, the Swedish University of Agricultural Sciences (SLU) and its predecessors have been responsible for the NFI. The responsibility means planning the design, estimation methods, field measurements, analyses and publication. The Swedish NFI is part of the country's official statistics which means that the conduct of the inventory is regulated according to an Official Statistics Act, and thus needs to satisfy specified quality requirements.

35.2 Uses and Users of NFI Information

The main users of information are found at the national and sub-national levels in Sweden. Governmental agencies such as the Swedish Forest Agency, the Swedish Energy Agency, and the Swedish Environmental Protection Agency use the information for policies in areas related to forestry, energy, and environmental quality.

In this context, results from a scenario system named Hugin (Lundström and Söderberg 1996) linked to NFI data have been found to be very useful for evaluating the long-term consequences of different policies in the project "Possibilities for forest utilization in the twenty-first century" (SKA99 2009). Thus, not only states and changes of forest conditions, but also forecasts under different assumptions, are generally used to evaluate the appropriateness of policies. Just as when the NFI was started more than 80 years ago, an important question regards sustainable harvest levels in Swedish forests. Currently, this question not only involves the maximum harvesting potentials, but also the balance between timber harvests, biodiversity preservation, use of bio-energy, use of forests for recreation, etc.

At sub-national level data from the inventory are used by county administrations, forest companies and various other organisations, including non-governmental organizations (NGO). Forest companies use the information for purposes such as evaluating the availability of raw material around planned industrial sites. Large companies frequently use the information and the scenario analysis system for evaluating the consequences of new governmental policies on their own forestry practices. Data also are used for estimation of forest estate values as a basis for taxation.

Further, data are used in different research projects. Traditionally this has concerned forest growth and productivity. Lately, the emphasis has shifted towards biodiversity and issues related to carbon sequestration. The usefulness of the inventory for research purposes has increased following the introduction of permanent plots.

At the international level, data are used for the reporting to United Nations Economic Commission for Europe (UNECE), Eurostat, Ministerial Convention on the Protection of Forests in Europe (MCPFE), and the Forest Resource Assessments (FRA) conducted by The United Nations Food and Agriculture Organization (FAO). Moreover, the Swedish system for greenhouse gases reporting in the Land Use, Land-Use Change, and Forestry (LULUCF) sector of the United Nations Framework Convention on Climate Change (UNFCCC), and its Kyoto Protocol (KP), is based on NFI data. A specific property of the inventory that makes it suitable for this purpose is that it covers all types of land use and cover classes, not only forests. Thus, conversions among land use classes can easily be followed on the permanent plots.

35.2.1 Reporting for UNFCCC Including Kyoto Protocol

The Swedish system for estimating and reporting sources and sinks of greenhouse gases to the UNFCCC and the KP is built around the NFI (Ståhl et al. 2003). The inventory provides all core parts for the reporting, including afforestation, reforestation, and deforestation and the conversion of areas among different land use categories (on a sampling basis). Primarily, the permanent plots of the NFI are used for that purpose. Overall, data for approximately 30,000 plots distributed over the country are available. To simplify the annual reporting, a specific database has been developed to produce the necessary change estimates and the interpolations and extrapolations that are needed, because plot measurements are only available every 5 years.

In principle all five carbon pool changes can be followed with repeated measurements. For biomass, each individual tree is followed and the biomass pools are estimated by applying specific biomass models for above-ground as well as below-ground parts of trees. Soil sampling is conducted and the intent is to follow the soil and litter carbon pools based on repeated measurements. The same applies for dead wood. Biomass models are available from earlier studies conducted by Marklund (1988) and Petersson and Ståhl (2006). More details about the Swedish greenhouse gas reporting system can be found in Ståhl et al. (2004).

35.2.2 Biodiversity Assessment and Reporting

Based on conventional NFI variables such as stand and tree age, tree species composition, diameter distribution and the number of trees, general biodiversity indicators can be estimated (Stokland et al. 2003). In addition, variable groups have been introduced to NFI to better assess the status of forest biodiversity. The most important indicators are given below.

35.2.2.1 Ground Vegetation

Ground vegetation type is determined on both temporary and permanent sample plots. The classification scheme is based on species composition and coverage for a list of common species. An additional vegetation description for very small sub-plots on a subset of plots is provided.

35.2.2.2 Dead Wood

In 2003, a new protocol for the inventory of dead wood was integrated into the Swedish NFI. Dead wood information is also used for carbon reporting. For each dead wood object, observations or measurements for 13 variables are recorded; of these, half are conventional forest information and half are related to biodiversity assessment and carbon accounting.

35.2.2.3 Special Indicators

For selected living and dead trees, additional information on the occurrence of ant hills, polyporous fungi, nesting holes and wood-pecker traces is collected.

35.2.2.4 Information on Pendulous Lichens

The lichen inventory is performed on sample trees of Norway spruce. The whole crown is considered. If branches are absent, then lichens growing on the stem also are considered. The maximum lengths of individual lichens specimen and height limits in tree crowns are measured/estimated.

35.2.2.5 Forest Continuity

A judgement as to the continuity of tree cover since year 1700 is made on the site/ stand (20 m plot radius). The continuity criteria are occurrence of old trees and lack of signs of major ecosystem changes or earlier agriculture activities.

35.2.2.6 Sparse Objects of Relevance for Biodiversity

At the stand level (20 m plot radius) dead trees, high stumps and overstorey trees with diameter at breast height (*dbh)* >15 mm and larger trees (the minimum diameter depends on the species and the region) are inventoried.

35.2.2.7 Stand Structure

Tree and bush layers are determined on both temporary and permanent plots. A maximum of three tree layers can be described. If more layers exist, two layers close in height are combined. Age evenness is estimated at stand level.

The Swedish Parliament has adopted 15 national environmental quality objectives to be attained by the year 2020. Within each environmental quality objective, a core set of indicators has been chosen which will guide decisions on as to the detailed data that must be collected and evaluated. Data from the Swedish NFI are currently used to follow up interim targets for four indicators within the Environmental quality objective "Sustainable Forests" (Anonymous 2008)

- The amount of hard dead wood (slightly or non decomposed trunks)
- The area of mature forest with a large deciduous element
- The area of old forest
- The area regenerated with deciduous forest

35.3 Current Estimates

The basic estimates are given in Tables 35.2a and b. These variables and their reference definitions are selected and formulated in the work of COST Action E43. The estimates of the quantities and standard errors, based on data from

Table 35.2a Basic area estimates from years 2002–2006

Quantity	Estimate (1,000 ha)	Description	SE[a] (1,000 ha)
Forest land (FAO-definition)	28,366	Land with, or with potential of forest with at least 10% crown cover and minimum height of trees of 5 m and a minimum area of 0.5 ha	227
Other wooded land (FAO-definition)	2,891	(a) Land, but not forest land, with, or with potential of forest with at least 5% crown cover and minimum height of trees of 5 m (b) Land, but not Forest land, with, or with potential of trees and bushes with at least 10% accumulated crown cover and minimum height of 0.5 m	87
Other land (FAO-definition)	10,077	Not Forest land or Other wooded land	141
Forest land in UNFCCC LULUCF reporting	28,366	Same as Forest land	227
NFI coverage		All Sweden. Data for total stratum-areas (land and water areas) are delivered from the Swedish NFI	
LULUCF area estimates for the land classes		Forest land, cropland, grasslands, wetlands, settlements, other land	
Productive forest land (National definition)	22,906	Average annual productivity ≥1 m^3/ha of stem wood over bark and over the rotation period, area outside Protected Forest Areas, i.e. National Parks and Nature reserves	183
Total land area	41,334	Land area and fresh water areas (rivers and lakes) within Protected areas, i.e. National Parks, Nature reserves	–[b]

[a]Standard error.
[b]Assumed to be error free.

Table 35.2b Basic volume estimates from years 2002–2006

Quantity	Estimate	Description	SE[a]
Growing stock volume on productive forest land		–	
Million cubic metre	2,931		26
m^3/ha	128		0.8
Annual increment of growing stock of trees on productive forest land		–	
Million cubic metre	110		1
m^3/ha	4.8		0.03
Annual drain on productive forest land		Total harvested volume and total	
Million cubic metre	100	natural drain	1
m^3/ha	4.4		0.03
Dead wood volume on productive forest land		Minimum length, 1.3 m, minimum diameter, 10 cm	
Million cubic metre	166		3.3
NFI is the main information source for the following carbon pool changes		Above- and below-ground biomass, dead wood, litter, soil organic carbon	

[a]Standard error

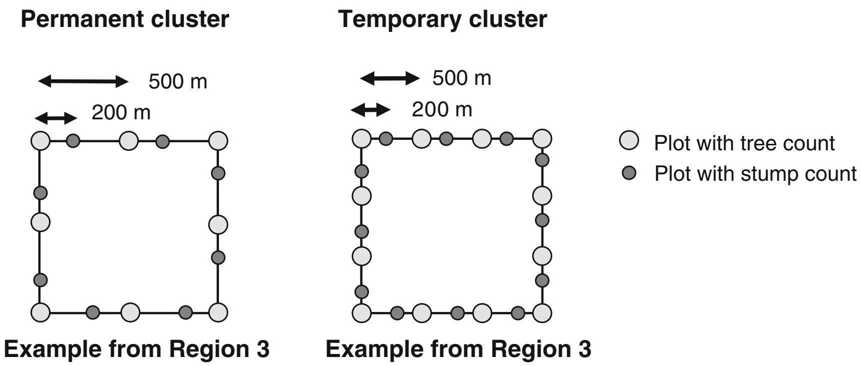

Fig. 35.2 Examples of plot configuration within permanent and temporary clusters from region 3. Only on light grey plots tree count is performed while stump inventory is performed on dark grey plots

2002–2006 are provided. For forest land, two parallel definitions are in use in field measurements: the national definition and the TBFRA 2000 definition (UNECE/FAO 1997) adopted for NFI in 1998 for use in the international reporting. TBFRA 2000 forest definitions are the same as COST Action E43 reference definitions.

35.4 Sampling Design

The Swedish NFI is implemented using defined circular plots. The plots are arranged into clusters that are quadratic or rectangular in shape and vary in size between different parts of the country (Fig. 35.1).

The clusters are systematically distributed over the whole of Sweden. The distance between them is less in southern Sweden than in northern Sweden. The Swedish NFI uses two kinds of clusters: one is temporary and the other is permanent. The temporary cluster is only surveyed once, whereas a permanent cluster is resurveyed regularly.

On each cluster there are two different types of plots; (a) plots for which tree counts are conducted using radii 7–10 m depending on *dbh* and (b) plots for which stump counts are conducted (Fig. 35.2).

35.5 Estimation

Standard results from the inventory are of different kinds. Some main types of output are:

- Estimates of the present state of the forest
- Time series (series of present state estimates)

- Change estimates
- Forecasts of future conditions

Each type is treated in a separate section below with respect to models and estimation principles used.

35.5.1 Estimates of Present State

The standard procedure for calculating estimates of the present state for a given variable in a given region is to calculate separate estimates for a specific year using (a) data from permanent plots from that year, (b) data from temporary plots from that year, and (c) data from past inventories of temporary plots, updated using difference estimates from permanent plots. Thus, three different estimates are obtained, and these are then combined using principles of weighting inversely proportional to the variances with consideration of co-variances among the estimates (Raj 1968). Some variations on this theme exist regarding the use of data from temporary plots inventoried in the past. In general, at least for estimates within restricted areas, moving averages over several years are required to obtain estimates with reasonable low standard errors. Thus, to obtain an estimate for the year 1995 (e.g.) a standard procedure would be to calculate estimates for 1993–1997 according to the principles above, and then calculate an average estimate which would correspond to the state in reference 1995.

35.5.2 Time Series

Because data are available in digital format from 1953, presentations of time series for different are easily compiled. The standard approach, although in some cases questionable (see Section 35.5.3) is to calculate a series of moving averages to present state estimates. Currently, data from the first (1923–1929) and second (1938–1952) NFI's are entered into database format. When this work is finished, it will be possible to produce time series from 1923 and onwards for core variables on a routine basis.

35.5.3 Change Estimates

Change estimates between two time points may be calculated as the difference between present states according to the principles outlined above. However, from a theoretical point this would give far too much weight to the information from temporary plots in relation to the information from permanent plots. Thus, in principle another estimation procedure should be adopted when changes between two specific time points are estimated. In an ideal case for which the time difference for the change estimate corresponds to the re-measurement interval for permanent plots, two separate estimates of the change can be calculated: (a) the difference in state based on the permanent plots, and (b) the difference in state using the temporary plots. Thus, two different estimates are obtained, and these are weighted inversely proportional to their variances. However, in general, the weight given to the permanent plots in this case will be much greater than the weight given to the temporary plots, i.e. the permanent plots are very powerful for the estimation of changes (Ranneby et al. 1987).

35.5.4 Forecasts of Future Conditions

Although state and change estimates are very important outputs, the most powerful outputs from the Swedish NFI are probably the results produced with the forecasting system Hugin (Lundström and Söderberg 1996). This system utilises NFI data as input and estimates future forest conditions and resource utilisation potentials for different scenarios. The main dynamic part of the system is the growth and yield models for single trees derived by Söderberg (1986) using NFI data. Hugin starts by updating the NFI data to a certain reference year and then produces modelled output every tenth year for an arbitrarily long forecasting period.

35.5.5 Error Estimation

The precision estimates are calculated on a routine basis (Li and Ranneby 1992). The density between both the tracts and plots is adjusted using information from a 5-year period to give good precision for estimates at a county level.

Table 35.3 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current Swedish NFI

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	Yes	NFI	ND $\neq$ RF, both are employed in the field
Growing stock volume	Yes	Yes	NFI	ND = RF
Above-ground biomass	Yes	Yes	NFI, models	ND = RF
Below-ground biomass	Yes	Yes	NFI, models	ND = RF
Dead wood volume (=$DW_{10\ cm}$)	Yes	Yes	NFI	ND = RF
Dead wood volume by decay stage classes	Yes	Yes	NFI	ND = RF
Afforestation deforestation reforestation (Kyoto 3.3)	Yes	Yes	NFI, statistics	ND = RF
Forest type	No	No	NFI	Can be derived from NFI data

35.6 Options for Harmonized Reporting

The status of harmonization of the Swedish NFI is presented in Table 35.3.

35.7 Current and Future Prospects

From 2008 onwards, data from the NFI will be used for reporting forest habitats in connection with the implementation of the European Union's Habitats Directive. An important topic is further development in combining NFI and remotely sensed data with to produce better estimates. Here the potential of using laser-scanning data for forest resource assessment is an important topic during the coming years. The use of NFI data for forecasting and scenario analysis will increase in the future. New analyses and planning tools for sustainable multi-purpose forestry, Heureka, are currently in development. New techniques for presentation of results and web-based services to make data more accessible will be developed to provide data and results for new user groups.

35.8 Influence of COST Action E43 on Swedish NFI

The work and discussions in the COST Action E43 group has contributed to a suggestion for a new national forest definition for Sweden (Möller and Ståhl 2007). A new variable, the point of time for land-use changes in permanent plots, has also been included in the NFI to facilitate future reporting on greenhouse gas emissions.

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Chapter 36
Switzerland

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36.1 Development of Switzerland's National Forest Inventory

The first demand for a Swiss National Forest Inventory (NFI) was initiated in 1956 by the former director of what is today the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). In the late 1960s, the NFI was included in the guidelines of government policies, which made it possible to start developing methods for a comprehensive and permanently instituted NFI at WSL in Birmensdorf, near Zurich. The NFI research department was founded at the WSL in 1973.

In the course of the policy preparation, the information needs of the forest policy makers and the cantonal forest services were clarified. At a very early stage, the original idea of an inventory based on standing timber has been superseded by the idea of a broader, multi-purpose inventory. Apart from the important forest management indicators, such as standing timber, increment, exploitation, tree species composition, and stand structure, the inventory is expected to also include information about soils, forest vegetation, forest functions, and harvesting conditions.

In 1981, the Swiss Federal Council decided to implement the first NFI and made the necessary funds available. The WSL was mandated by the Swiss government to conduct the NFI. The field data collection for the first NFI started in 1983 and was finished in 1985. The second and third NFI followed in the years 1993–1995 and 2004–2006. The milestones are thus:

1956	First demand for a Swiss NFI by the former director of the WSL
1965	NFI project included in guidelines of national policy
1967	Start of preparation work for a first Swiss NFI
1973	Foundation of NFI research department at WSL
1983–1985	Field data collection for the first NFI
1993–1995	Field data collection for the second NFI
2004–2006	Field data collection for the third NFI

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Table 36.1 The national forest inventories of Switzerland with the approximate number of forest plots (includes shrub forest plots for NFI3)

Inventory	Years	Field plots	Sampling design
NFI1	1983–1985	11,000	Sampling grid 1 × 1-km; terrestrial data collection on forest plots (without shrub forest); aerial photographs for location/installation of permanent plots and exclusion of clearly non-forest and shrub forest plots
NFI2	1993–1995	6,300	Sampling grid 0.5 × 0.5-km on aerial photographs; sub-grid 1.414 × 1.414-km for terrestrial data collection on forest plots (without shrub forest); terrestrial sample is a systematic sub-sample of the NFI1 sample (permanent plots); aerial photographs used for exclusion of clearly non-forest and shrub forest plots and in the estimation procedures (two-phase sampling for stratification)
NFI3	2004–2006	7,000	Sampling design identical to NFI2 (permanent plots); terrestrial data collection extended to shrub forest plots; tree cover assessment on the first-phase sample of aerial photographs (including plots outside forest)

The characteristics of the three inventories are shown in Table 36.1.

36.2 The Use and Users of the Results

The Swiss NFI provides an important basis for decision making in Swiss forestry policy. The WSL is responsible for planning, data collection and analysis, and scientific interpretation; the Federal Office for the Environment (FOEN) is responsible for the political evaluation and implementation.

The main results, with scientific interpretation, are available as carefully edited books with illustrations and many tables (EAFV 1988; Brassel and Brändli 1999). In addition, many tables may be downloaded via Internet. The interpretation in terms of forest policy is published by the FOEN (SAEFL 1999).

The conclusions from these reports have been one of the corner stones in the formulation of the Swiss National Forest Programme (Swiss NFP), an action programme at federal level that defines the state's activities in the forest sector and coordinates the sector's co-operation with other sectors. It is the basis of Switzerland's new forest policy for the period 2004–2015, in which the long-term vision for the desired status of the forest has been developed, based on an analysis of current problems and trends (SAEFL 2004).

Information from the NFI also provided the basis for the Forest Report 2005 (SAEFL and WSL 2005) which was, for the first time, an attempt to present a complete picture of the state of the forest in Switzerland and of its significance for the population. In the report, the facts and figures about the condition of Swiss forests are divided into the six sustainability criteria and indicators established by the Ministerial Conference on the Protection of Forests in Europe (MCPFE).

Information and data from the Swiss NFI are required in many sectors such as the media, national and cantonal administrations, research, education, policy, private forest and forestry related companies, such as the wood industry. While the standard results are presented in tables grouped by the five geographical regions Plateau, Jura, Pre-Alps, Alps and Southern Alps, detailed and specialized data analysis is often carried out for specific uses on demand.

The Swiss NFI supports local and cantonal forest authorities in the planning, conduct, database management and analysis of their surveys. Co-operation with Cantons varies from consultancy on technical aspects to regional inventories conducted with NFI methodology on an intensified sampling grid.

Both data and experts from the Swiss NFI play an important role in many research projects. Scientists from the Swiss NFI are involved in academic teaching and education, notably in inventory statistics, resources modelling and analysis, geomatics, geographic information sciences including data and meta-data management, remote sensing and pattern recognition.

The Swiss NFI also provides forest resources information for international statistics in the context of the Global Forest Resources Assessment (FRA) conducted by the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Economic Commission for Europe (UNECE), the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). For the latter, Switzerland decided to report activities in the Land Use, Land-Use Change and Forestry (LULUCF) sector under Articles 3.3 and 3.4.

36.3 Current Estimates

The Swiss NFI covers the entire area of Switzerland, and a piece of land may be classified as forest independent of the legal/cadastral or proprietary status of the land. Included are forests in national parks and forest with protective functions against natural hazards.

It is of considerable importance in the Swiss NFI, that the forest (or non-forest) decision on the aerial photograph is close to the terrestrial decision. The most important reason is that a plot classified as a non-forest plot in the photo interpretation is, to reduce the cost of the inventory, not visited by a field team, except if its distance to the forest is small (in feature space) and a terrestrial classification as forest plot can not be excluded. Therefore, the forest definition of the Swiss NFI is influenced by the need for predominantly similar forest (or non-forest) decisions in the aerial and terrestrial inventory.

The 'forest' definition first requires a minimum dominant height of trees of 3 m, and then a minimum width of the stand for a given crown cover. The minimum width is 25 m for a crown cover of 100%, and 50 m for a minimum crown cover of 20% (and values in between). There is no explicit minimum size threshold for stands to be considered forest. The forest boundary line follows the outer edge of the stems of the boundary trees. Boundary trees must have a height of at least 3 m and the distance between boundary trees must be less than 25 m.

Land can be classified as 'shrub forest' for two reasons: (a) if all conditions mentioned above are fulfilled except shrub species can comprise 2/3 share of the crown cover, and (b) if (a) is fulfilled, but the dominant height has not been reached because the shrub species are *Alnus viridis* (Chaix) DC or *Pinus mugo* Turra, two species which cover large areas at the timber line of the Alps.

Stem volumes for growing stock and deadwood include stumps, stem tops and bark; branches are excluded. The minimum diameter at breast height (*dbh*) threshold for all living stems and standing dead stems is 12 cm. Deadwood includes standing, dead stems and all sections of downed woody material with a diameter greater than 7 cm. No minimum length threshold is defined for such pieces.

Current estimates from NFI3 are presented in Tables 36.2a and b.

Table 36.2a Basic area estimates

Quantity	Estimate (1,000 ha)	Description	SE[a] (%)
Forest	1,213	National forest definition, similar to reference definition for forest	<1
Shrub forest	66	National definition, similar to reference definition for other wooded land	4
Total land area	4,128	Includes lakes and other non-productive land	–[b]

[a]Standard error.
[b]Assumed to be error free.

Table 36.2b Basic volume estimates

Quantity	Estimate	Description	SE[a] (%)
Growing stock volume		On forest land (national definition), stem volumes; included are stumps, stem tops and bark excluded are branches; *dbh* threshold 12 cm	
Million cubic metre	405.8		1
m^3/ha	345.8		1
Deadwood volume		On forest land (national definition), volumes of standing, dead stems (like growing stock with a reduction for broken stems); included are also sections of downed woody material coarser than 7 cm, no minimum length threshold	
Million cubic metre	38.4		4
m^3/ha	32.8		4

[a]Standard error.

36.4 Sampling Design

36.4.1 Aerial Photographs

Aerial photographs have played a key role in the Swiss NFI since its beginning. They are made available from the Swiss Federal Office of Topography.

In NFI3, 7500 true colour stereo-photos taken between 1998 and 2004 on a scale of approximately 1:30,000 have been used (flight height 5 km, ground resolution approximately 40 cm, positional accuracy approximately 1 m). The photo interpreter works at a 3D computer screen with polarized eyeglasses which produce a three-dimensional view of the landscape. The database system retrieves the digital terrain model (DTM) and orientated stereomodels within few seconds.

Photo interpretation is done on a sample of systematically distributed interpretation areas (plots) of 50 × 50 m on a grid of 0.5 × 0.5 km covering all of Switzerland. The total sample size is approximately 165,000 plots. The mean work time per plot was approximately 5 min. Eight interpreters have been employed on a part-time basis.

All measurements are directly recorded into a spatially enabled database. The measurements and interpretations include:

- Identification of the forest boundary line (if any)
- Assessment of height and land cover type (11 categories) at 25 sub-sampling points within the interpretation area
- Forest (or non-forest) decision for the central point of the plot
- For forest plots: forest type in six categories (shrub forest, young growth, pole wood, young to medium timber, old timber and mixed forests)
- For non-forest plots: height measurement of individual trees and/or height and length measurement of hedges and groups of trees within the plot (tree resources outside forest)
- For forest plots on the sub-grid of the terrestrial inventory: identification and co-ordinates of orientation points for field crews

The aims of the photo interpretation are, first, to reduce the cost for the field survey by identifying plots clearly outside forest and, second, to provide the co-ordinates of orientation points near forest plots. Further, information from the photo interpretation is used in two-phase estimation procedures that reduce sampling errors. Estimation of tree resources outside forest (biomass), analysis of landscape patterns and diversity, and small area estimation are new NFI applications that are currently under development.

36.4.2 Terrestrial Inventory

The terrestrial sample is a sub-sample of the aerial sample (two-phase sampling is employed). Control surveys show that the positional accuracy of aerial and field plots is high. The grid geometry for NFI3 was 1.414 × 1.414-km (approximately 7,000 forest plots).

The Swiss NFI uses permanent plots on which trees are re-identified and re-measured. Two concentric circles with a size of 200 m^2 for trees with 12 cm $\leq$ *dbh* $<$ 36 cm, and a size of 500 m^2 for trees with *dbh* $\geq$ 36 cm are used. This results in approximately 11 trees per plot. On a sub-set of approximately two trees per plot, the upper stem diameter in 7 m above ground and the tree height are measured. The sample inclusion probabilities of these 'tariff trees' are proportional to the prediction error of the tariff function.

Regeneration trees from 10 cm height to 12 cm *dbh* are measured on two sub-plots. Downed woody material is measured along three transect lines of 10 m length and includes all pieces with a diameter >7 cm at the intersection point with the transect line (Böhl and Brändli 2007). Some variables describing stand and site characteristics are also assessed on a larger interpretation area of 50 × 50 m.

Lichens and fungi have been recorded as indicators for autochtony and biodiversity. Damage on trees, and the structure and other characteristics of the stand allow an assessment of the protective function of the forest. The composition of forest boundaries, often with particular mixtures of tree and shrub species, has been assessed on sections of 50 m for forest plots closer then 25 m to a forest boundary (15% of forest plots).

Some technical and operational details of the terrestrial inventory (NFI3):

- Duration of data collection: 3 years (March/April to October/November)
- Number of field crews: approximately 11
- Persons per crew: 2;
- Number of plots per day: 1–3 per field crew depending on topographical conditions
- Time for preparation, travel and walk: approximately 65%; only 35% of the overall time spent by the field crews is data collection on plots (these data are without trainings and control survey)
- Training: approximately 10% of overall time is spent on training of field crews
- Control survey: approximately 10% of plots are remeasured by a second crew (blind checks)
- Data recording: standard tablet-PC (proprietary software WSL); data exchange via mobile phones
- Instruments: Vertex® for tree height measurements, global positioning system (GPS) receivers

36.4.3 Forest Service Survey

As in NFI1 and NFI2, the local forest service has been interviewed in NFI3 to get the following additional information for each terrestrial forest plot:

- Silvicultural treatment (type and year of the last and planned intervention)

- Harvesting and transportation techniques
- Forest management, planning and forest functions
- Recreational use
- Origin of stands and forest (natural/artificial)

36.4.4 Forest Road Survey

Additional survey and monitoring of forest roads covering all of Switzerland is integrated into the NFI. The data are collected on existing maps and verified by the local forest services. It includes a classification of road types.

36.4.5 Quality Assurance

Several quality control and quality assurance tools are implemented in the Swiss NFI. Methods, applied models and field manuals are documented (Bachofen and Zingg 1988; Brändli et al. 1994; Brassel and Lischke 2001; Ginzler et al. 2005; Keller 2005). Between the second and third inventory, impacts (NFI services and NFI utilization) of the first and second inventory, as well as the demand for information, products and services from the third inventory have been investigated and evaluated together with external experts and users (Bättig et al. 2002).

How representative the permanent grid was, has been tested on a control grid of 700 plots (during NFI2). No significant bias between estimates on the permanent grid and on the control grid has been found.

Training and controls (blind checks) of data collection of field teams and photo interpreters are done within a randomized framework; 3% of the aerial plots are reassessed by a second interpreter and 10% of the terrestrial plots are re-measured by another field crew. These data provide input for training and valuable information on the quality of assessments.

36.5 Estimation Techniques

36.5.1 Estimators

The Swiss NFI is a permanent inventory. States and changes of all variables are assessed on re-measured (permanent) plots.

The design of the Swiss NFI can be described as two-phase sampling for stratification. The stratification distinguishes forest, shrub forest and non-forest plots based on auxiliary variables collected in the first phase (aerial photographs).

All estimates are computed with the same two-phase ratio estimator for stratification. In most cases the estimates are given for the five main regions Jura, Plateau, Pre-Alps, Alps and Southern Alps. The estimates for the entire country are post-stratified estimates, where the strata are the five main regions of known size.

In form of a client/server architecture, the Swiss NFI data are maintained in a relational database; computation of estimates is done with SAS and the user interface is web-based (HTML).

36.5.2 Volume Prediction

The prediction of stem volumes is a two-step procedure. Based on 40,000 trees measured in sections over the last decades, *volume models* for seven species groups covering all tree species of Switzerland have been derived. The explanatory variables are *dbh*, upper stem diameter (7 m above ground) and tree height. These models have a high precision and are independent of site and stand conditions.

The volume functions have been developed for stem volume over bark. Included are stumps and stem tops, but branches are excluded. The functions are available for stems with *dbh* $>$12 cm (Kaufmann 2000).

The *tariff functions* are derived from the sub-set of NFI sample trees with additional measurement of the upper stem diameter and the tree height, i.e. with a ‘true’ volume from the volume function. The explanatory variables for the tariff volume of all trees in the sample are the tree variables *dbh* and tree species, and several plot variables describing stand and site conditions. The tariff function is less precise than the volume model.

The so-called ‘tariff trees’, the sub-set of trees with additional upper stem diameter and height measurements, are selected with known sample inclusion probabilities and the residual between the ‘true’ volume (volume function) and the predicted volume (tariff function) is known for tariff trees. This allows correction for a potential bias of tariff functions, for instance for a (small) domain of special growth conditions (generalized local density estimator; Mandallaz 2008).

Conversion factors are used to predict volumes of bark, stumps, stem tops or branches, as well as biomasses and carbon contents.

36.6 Options for Harmonized Reporting

Forest is assessed as a point decision in the field on the basis of the national definition (see Section 36.3). The difference between national and reference definitions may be relevant for scattered stockings at the timber line or in landscapes under mixed agro-forestry use. A similar conclusion can be drawn for national shrub forest compared with the reference definition for other wooded land. However, the difference can not be quantified at the moment.

In the Swiss NFI, *dbh* measurements are available for trees and shrubs with a *dbh* > 12 cm. This threshold holds for all stems, dead and alive, standing and lying. The number of stems by species are also available for standing, living trees with *dbh* < 12 cm, but volume models are not available yet for these stems. On the other hand, there are conversion functions available to exclude stumps, which are included in national growing stock.

Since NFI3, downed deadwood is assessed using line intersect sampling. There is no length threshold applied for such pieces, and the diameter threshold is 7 cm at the point of intersection with the transect line. It is planned to indicate the status with respect to the agreed length threshold for downed dead wood pieces in the next inventory.

Decay stages of lying dead stems are assessed using different variables that will allow a classification according to a reference definition. Decay stages are not assessed for downed woody debris in line intersect sampling.

Above-ground and below-ground biomass are estimated by applying country specific biomass expansion factors to single trees. So far, trees (and shrubs) with *dbh* < 12 cm are excluded.

The Swiss NFI definition of forest types is a classification of stands according to their accessibility, management (high forest, coppices), structure and stage of development. In addition NFI data are reported by site fertility, potential natural forest community, altitudinal vegetation zone and broadleaves/conifers ratio. The reference definition of European forest types can be derived from different NFI variables.

Detailed information on afforestation and deforestation has been recorded since NFI3 at the plot level. However, Swiss reporting of afforestation and deforestation to the UNFCCC is based on external information. Deforestation is based on federal statistics. According to the Swiss federal law on forests, the extent and the spatial distribution of the total forest area in Switzerland must be preserved. Therefore, any change of the forested area must be authorized. Afforestation reported to the UNFCCC is based on the Swiss Land Use Statistics of the Swiss Federal Statistical Office, which provides an excellent data base for deriving accurate, detailed information on not only forest land, but all types of land use and land cover.

In Switzerland, afforestation accounted under Article 3.3 is limited to plantations. Spontaneous conversion of non-forest land to forest land by abandonment of land or natural processes is not counted as afforestation (Thürig and Schmid 2008).

Table 36.3 presents a brief summary of the status of harmonization in the Swiss NFI.

36.7 Current and Future Prospects

The basic feature of a two-phase sampling design on permanent plots will remain unchanged for the near future. However, data collection will change from the periodic system to an annual system with interpenetrating grids on the existing

Table 36.3 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current Swiss NFI

Estimate	ND	RD	Responsible
Forest area	Yes	No	NFI
Growing stock volume	Yes	(Yes)[a]	NFI
Above-ground biomass	Yes	(Yes)	NFI, external models
Below-ground biomass	Yes	(Yes)	NFI, external models
Deadwood volume	Yes	(Yes)	NFI
Deadwood volume by decay stages	Yes	(Yes)	NFI
Afforestation, Deforestation, Reforestation (Kyoto 3.3)	Yes	No	NFI, Land Use Statistics
Forest type	Yes	Yes	NFI

[a](Yes) means estimates according to RD can be calculated.

terrestrial grid of the NFI. Re-measurement of plots is expected after 9–10 years, reports every 5 years.

The hot topics and methods under investigation are: biomass and carbon pools and change estimation, Kyoto reporting, annual changes, airborne LiDAR and multi-spectral stereo-photos, tree resources outside forest, vegetation and soil, protection functions of forests, estimation procedures under the new annual design, small area estimation, volume functions for small trees, and forest definition.

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Chapter 37
United States of America (USA)

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37.1 Development of the National Forest Inventory of the USA

The national forest inventory of the United States of America (USA) is conducted by the Forest Inventory and Analysis (FIA) program of the U.S. Forest Service, an agency of the U.S. Department of Agriculture. The FIA research program has had several names but has been in continuous existence since 1928. It is the only organization that collects, compiles, archives, analyzes, and publishes state, regional, and national forest information on all ownerships of forest land in the USA. The history of the program, known in the past as forest survey, is documented in numerous publications including LaBau et al. (2007), Gregoire (1993) and Van Hooser et al. (1993); recent history is documented in McRoberts et al. (2005) and Bechtold and Patterson (2005).

From a long-term historical perspective, forest inventories in the USA have traditionally been commodity oriented, with emphasis on estimating the area and volume of the nation's timber supply by state. Although these statewide inventories covered all forest land, field work was typically conducted only on productive, unreserved forest land. The design and implementation of these inventories have been the responsibility of regional FIA programs that have administered them with plot configurations, sampling designs, measurement protocols, analytical techniques and reporting standards frequently tailored to regional requirements. These inventories were characterized as periodic because field crews were concentrated in one or two states until measurement of all plots was completed. States were selected for inventories on a rotating basis with time intervals between inventories for the same state ranging from 6 to 18 years. The plot measurement component of periodic inventories required from 1 to 4 or more years, with the analysis component requiring an additional 2–5 years.

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The timeliness, quality and usefulness of estimates obtained from periodic statewide inventories came under scrutiny in the 1980s and 1990s. Estimates were degraded by the effects of conducting inventories over multiple years, and the bias and uncertainty of estimates increased over time because of factors such as change in land use, tree growth and mortality, and removals between inventories. The periodic nature of these inventories made consistent interstate estimation difficult, even within regions, and interregional estimation was even more difficult because of varying plot configurations, sampling designs, and measurement protocols. When compounded by the lack of measurements on all forested lands and the inconsistency in measurements for national forest lands in some regions, these factors caused national compilations to depend on a variety of ad hoc techniques. Finally, the environmental and forest ecosystem health interests of groups challenging the commodity focus of FIA inventories were difficult to address using only traditional FIA measurements. FIA clients recognized the deficiencies in these regional, periodic inventories and registered their dissatisfaction.

In response to client concerns regarding the health of forest ecosystems, the Forest Health and Monitoring (FHM) program was initiated in 1990 as a cooperative effort among state and federal agencies. The FHM program focuses on assessing and monitoring the health and sustainability of the nation's forests and engages in four primary activities: detection monitoring, evaluation monitoring, intensive site monitoring, and research on monitoring techniques. Together these four activities permit predictions of where and how future ecosystems might change under various environmental and management conditions.

In response to client concerns regarding the timeliness of traditional FIA estimates, in 1990 one of the regional FIA programs initiated a pilot study with the objective of annually producing statewide inventory estimates that were no more costly and no less precise than those obtained from periodic inventories in the year of their completion. This pilot study focused on intensive use of modelling and remote sensing techniques. In the mid-1990s, another regional program initiated a second pilot project with the objective of a 5-year cycle of complete re-measurement of all plots. This pilot study relied heavily on additional state funding. In addition, two national panels of inventory experts recommended a nationally consistent approach to the collection, analysis and reporting of inventory data.

In 1998, the U.S. Congress directed the Secretary of Agriculture and the FIA program to develop a strategic plan for forest inventory featuring an annual system, state reports every 5 years, a set of common variables with national definitions and measurement standards, and integration of the field sampling components of the FIA and FHM programs. The coalescing of the two pilot studies and national cooperation in standardizing key inventory components resulted in an annual forest inventory program that has now been implemented in nearly all states.

The annual inventory program uses the ends-ways-means strategic planning model to promote and facilitate national consistency. 'Ends' are the criteria that must be satisfied for the program to be characterized as nationally consistent; 'ways' are the procedures that lead to achieving the ends; and 'means' are the resources that are committed to the effort. The program 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 program and provide direction for methodological research. To facilitate achieving the ends, 10 ways have been prescribed:

- Way 1: A national set of prescribed common variables with a national field manual that describes measurement procedures and protocols for each variable.
- Way 2: A national plot configuration.
- Way 3: A national sampling design.
- Way 4: Estimation using standardized 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 common variables.
- Way 8: Publication of statewide tables of estimates for prescribed common variables at 5-year intervals.
- Way 9: Documentation of the technical aspects of the program including procedures, protocols, and techniques.
- Way 10: Peer review of, and public access to, the technical documentation.

In summary, the FIA program is nationally consistent in its crucial components and is implemented through four regional programs (Fig. 37.1).

37.2 The Uses and Users of the Results

37.2.1 General Use

FIA data is the primary source of large area forest information for use by public land management and planning agencies, forest industry, environmental groups, and non-governmental organizations (NGOs). Inventory data and estimates for each state are made available annually, 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 20-year predictions of likely

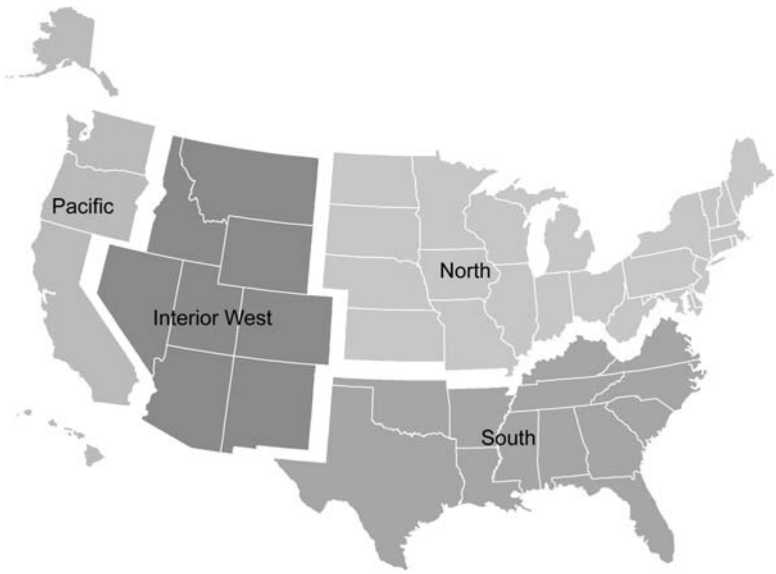

Fig. 37.1 FIA regions

trends in key resource attributes. The FIA program also reports national assessments on a 5-year cycle. In addition, the FIA program conducts special studies related to forest ownership patterns and trends, utilization of timber outputs, and non-timber resources such as recreation, hydrology, and wildlife habitat.

FIA data is used by a wide array of other public and private organizations. In response to extensive forest wildfires in the western USA, FIA data was the primary source of information for a biomass assessment for western states (Rummer et al. 2003). FIA is also the primary source of information for forest carbon reporting in the USA (Birdsey and Lewis 2003; O'Neill et al. 2005). In addition, FIA data was 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 is used in assessments of the status of ecosystems in the USA by the Heinz Center (Heinz 2002), an NGO. At the international level, FIA provides baseline data for sustainability reporting based on the Montréal Process criteria and indicators (Montréal process 2005). In addition, the FIA program supports the Forest Resources Assessment (FRA) program of the Food and Agriculture Organization of the United Nations (FAO).

37.2.2 Biodiversity Assessment

The Phase 3 component (see Section 37.4.1) of the FIA program is the primary source of information for assessing the status of the biodiversity of American forests. Data from the downed woody materials Phase 3 component of the program is used for estimating deadwood volume and fuels (Woodall 2003a, b). In addition, FIA data has been used for a variety of biodiversity research projects including national and multi-national assessments of tree species richness (McRoberts and Meneguzzo 2007; Magnussen et al. 2007), local and regional species and diameter diversity assessments (McRoberts et al. 2008), and a conifer versus deciduous diversity assessment (McRoberts 2009).

37.3 Current Estimates

The current estimates of the basic quantities from year 2008 are given in Tables 37.1a and b.

37.4 Sampling Design

The current FIA sampling design was initiated in the mid-1990s and is based on a tessellation of the entire country into approximately 2,400-ha hexagons derived using procedures proposed by the Environmental Monitoring and Assessment Program (EMAP) (White et al. 1992) (Fig. 37.2). The size of the hexagons produces a sampling intensity designed to satisfy national precision guidelines for estimates of forest area and volume (USDA-FS 1970). The base federal sample consists of one permanent plot in a randomly selected location in each hexagon. This general approach has been described by Cochran (1977, p 228) as systematic unaligned sampling. Three important features of this sampling design merit consideration. First, with this approach, a high proportion of existing plot locations could be retained. At the time the design was initiated, a large number and variety of sampling designs were in use across the country. Using geographical information system (GIS) techniques, the hexagons were overlaid on the existing sample plot arrays. If a hexagon contained no existing plots, a location was randomly selected without

Table 37.1a Basic area estimates

Quantity	Estimate[a] (1,000 ha)	Description	SE[b] (%)
Timberland	208,102	Same as forest land plus capable of producing 1.37 m^3/ha (20 ft^3/ac) per year and not withdrawn from timber utilization	0.191
Forest land	304,022	0.4 ha (1 ac), 36.58-m (120 ft) minimum width, 10% stocking, forest land use	0.163
Total land area	916,209		–[c]

[a]Smith et al. (2009).
[b]Standard error.
[c]Assumed to be error free.

Table 37.1b Basic volume estimates

Quantity	Estimate[a]	Description	SE[b] (%)
Growing stock net volume on timberland million m^3	37,524	Live trees with *dbh* ≥ 12.7 cm above 30.48 cm stump and to top height diameter of 10.16 cm for commercial species meeting standards of quality or vigor; overbark; excludes volume of rot and poor form	0.457
Growing stock volume	40,012	Live trees with *dbh* ≥ 12.7 cm above 30.48 cm stump and to top height diameter of 10.16 cm for commercial species meeting standards of quality or vigor	n.a.[c]
Net annual growth of growing stock on timberland		Average annual increase in volume between inventories; includes trees reaching minimum size; excludes cull trees and trees that died	
million m^3 per year	1,076		0.652
m^3/ha per year	5.17		n.a.[c]
Net annual removals of growing stock on timberland		Average growing stock volume of trees annually removed from timberland for roundwood products, logging residues, volume destroyed during land clearing, and standing volume on lands reclassified from timberland to another class	
million m^3 per year	494		n.a.[c]
m^3/ha per year	2.37		n.a.[c]
Salvable deadwood volume	0.80	Net volume of merchantable sound dead trees on timberland	n.a.[c]

[a]Smith et al. (2009).
[b]Standard error.
[c]Not available.

regard to land use or cover, and a permanent plot was established in the hexagon; if a hexagon contained only a single plot, it was selected for the hexagon; and if a hexagon contained multiple plots, one was randomly selected. Second, many large area sampling designs are based on grids aligned with lines of longitude and latitude. For countries with large north-south extents, convergence of the lines of longitude causes plots further from the equator to represent less sampled area than plots closer to the equator. The hexagonal approach avoids this difficulty. Third, many spatial analyses rely on variograms to quantify spatial correlation (Cressie 1993). Frequently, the short-distance components of variograms are most important, but accurate estimation of these components is difficult unless some plot locations are in relatively close proximity. The random location of plots within hexagons facilitates estimation of these short-distance variogram components. 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. Panels are selected to have their plots measured on a rotating basis, and measurement of all plots in a panel in a state is completed before measurement of plots in a subsequent panel is initiated. With this approach a complete sample of each state is obtained every year.

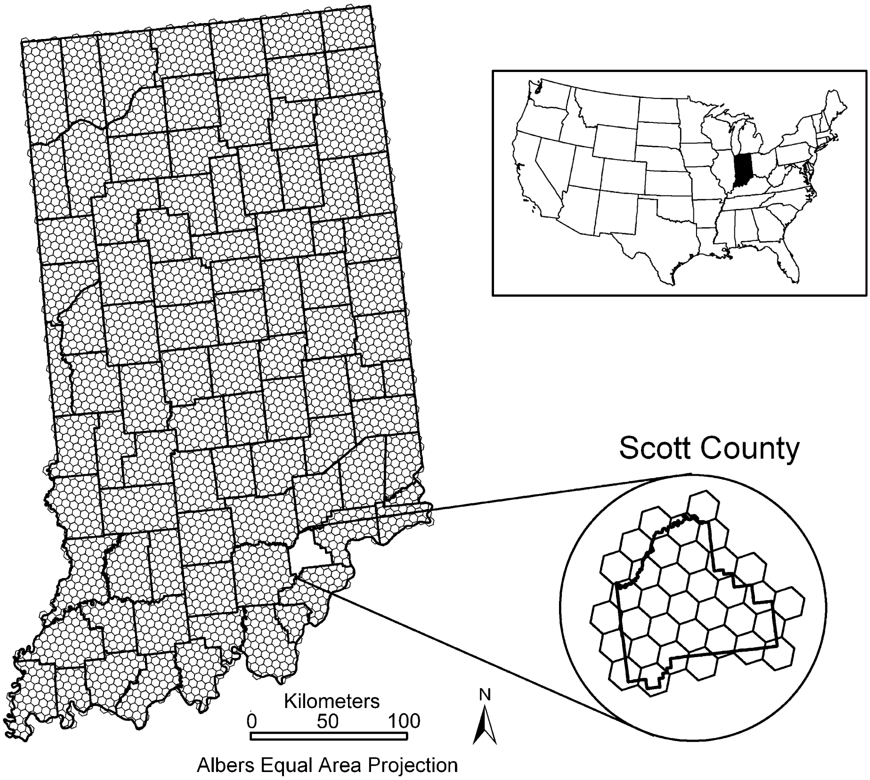

Fig. 37.2 Sampling hexagons with random locations of plots

37.4.1 Sample Plots

FIA conducts inventories in three phases. The primary objective of Phase 1 is to stratify the population area for purposes of reducing the variances of estimates. Although approaches to stratification vary by region to accommodate unique local forest features, the use of classified satellite imagery is emerging as the preferred source of information for this purpose (McRoberts et al. 2002, 2006). The positive results of stratification are that variances are reduced by factors as great as 5.0 for area estimates and 3.0 for volume estimates with no additional sampling or associated costs.

The objective of Phase 2 is to establish and measure an array of permanent field plots at an intensity of one plot per 2,400 ha. Some states provide additional funding to support more intensive sampling. Aerial photography is used to observe each plot to assure forest land use before sending a field crew to the plot location. Despite the cost of photography and photo-interpretation, considerable savings are achieved with this approach because the expense of travel to and from plot locations is the greatest component of the total cost of measuring a plot.

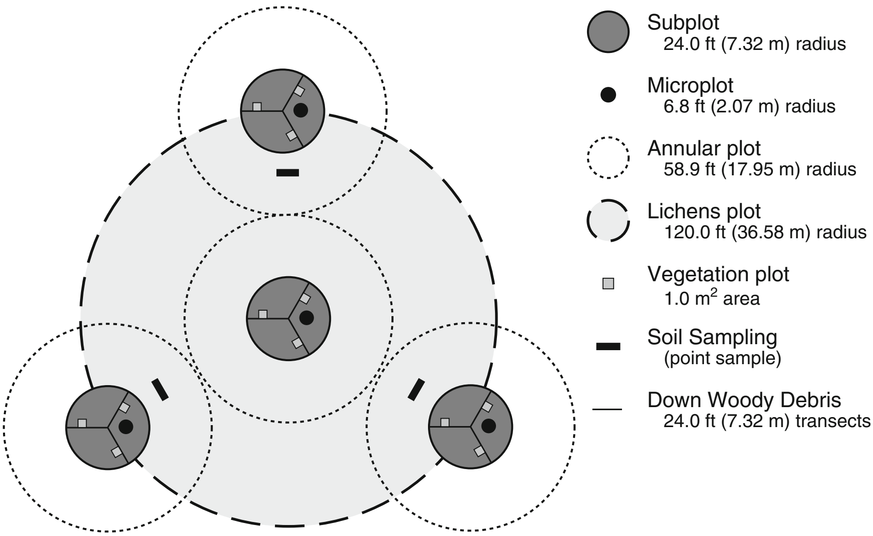

Fig. 37.3 Phase 2 and 3 plot configurations

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. Locations of Phase 2 plots are established randomly within hexagons without regard to land cover, land use, ownership, or other factors. Plots are installed on all public forest land and on private forest land with permission of the land owner. All Phase 2 plots conform to the national standard plot configuration (Fig. 37.3) and consist of four 7.32-m (24-ft) radius circular sub-plots configured as a central sub-plot and three peripheral sub-plots located at a distance of 36.58 m (120 ft) and azimuths of 0°, 120°, and 240° from the centre of the central sub-plot. Each sub-plot includes a 2.08-m (6.8 ft) radius microplot on which seedlings and saplings are measured and a regionally optional 18.0-m (58.9-ft) annular macroplot on which additional large trees are measured. 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. Estimates of growth, mortality, removals, and regeneration are obtained by comparing observations and measurements for the same plots from previous inventories.

The Phase 3 sample consists of a one-sixteenth systematic subset of the Phase 2 sample, resulting in a sampling intensity of one plot per approximately 39,000 ha. Because each Phase 3 plot is also a Phase 2 plot, all Phase 2 observations and measurements are acquired for all Phase 3 plots. Additional measurements on Phase 3 plots relate to forest ecosystem function, condition, and health, are generally acquired during summer months, and may be grouped into categories: (1) crown condition, (2) soil erosion potential, (3) soil fertility and/or toxicity, (4) lichens, (5) ozone bioindicators, (6) vegetation structure, and (7) down woody material.

Each sub-plot on a Phase 3 plot includes a 36.6-m (120-ft) radius lichens plot, three 1.0-m^2 (10.76 ft^2) vegetation plots, a 7.32-m (24-ft) down woody material transect, and a soil sampling area.

37.4.2 Management

37.4.2.1 Personnel

The full-time equivalent in staff for the FIA program in 2007 was 580 person-years (Table 37.2). Field crews represent the largest staff component.

37.4.2.2 Quality Assurance

The primary features of the quality assurance/quality control (QA/QC) component of the FIA program are nationally consistent measurement protocols and procedures, extensive crew training and independent checks. Each field crew receives several weeks of training after which they are tested and certified for their ability to satisfy national measurement quality objectives. Experienced crew members are paired with new crew members to provide additional on-the-job training during the field season. Field crews use portable data recorders that are programmed with data checks to provide alerts if data are illogical or outside of established norms. Plot measurements are reviewed by field crews for attributes that the data recorders do not check and are edited before being transmitted to the office. Data are checked further for errors during office processing. In addition, a series of plot checks are conducted. ‘Hot checks’ are inspections conducted as part of the training process by QA/QC staff and provide immediate feedback about a crew’s performance. ‘Cold checks’ are remeasurements of field plots by QA/QC staff with original crew data available at the time of the remeasurement. ‘Blind checks’ are remeasurements of

Table 37.2 Full-time equivalent staff positions[a]

Estimate	North	South	Interior West	Pacific	National office	Total
Administration	6.4	8.7	11.0	4.5	2.0	32.6
Phase 1	5.0	6.7	2.0	0.0	0.0	13.7
Field	84.6	125.6	70.2	58.0	0.0	338.4
Information management	20.9	14.5	11.1	15.9	0.0	62.4
Analysis	13.9	20.0	5.3	10.1	5.0	54.3
Techniques research	13.3	5.1	4.7	6.7	0.0	29.8
Quality assurance	8.1	18.2	12.7	5.2	0.0	44.2
Total	152.2	198.8	117.0	100.4	7.0	580.5

[a]USDA FS (2007).

plots by independent field crews without access to the original crew data. No corrections are made as a result of blind checks; rather the two data sets are maintained separately as a means of assessing uncertainty in measurements.

37.5 Estimation Techniques

In general, FIA estimation techniques are characterized 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 programs, (2) to facilitate development of the national program including the national information management system, (3) to provide a defensible statistical basis for the sampling and estimation components of the program, and (4) to promote credibility with clients and stakeholders. An external editor was engaged to coordinate double-blind technical reviews of the documentation by subject matter and statistical experts from the university, government, and forest industry sectors. After several rounds of reviews and revision, the documentation has been released as a report of the U.S. Forest Service (Bechtold and Patterson 2005). Although the primary intended audience for the documentation is the national FIA program itself, the program's clients and stakeholders also may find it useful for understanding FIA methods.

The FIA program uses stratified estimation to obtain estimates of population parameters for most variables. Because all plots are permanent, post-sampling stratification is used where strata are derived from the predicted classes of satellite imagery. With stratified estimation, each plot is assigned to one and only one stratum; for FIA, plots are assigned to the stratum associated with the pixel containing the plot centre. The stratum weights are obtained as the proportions of pixels assigned to the stratum. Estimates of population means and totals are calculated via Cochran (1977) as,

$$\hat{\mu} = \sum_{h=1}^{L} w_h \bar{y}_h \tag{37.1}$$

where w_h is the weight for the h^{th} stratum, $\bar{y}_h$ is the mean for the h^{th} stratum, and L is the number of strata. The variance of the estimate of the population mean is,

$$Var(\hat{\mu}) = \sum_{h=1}^{L} w_h^2 Var(\bar{y}_h). \tag{37.2}$$

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 status, tree density, forest type and tree size class. If multiple conditions are identified in a plot, field crews assign allied trees to the condition class in which they occur and record information necessary for estimating the proportion of the total plot area that is within each condition. Per unit area estimates by condition class (e.g., volume by forest type) are calculated using a ratio estimator of the general form,

$$\bar{y} = \frac{\sum_{i=1}^{n_h} y_i}{\sum_{i=1}^{n_h} a_i} \tag{37.3}$$

where y_i is the 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. The general form of the variance estimator is as documented by Särndal et al. (1992).

The following sections provide brief overviews of estimation procedures for area, volume, components of change, and sampling errors, see also Bechtold and Patterson (2005).

37.5.1 Area Estimation

Area estimation is based on the known areas of the strata used for variance reduction and the plot observations. The stratum estimate of total area by condition class is the product of the known stratum area which is assumed to be error free and the mean of the proportion area by condition class over all plots in the stratum. Specific details, particularly for unique situations, are documented in Bechtold and Patterson (2005).

37.5.2 Volume Estimation

Stem volume of individual trees with $dbh \geq 12.7$ cm (5 in) is estimated using statistical models as the volume of the bole 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 combinations of observations or measurements for species, diameter, and height. 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. All live volume and growing stock volume are estimated separately for forest land and timberland.

37.5.3 Components of Change

FIA inventories are designed to produce data to estimate the components of change (growth, removals, mortality) that are aggregated to estimate net change over time. Estimation of most components of change are based on the observed changes in condition and tree measurements between inventories. In addition, the FIA program produces a non-sample based estimate of timber removals using data obtained from surveys of the consumption of roundwood by timber-using industries and import/export information.

37.5.4 Error Estimation

Sampling errors are calculated as the product of 100 and the ratio of the standard error of the estimate and the estimate itself. The FIA program also calculates precision using a technique that permits comparisons across areas of different sizes. With this approach, precision (*PREC*) is defined as,

$$PREC = \frac{\sqrt{Var(\hat{Y})}}{\hat{Y}}\sqrt{\frac{\hat{Y}}{S}} \tag{37.4}$$

where, $\hat{Y}$ is the estimate

$$S = \begin{cases} 404,690ha\,(10^6\,acres)\,for\ area \\ 28,316,980m^3\,(10^9\,ft^3)\,for\ volume \end{cases}$$

The program has established precision guidelines of

$$PREC = \begin{cases} 0.03 & \text{for area estimates} \\ 0.05 & \text{for volume estimates in the eastern USA} \\ 0.10 & \text{for volume estimates in the western USA} \end{cases}$$

37.6 Harmonization

Table 37.3 Availability of estimates based on national definitions (ND) and reference definitions (RD) in the current USA FIA

Estimate	ND	RD	Responsible	Remark
Forest area	Yes	No	NFI	ND requires 0.4 ha, but measurements do not permit omission of plots with 0.4 ha ≤ area < 0.5 ha.
Growing stock volume	Yes	No	NFI	Minimum *dbh* = 2.54 cm; also, different definition of forest area.
Above-ground biomass	Yes	Yes	NFI	–
Below-ground biomass	Yes	Yes	–	–
Dead wood volume	Yes	Yes	–	–
Dead wood volume by decay stage classes	Yes	Yes	–	–
Afforestation Deforestation Reforestation (Kyoto 3.3)	Yes	Yes	–	Subject to differences in definition of forest land
Forest type	No	Yes	–	Mostly not a relevant question because forest types are all different

37.7 Future Prospects

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. For small area estimation, model-based inferential approaches based on combining inventory plot data and satellite imagery have been proposed. Plot data (except for exact plot locations) and estimates of primary quantities are made available annually via the Internet. A complete report for each state is published every 5 years. The report includes discussions of trends, health and disease issues, and spatial depictions of resources. Issues related to North American harmonization have been discussed with the Canadian and Mexican NFIs.

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Chapter 38
FAO NFMA – Support to Developing Countries on National Forest Monitoring and Assessment

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38.1 Development of the Support to National Forest Monitoring and Assessment Programme

The interest in forests and forestry has never been as great as it is today. In many countries forests are increasingly recognized as a crucial element for people who depend on forest resources as a source of a wide range of goods and services and opportunities for revenue generation. The future of forests depends upon national forest policies and their implementation by countries, particularly because deforestation and forest degradation are occurring at unprecedented rates and contributing to global warming and food insecurity.

The loss of forest cover, especially in developing countries, has become an international concern particularly considering that forestry and land use change account for nearly 20% of the global greenhouse gas emissions (GHG). The UNFCCC COP-13 held in December 2007 in Bali, adopted a decision to reduce GHG emissions from deforestation and forest degradation in developing countries (UNFCCC 2008). For this, and for other national information needs, monitoring of forest resources has become critical for countries as well as for international reporting. However, past Global Forest Resources Assessments (FRA) clearly highlighted the lack of institutionalized systems of national forest inventory (NFI) and monitoring, particularly in developing countries, where national data on forest are often acquired using methods other than observations of ground plots whose locations are based on probability sampling designs or rely solely on remote sensing analysis (FAO 2005).

During the last 9 years, the Forestry Department of FAO has invested substantial resources to develop a programme of support to national forest monitoring and assessment (NFMA) with the mandate of quickly responding to country requests for enhanced forest data acquisition and assist them in setting up and organising

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national forest monitoring and assessment systems (FAO 2009). The context in which NFMA operates is mainly that of countries in development, often with serious shortcomings in terms of technical, financial and institutional capacity. In this context, the actual process of data collection and analysis must be preceded by the process of building, or solidifying, the base for efficient and sustainable system for national forest monitoring. This means that the greatest challenge is to optimize available resources while maintaining scientific rigour.

38.2 Approach

The NFMA approach is characterized with three standards:

- *Demand driven*, meaning that the countries request FAO support and define the assessment scopes as well as information requirements. In some cases data requirements go beyond forestry parameters to include information for a wider range of land uses and natural resources such as agriculture, water and soil, such as in the case of Zambia or Kenya where Integrated Land Use Assessments (ILUA) were carried out. In its standard approach NFMA includes assessment of both biophysical and socio economic variables.
- *Participatory*, in the sense that the involvement of a wide range of stakeholders is encouraged, including government institutions, the private sector, NGOs, local communities, universities, research institutes, donors and international organizations, thus strengthening the national networks of experts.
- *Harmonized*, so that terms and definitions are consistent among national institutions and refer to internationally agreed terms and definitions. The harmonization allows comparison between countries and facilitates reporting to international reporting processes.

Finally, NFMA focuses on the establishment of a long term monitoring system with the objective of establishing a system that will be sustainable in time with repeated periodic measurements. This is accomplished by strengthening national capacity and institutionalizing the inventory process.

38.3 Objectives

NFMA's development objective is to contribute to the sustainable management of forests and trees outside forests by providing national decision makers and stakeholders with the means of acquiring accurate, relevant and cost-effective information on the state, uses, management of the forestry resources and land use changes. Such information is particularly relevant for national and international dialogue on forestry related policy issues and socio-economic development.

Specifically, FAO support to national forest monitoring and assessments aims at:

- Assisting countries in building their national capacities to design, plan and implement national field and remote sensing based forest inventories, to manage the generated information and disseminate it to decision makers.
- Generating baseline information on a wide range of forest and tree parameters on the basis of a harmonized set of variables, vegetation classification system and standard forest and tree survey sampling design for continuous monitoring. It covers the social, environmental and economic dimensions of forests and trees.
- Producing information on the management and uses of forests and their linkage to local communities and livelihood.
- Support the national policy and decision making processes and facilitate reporting to international conventions and processes (UNFCCC, CBD, CCD, UNFF, FRA etc.) (UNFCCC 2009; CBD 2009; UNCCD 2009; UN 2009; FAO 2005).
- Promoting multilateral cooperation, international partnerships, and experience sharing among countries to channel state-of-the-art technologies for NFMAs.

38.4 The Use and Users of the Results

The NFMA methodology is adaptable by nature and continuous revisions and adjustments are made in order to best respond to evolving national and international reporting needs.

38.4.1 National Policy and Planning

The majority of the countries to which NFMA is introduced has never had an NFI. Decision making has been based on assumptions and not on reliable information. For this reason, establishing an institutionalized national forest monitoring system constitutes a major step ahead. The data produced from a national forest assessment is primarily used to create better awareness and as a sound information baseline for national level policy making and strategic planning for sustainable use and management of forestry resources.

The NFMA approach promotes the use of the results for developing national forest programmes (nfps).The integrated approach, involving a wide range of stakeholders creates the conditions for an inter-sectoral policy dialogue in which various factions are brought together for proposing most appropriate and concerted solutions to tackle forest-related challenges.

38.4.2 International Reporting

At the same time, international conventions and mechanisms are increasingly demanding forest data. The ability to report to, for example, UNFCCC, CBD, CCD, UNFF and FRA, in the appropriate and harmonized classification system, gives the countries the ability to participate in the global forestry dialogue.

38.4.3 The Use of NFMA Data in UNFCCC Including Kyoto Reporting

Awareness of climate change threats has led to an increased demand for data on monitoring and managing carbon. NFMA methodology has recently been extended to address the reporting needs under the UNFCCC, including Kyoto reporting and Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD) monitoring. This includes the development of methods for collecting data on all five forest carbon pools, and assisting the countries in reaching Tiers 2 or 3 reporting levels, providing there are sufficient financial resources to reach the required precision. IPCC guidelines are used to generate carbon estimates from inventory data (IPCC 2006). So far NFMAs have been only completed for a single inventory year, so it is not possible at this stage to generate estimates on change in carbon stock. However NFMA is designed as a monitoring system with repeated measurements thus allowing the production of time series necessary to assess change. As an example, Guatemala and Zambia are already planning their second NFMA.

38.4.4 The Role of NFMA in Assessing the Status of Biodiversity

A site's biodiversity is expressed in terms of the characteristics of its species, soil, fauna, forest structure, forest type distribution, forest area fragmentation. Diameter distribution by species and regeneration levels also provide indications of the current status of each individual species. The collection of all this information is part of the standard NFMA methodology.

In NFMAs biodiversity is assessed by the number and frequency of species and providing information on forest structure and the spatial distribution and extent of forest types (as indicated above). However, in the data analysis phase conclusions can be drawn from estimates of correlations among variables. In particular, estimates of correlations between information gathered through socio-economic interviews of local people and biophysical variables can shed light on the impact of humans on forest resources (e.g. a correlation between tree species frequency and measures of forest disturbance).

Data on fauna species are sometimes indicated as a priority for NFIs and indicators of presence/absence of key wildlife species have been introduced in some countries, such as Congo, Angola and Comoros islands. The NFMA socio-economic interview scheme, in its standard approach, also allows collecting indicative data on fauna presence and human–animal interaction.

38.5 Methodology

The NFMA methodological approach combines field inventory and remote sensing. In the field, the collection of data on biophysical variables is complemented by interviews of local population to derive information on socio-economic aspects (use and users of forestry resources) and to better understand the interaction between humans and the land they live on. Remote sensing is used to provide information on spatial distribution and extent of forests. Details on inventory methods are outlined in the following sections.

38.5.1 Sampling Design

The sampling design adopted for the NFMA is systematic. Sampling units (SU) are selected at least at the intersection of every degree of the latitude/longitude grid. Depending on country's situations and information needs, a higher sampling intensity is applied to get sufficient sampling intensity and precision. Stratification may be adopted to optimize the design (precision and costs), based on stable strata such as ecological zones. The number of SUs (tracts) to be surveyed is determined by the required statistical reliability of the data, the available financial and human resources for the assessment, and with a view of enabling periodic monitoring.

The major sampling unit is a square tract of 1 × 1 km. Each sampling unit contains a cluster of four permanent, rectangular, half-hectare sample plots, placed in perpendicular orientations. Smaller sub-units are delineated within each plot: three sets of subplots, three measurement points and three fallen deadwood transect lines.

Each plot is also divided into land use/cover sections (LUCS) representing homogeneous land use/vegetation cover units (forest, grasslands, crops etc.) with variable sizes and shapes that have been identified in the field.

Figure 38.1 and Table 38.1 show the design of the different inventory units and related specifications.

38.5.2 Field Data Collection

A wide range of biophysical and socio-economic data is collected in the field. Socio-economic data are gathered through interviews with key informants, focus

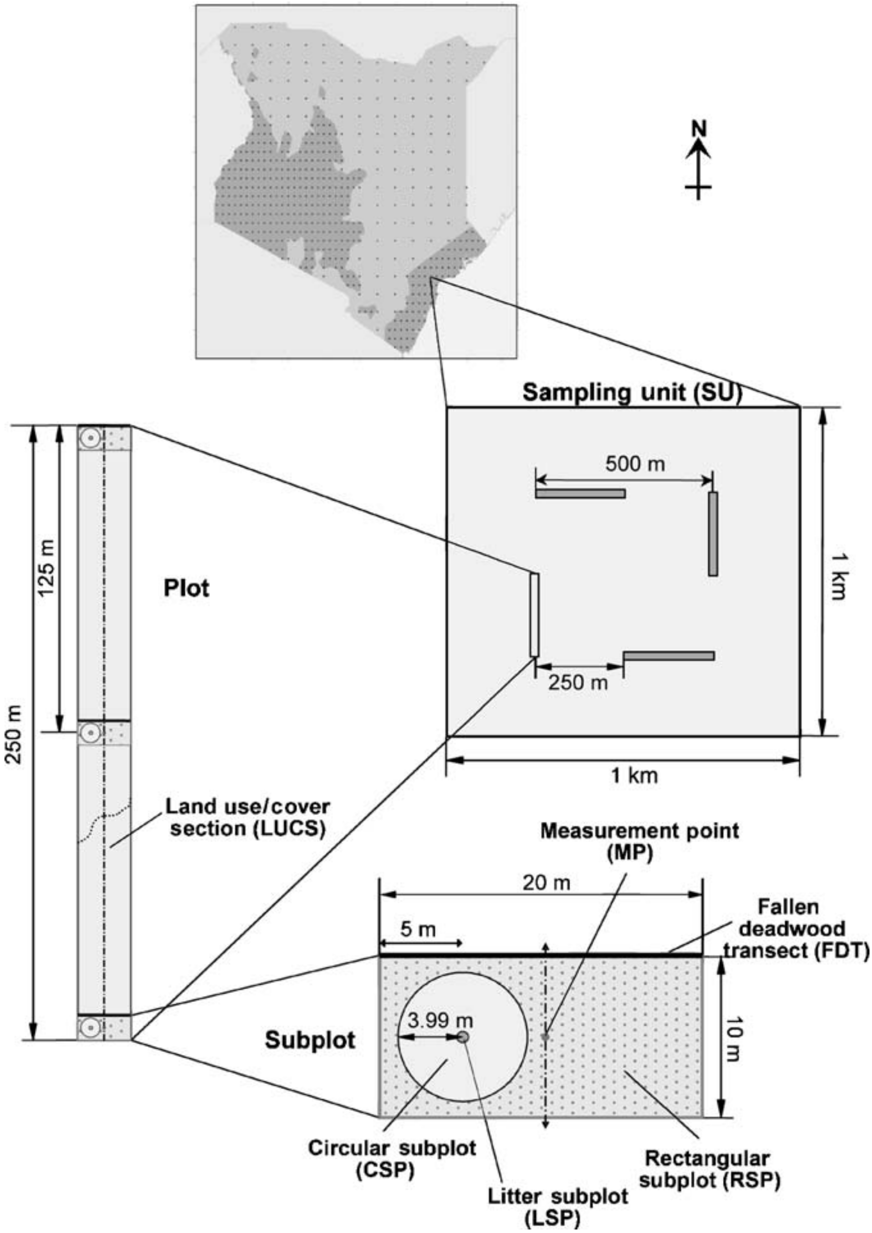

Fig. 38.1 Sampling unit, plot and subplot design

Table 38.1 Survey unit specifications[a]

Unit	Shape	Size (area)	Number
Sampling unit (SU) (or tract)	Square	1,000 × 1,000 m (1 km^2)	1
Plot	Rectangle	250 × 20 m (5,000 m^2)	4/SU
Rectangular subplot (RSP)	Rectangle	20 × 10 m (200 m^2)	3/plot
Circular subplot (CSP)	Circular	Radius r = 3.99 m (50 m^2)	3/plot
Litter subplot (LSP)	Circular	Radius r = 18 cm (0.1 m^2)	3/plot
Fallen deadwood transect (FDT)	Line	20 m	3/plot
Land use/cover sections (LUCS)	Variable	Variable	Variable
Land use/cover class (LUCC)	Variable	Variable	Variable
Household survey area (HSA)	Circular	Radius r = 2 km (12.6 km^2)	1

[a]All units (shape and size) can be adapted and optimized according to country context.

groups and randomly selected households, while biophysical information is collected through measurement and observations.

Different data are collected according to the survey unit:

- Sampling unit (or tract): general data on location, population, water and wildlife observation.
- Plot: identification of different land use/cover sections (LUCS) and measurements of trees and stumps with diameters at breast height (*dbh*) ≥ 20 cm, or ≥ 10 cm for the trees outside forest.
- Land use/cover section (LUCS): Information collected includes:
  - General information related to the area (designation, land tenure, environmental problems, vegetation cover, etc.).
  - Forest and other wooded land management practices (harvesting, silviculture, etc.) and structure.
  - Crop management practices.
- Land use/cover classes (LUCC): corresponds to each land use class found in the SUs (in all four plots). Information on forest and trees products, on environmental services, invasive and threatened species, wildlife abundance, and land use change is collected at this level.
- Rectangular Subplot (RSP):

  Data related to small diameter trees and stumps (10 cm < *dbh* < 20 cm) in forest. Data related to shrubs Indicator plant species.

- Circular subplot (CSP): tree regeneration data (only in forest, other wooded land and woodlots).
- Litter subplot (LSP): data are collected on litter including all non-living biomass with diameter less than 10 cm. The average depth of the litter layer and its main composition are also recorded.
- Fallen deadwood transect (FDT): measurements of fallen deadwood branches (≥ 10 cm) are taken along the transect lines. The decomposition status of the deadwood branches is also registered.

Table 38.2 Trees and stumps measured per level and corresponding forms

Level	Measured trees/stumps		Measurements
	Forest	Other LUCC	
Plot	*dbh* $\geq$ 20 cm	*dbh* $\geq$ 10 cm	Species, location, diameters, total height, health, quality, decomposition status of dead trees
Rectangular subplot (RSP)	*dbh* $\geq$ 10 cm	None	Species, location, diameters, total height, health, quality, decomposition status of dead trees
Circular subplot (CSP)	Tree height $\geq$1.30 m and *dbh* < 10 cm	Tree height $\geq$1.30 m and *dbh* < 10 cm (only in OWL and woodlots LUCC)	Number of trees by species

- Measurement point (MP): topographic and soil data are collected at the three measurement points.

The measurements of trees (living or dead) and stumps are summarized in Table 38.2

Soil measurements: two methods are proposed to collect data on soil, depending on information requirement and available funds: soil visual assessment, based on observations carried out in the field, and soil sample collection, which implies subsequent laboratory analysis to measure, in particular, soil carbon. Both methods might also be applied jointly because they provide different information.

Data on products and services (on forest, trees outside of forests, crops and fish products) are collected for each land use/cover class (LUCC) present in the sampling unit (SU). This information originates from interviews with local people or from people accompanying the field team but is also verified and complemented through direct field observations.

38.5.3 Remote Sensing

Remote sensing is used in combination with the field survey to improve estimates of extent of forest and other attributes (carbon stocks), provide information on the spatial distribution of forest and land uses, on forest fragmentation and area change and therefore help in the stratification process. Integration of remote sensing and field data is also done through GIS modelling. Two main techniques for remote sensing mapping are employed (either alone or combined):

- Full-cover mapping: to produce national maps and statistics of forest cover
- Sampling survey for in-depth studies to assess, e.g., changes of forest resource as well as trends and deforestation

38.5.4 Project Management

A typical NFMA project follows a conceptual framework that includes consecutive phases: (1) planning and designing, (2) data collection, (3) analysis and reporting.

Phase one includes (1) planning of project activities, (2) defining information needs through wide participation of stakeholders, (3) fine tuning and adaptation of the NFMA approach to meet specific country scenarios, (4) designing forest/land use classification systems, (5) setting up the project organisation and its institutional and monitoring arrangements, (6) procurement of field inventory equipment and remote sensing data, (7) recruiting professionals and support staff, (8) procuring equipment and supplies, (9) developing manuals and guidelines, (10) training of national staff, and (11) designing and developing the database application. This phase requires 6–9 months depending on the country.

Phase two is mainly for data collection through a field survey at sample plots and through a remote sensing survey. Approximately 12–18 months are needed to complete the fieldwork and remote sensing survey.

Phase three, lasting 6–9 months depending on the countries, is dedicated to processing and analysing the field data, producing thematic maps and reports, disseminating the findings (info packaging) and initiating the policy analysis.

According to the size of the country, resources available and other factors, NFMA projects usually have durations of 18 and 36 months. Starting from a standard set up, each project is customized according to the country context and needs. Country specific methodology, documentation, and reports are produced.

More details on NFMA project management including cost and time analysis can be found at NFMA's website (FAO 2008, 2009).

38.5.5 Data Analysis, Reporting and Dissemination

Data collected are managed and analyzed (stored, queried, updated) through a country specific database built from a template database application.

Results are produced and final reports include all major statistics of the variables collected. The depth of the analysis is often dependent on the capacity and availability in country and in general the potential of the data gathered allows for further analysis. In some cases, academic and research institutions are involved for a more in-depth use of the data and to highlight correlations and dependencies among sets of variables. The better the analysis, the more useful the information is for policy and decision makers.

Throughout the duration of the project, informative notes are released to press agencies with the purpose of sensitizing the population as a whole on the development of the project and its importance. At project's end, final reports are produced as well as policy and thematic reports. A full coverage of the project's details and results is also displayed on web portals. A full display of countries aggregated data is currently under development.

Table 38.3 Status of NFMA Country projects activity

NFMA project completed	NFMA project ongoing
Bangladesh	Algeria
Cameroon	Angola
Costa Rica	Brazil
Guatemala	Comoros
Honduras	Ecuador
Lebanon	Kenya
Philippines	Kyrgyzstan
Zambia	Nicaragua
	Perú
	Republic of Congo
	Tanzania
	The Gambia
	Uruguay
	Vietnam

38.6 Current and Future Prospects

NFMA projects undertaken with FAO assistance are funded through different sources, including the Technical Cooperation Programme (TCP) of FAO, Unilateral Trust Funds (UTF), the Government Cooperation Programme (GCP) and contribution in cash or in-kind from the concerned governments. Other projects are also financed from extra budgetary resources under partnership agreements among FAO and donors like Sweden, the Netherlands, Finland, Republic of Korea and Norway (UN-REDD). NFMA continuously supports countries in finding new and suitable sources of funding.

From the methodological point of view, NFMA actively works to update and refine its approach in order to provide the countries with the best possible processes in line with world's trends, always considering the specificity of the context in each country. Expert consultations, ad hoc consultancies and feedback and experience gained while working in the countries enable constant improvement of methods, tools and processes.

The countries requesting support to carry out NFMA far exceed the actual capacity of FAO to respond. For this reason, new sources of funding are continuously being sought. As of 2009, NFMA has completed projects in nine countries and is currently working in 14, as shown in Table 38.3 and Fig. 38.2.

38.7 Harmonization and Synergies of NFMA Projects

The NFMA programme constantly seeks new synergies and partnerships with international and national institutions and programmes. South–south collaboration is one of the pillars of the programme, as national specialists trained in one country

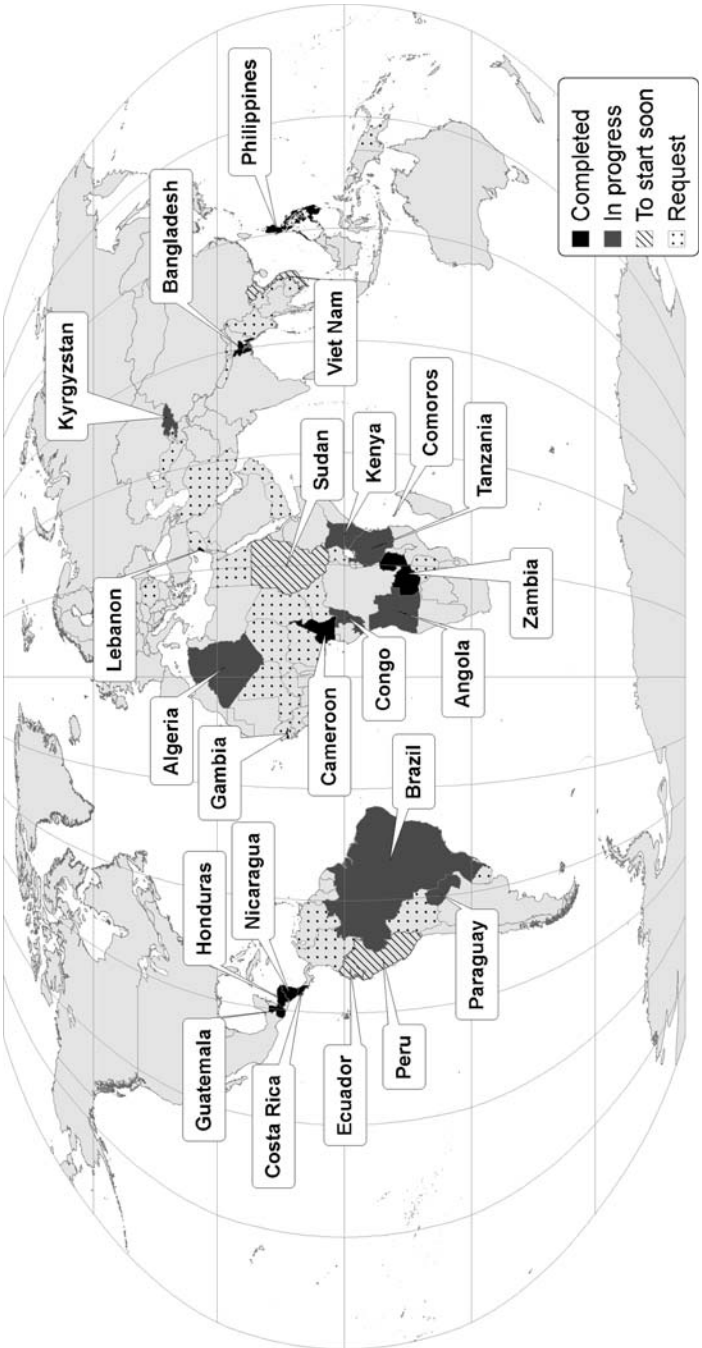

Fig. 38.2 Map of NFMA Country projects and pending requests

assist other countries in developing their NFMA, thus creating a network of technical experts who transfer their knowledge and share their experiences.

Partnerships with IPCC and UN-REDD have been established in order to jointly test new methodologies. The collaboration is strengthened by the fact that some of the countries in which NFMA is working are also UN REDD countries.

A network of experts (including NFI experts who participated in COST Action E43) (COST Action E43 2009) has provided guidance to evaluate the NFMA program through consultancies, technical meetings and expert consultations. In addition, an advisory board will be created in late 2009 to provide further and regular direction to the programme, review its achievements and provide recommendations on the way forward.

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Appendix

A Sample of COST Action E43 Reference Definitions

Lanz A, Alberdi I, Barbati A, Barsoum N, Brändli U-B, Chirici G, Cienciala E, Condés S, Di Cosmo L, Freudenschuss A, Gabler K, Gschwantner T, Hylen G, Ilvesniemi H, Kusar G, Kändler G, Lawrence M, McRoberts RE, Nabuurs G-J, Petersson H, Priwitzer T, Robert N, Rondeux J, Schadauer K, Ståhl G, Tomter S, Tomppo E, Tosi V, Vidal C, Weiss P and Winter S

A short compilation of reference definitions elaborated by the participants of COST Action E43 is presented subsequently. The complete reference definitions are given together with explanatory notes and additional background information in Lanz et al. (2009). The definitions are presented separately for the three Working Groups of COST Action E43, and classified on the basis of the levels of agreement given in Table A.1.

Table A1.1 Classification of reference definitions by agreement

	long-term agreed
	may change, but used as mid-term reference
	discussed, not yet agreed.
	discussed, not likely to reach reference soon

Working Group 1 Definitions

Tree Related Definitions

1. Tree and shrub 

A tree, for NFI purposes, is a woody perennial of a species typically forming a single self-supporting main stem and having a definite crown.

A shrub, for NFI purposes, is a woody perennial of a species typically not forming a single main stem and not having a definite crown.

2. Whole tree ☺

The whole tree comprises all parts and organs of a tree, ranging from the leaves, flowers, fruits and buds to the branches, stem, stump, roots and fine roots.

3. Above-ground and below-ground elements of a tree ☺

The above-ground part and below-ground part of a tree are separated by the surface of the ground.

4. Stem ☺

The stem of a tree is the above-ground part of the main (off) shoot with apical dominance.

5. Lateral parts ☺

The above-ground lateral parts of a tree are separated from the main stem by the theoretical intersection surface of the main stem.

6. Foliage ☺

The foliage of a tree comprises all above-ground temporary parts such as leaves and needles, reproductive parts and buds. It is separated from the main stem and the lateral parts by the location where the foliage is attached to the main stem or lateral parts.

7. Stump ☺

The stump of a tree is the above-ground base part of the stem which would remain after a tree was cut under normal felling practices.

8. Stem top ☺

The stem top of a tree is the topmost part of the stem from an over-bark base-diameter of $Z_{\text{stem top}}$ cm to the stem tip.

9. Bole ☺

The bole of a tree is the above-ground part of the stem between the stump and the stem top.

10. Large and small branches ☺

The large branches of a tree are the portion of the above-ground lateral parts of a tree with a diameter of more than or equal to Z_{branches} cm. The small branches of a tree are the portion of the above-ground lateral parts with diameter of less than Z_{branches} cm

11. Bark ☺

The bark of a tree includes all tissues of the main stem, lateral parts and below-ground parts between the xylem and the epidermis of the phellem

12. Base point ☺

On level terrain the base point is the point resulting from the intersection of the stem axis and the ground surface. On sloped terrain and on inclined trees the identification of the base point requires the previous identification of an intersection point. This intersection point is the highest point on the cross-sectional area that results from the intersection of the ground surface with the stem. A line through the intersection point and perpendicular to the stem axis yields the base point in these cases.

13. Tree height

The height of a tree is the vertical distance between the base point and the highest point of the tree.

14. Stem length

The stem length of a tree is the distance along the stem axis between the base point and the stem tip.

15. Breast height

The breast height of a tree is located at 1.3 m from the base point along the axis of the stem.

16. Diameter at breast height (*dbh*)

The diameter of a tree at breast height is the average of the diameters measured perpendicular to the stem axis at breast height over all possible measurement directions from 0° to 180°, i.e.,

$$dbh = E(x) = \int_0^\pi f(\alpha)x(\alpha)d\alpha = \frac{1}{\pi}\int_0^\pi x(\alpha)d\alpha$$

where $f(\alpha)=1/\pi$ is the probability density function of the measurement direction α, x a random variable corresponding the *dbh* when the measurement direction is selected randomly and $x(\alpha)$ is the diameter for a measurement direction of α.

17. DBH classes

A dbh class, denoting the (sub-)population of trees included in that class, is indicated (labeled) with the lower and upper class limit.

18. Stump height

The stump height is the distance along the axis of the stem from the base point to the point where the tree would be cut under normal felling practises.

19. Crown

The crown of a tree consists of the living branches and their foliage.

20. Crown projection area

The crown projection area of a tree is the area of the vertical projection of the outermost perimeter of the crown on the horizontal plane. It includes small openings within the crown.

21. Crown cover

The aggregation of the crown projection areas of the tree individuals in a stand (without double-counting overlapping crown projection areas) divided by the stand area yields the crown cover of the stand.

22. Living and dead trees

A living tree is a tree having a stem with an active or a dormant cambium. Otherwise the tree is dead.

23. Standing and lying stems

A lying tree is a tree whose main stem is in the majority of its length lying on the ground. Otherwise it is a standing tree.

Forest, Other Wooded Land and Other Land with Tree Cover

24. Forest

Forest is land spanning more than 0.5 ha, with trees higher than 5 m of a crown cover of more than 10%, or with trees able to reach these thresholds in situ.

Excludes: Areas fulfilling the thresholds specified above but with a maximum width of less than 20 m (linear formations), and land predominantly under agricultural or urban use.

Includes: Temporary unstocked forest land.

25. Other wooded land

Other wooded land (OWL) is non-forest land spanning more than 0.5 ha with trees higher than 5 m of a crown cover between 5% and 10%, or with trees and/or shrubs higher than 0.5 m of a combined crown cover of more than 10%.

Excludes: Areas fulfilling the thresholds specified above but with a maximum width of less than 20 m (linear formation), and land predominantly under agricultural or urban use.

26. Other land with tree cover

Other land with tree cover is non-forest (and not other wooded land) spanning more than 0.5 ha with trees higher than 5 m of a crown cover of more than 10%, i.e. stockings of trees on land predominantly under agricultural or urban use.

Excludes: Areas fulfilling the thresholds specified above but with a maximum width of less than 20 m (linear formations).

27. Forest boundary line

The boundary line of a forest area is derived from the α-shape of standing trees, and follows the outside of the tree crown projection area of these trees, except when other land uses are clearly defined. In these cases the boundary line will follow the delineation of other land features.

The same principle applies to the boundaries of Other Wooded Land, Other Land with Tree Cover.

28. Linear formations

A linear formation (e.g. windbreaks, strips of trees) of a width of less than 20 m, and

- Connected on only one end to a forest or other wooded land area

– Is not included into forest or other wooded land area.

The boundary to the forest or other wooded land area is created where the width is less than 20 cm.

- Connected on both ends to a forest or other wooded land area (resulting in an hourglass or dumbbell shape)

– Is included within the forest or other wooded land area, provided

    - The length of the formation is less than 20 cm.
    - The total area of the two forest or other wooded land areas and the linear formation is more than 0.5 ha.

29. Temporary unstocked forest area

A temporary unstocked (and inundated, buried and burned) forest area *is an area with clear signs of an old forest stocking and either*

1. With an existing natural tree regeneration able to reach forest thresholds at maturity, or
2. With a plantation of trees able to reach forest thresholds at maturity, or
3. With a natural regeneration or a plantation, expected to (be) install(ed) within 10 years after removal of the old stocking, which will be able to reach forest thresholds at maturity

30. Open area

An open area is an area not stockable, larger than 0.1 ha (and of a width of more than 20 m).

Volumes

31. Volume of living stems above stump

The volume of living stems above stump is the aggregated above-ground volume of all living stems, standing or lying, over a specified land area. Included are over-bark stem volumes – from the stump height to and including the stem top – of living stems with a diameter at breast height of more than 0 cm (height of more than 1.30 m). Branches are excluded.

32. Volume of standing dead stems above stumps

The volume of standing dead stems above stump is the aggregated above-ground volume of all standing, dead stems over a specified area. Included are over-bark stem volumes – from the stump height to an including the stem top – of standing dead stems with a diameter at breast height of more than 0 cm (height of more then 1.30 m). Branches are excluded.

33. Volume of standing stems above stump

The volume of standing stems above stump is the aggregated above-ground volume of all standing stems, living or dead, over a specified land area. Included are over-bark stem volumes – from the stump height to and including the stem top – of living and dead stems with a diameter at breast height of more than 0 cm (a height of more than 1.30 m). Branches are excluded.

34. Piece of coarse woody debris

A piece of coarse woody debris is a downed (not suspended) piece of dead wood lying on ground, with at least one section coarser than 10 cm (over bark) of at least 1 m in length.

35. Volume of coarse woody debris

The volume of coarse woody debris is the aggregated above-ground volume of all pieces of coarse woody debris over a specified land area. Included are over-bark volumes of those sections of the coarse woody debris pieces, which are coarser than 10 cm (over bark) on a length of at least 1 m.

36. Growing stock

Growing stock is the above-ground volume of living stems above stump over a specified area. Included is the stem volume from the stump height to and including the stem top and the bark. Branches are excluded.

37. Volume of dead wood

The volume of dead wood is the volume of standing, dead stems above stump and the volume of coarse woody debris over a specified land area.

38. Decay stages

The decay stage is the decomposition status of volume of dead wood. Four decay stages are identified on the basis of the percent presence of hard texture dead wood.

Dead wood has hard texture when in the field it cannot be penetrated more than 1 cm by a knife or when on the ground it resists to the weight of a man (approximately 80 kg) without significant alteration.

Decay stage A: when hard texture dead wood represent at least 90% of the total dead volume a dead wood piece is NOT DECAYED.

Decay stage B: when hard texture dead wood is between 60% and 89% of the total dead volume a dead wood piece is SLIGHTLY DECAYED.

Decay stage C: when hard texture dead wood is between 30% and 59% of the total dead volume a dead wood piece is DECAYED.

Decay stage D: when hard texture dead wood is between 5% and 29% of the total dead volume a dead wood piece is VERY DECAYED.

When hard texture dead wood is lower than 5% of the total dead volume a dead wood piece is part of the litter not of the dead wood volume.

Working Group 2 Definitions

Land Use Categories

Land use and land use transfers are central components in the reporting according to the Good Practice Guidance (GPG) report (IPCC 2003). Theoretically it is simple to develop a national system for estimating land use and land use transfers, but in practice data are often poor or even lacking. To harmonise definitions of land use, we suggest quite general and common definitions that most countries should be able to adopt.

In many countries all information about areas can be derived from the NFI, since the inventory covers all land/lake areas and not only forests. In other cases there will be a need to mix different sources of information. It is important to note the requirements in the Good Practice Guidance (GPG) related to Kyoto Protocol reporting – i.e. that the land use information must contain neither gaps nor overlaps – which may happen if information is derived by merging land use data from different sectors (e.g. forestry and agricultural statistics). In many cases NFIs have a strong position in being able to provide sample based complete information on land use categories.

39. Forest land ☺

We propose that the definition of Forest land should be that of Forest according to FAO: "Forest is 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 does not include land that is predominantly under agricultural or urban land use".

NFI-related details not clarified by FAO should be interpreted as according to the definitions given by Work Group 1 of COST Action E43.

According to Forest Resources Assessment (FRA) and Good Practice Guidance (GPG) LULUCF (IPCC 2003) definitions, even if not requested by the Marrakesh Accords, it is suggested that countries use also a minimum strip width (20 m) to define the Forest land.

40. Cropland ☺

The basic definition of Cropland provided in the Good Practice Guidance (GPG) report is supported. Cropland is defined as land that is regularly cultivated. The vegetation usually is agricultural crop but coppices grown for energy purposes and trees for fruit production may exist on croplands as well. Cropland also includes (managed) olive groves, vineyards, and fast-growing tree plantations (like poplars and willows) in agricultural areas.

41. Grassland ☺

We sustain the basic definition of Grassland provided in the Good practice Guidance (GPG) report. Grassland includes rangelands and pasture land that are not considered as Cropland. It is land used for grazing or unmanaged land covered predominantly with perennial grasses/herbs. Grazing is the predominant land use in case the land is used, but its intensity can vary greatly according to different management regimes. Therefore, Grasslands may be either managed or unmanaged.

42. Wetland ☺

The definition in the Good Practice Guidance (GPG) report is supported: "Wetland is land covered or saturated by water for all part of the year (e.g. peatland) and does not fall into the Forest land, Cropland, Grassland or Settlements categories." The management criterion relates to whether or not the water table is artificially changed (e.g. drained peatlands or water reservoirs). Temporary flooding is not enough for assigning land to this category.

Wetlands can be sparsely covered with trees, although their coverage should not exceed the thresholds for the Forest land definition. Similarly, the conditions on peaty or wet soils should not satisfy the definitions of Cropland or Grassland. For practical reasons we propose a minimum width (2 m) of ditches and streams for assigning them to the Wetland category. Further, when delineating Wetlands from other areas we propose that the Wetland category extends up to the limit where there is no longer a marked effect of water on the vegetation.

43. Settlement ☺

The Good Practice Guidance (GPG) report basic definition of Settlements is supported. *This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories*. This should be consistent with the selection of national definitions. Settlements include urban tree formations (trees grown along streets, in public and private gardens, and in different kinds of parks); the requirement is that these trees should be functionally associated to cities, villages, etc.

Further, roads (excl forest roads), railroads, power-lines in forests, airfields, cleared slalom slopes, golf courses and gravel pits all belong to the settlement category.

44. Other land ☺

The definition of Other land provided in the Good Practice Guidance (GPG) report is supported. This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.

One type of area that typically belongs to this category is Alpine land with sparse vegetation. The definition of "other land" according to the Good Practice Guidance (GPG) report includes only unmanaged land areas in this category. Alpine areas used as pastures thus should be reported as Grassland. However, alpine areas of this kind in northern Europe, used only for very extensive reindeer herding, would typically be reported as Other land.

Afforestation, Reforestation, Deforestation

According to the Kyoto Protocol, it is mandatory to report emissions and removals from Afforestation (A), Reforestation (R) and Deforestation (D). Afforestation and Reforestation are defined by the Good Practice Guidance (GPG) as "direct human-induced conversion of land to forest from another land use", while in the case of Deforestation, the Good Practice Guidance (GPG) definition refers to "the direct, human-induced conversion of forest to non-forest land".

45. Afforestation, Reforestation, Deforestation ☺

Spontaneous establishment of trees on abandoned managed land should be treated as Afforestation (or Reforestation) in case the regeneration is plentiful enough to secure that the thresholds for forest land can be reached. The latter judgment is made based on national circumstances. The time point of A (or R) generally is the point when the first activity in the regeneration scheme was conducted. In case of spontaneous regeneration of trees, the time point of A (or R) is when the national conditions for judging the area to reach forest thresholds are met. Thus, an agricultural area may pass from being (managed) Cropland, to being unmanaged Grassland, to being (managed) Forest land, following spontaneous regeneration of trees. The last land use transition should be considered A.

However, spontaneous regeneration of trees on lands that have never been managed should not be considered A, e.g. regeneration of trees in alpine areas due to rising temperature.

Deforestation refers to conversion of Forest to non-forest land. In this regard when a natural disturbance (e.g. an avalanche) causes permanent deforestation this is not classified as D, since D should be human induced.

Regarding the mimimum size of ARD areas these should harmonise with the forest definition, i.e. patches with ARD should be at least 0.5 ha large. If ARD areas are gradually accumulating they should be reported when the accumulated size has passed 0.5 ha.

Carbon Pools

46. Above-ground biomass ☺

In above-ground biomass we propose to include all biomass of living vegetation, both woody and herbaceous, above the soil, including stems, stumps, branches, bark, seeds, and evergreen foliage.

We suggest to include all living vegetation – woody and herbaceous – above the soil and to include in the term “foliage” only evergreen leaves. Otherwise there might be a risk of double accounting of deciduous leaves (on the trees and as litter horizon).

47. Below-ground biomass ☺

In this pool all living biomass of live roots from trees should be included. Fine roots of less than 2 mm diameter are excluded, because they generally cannot be distinguished properly from soil organic matter.

For reasons of feasibility and operability a pragmatic approach is suggested that includes only roots from trees for the category of below-ground biomass (different to the above-ground biomass). However, in exceptional cases substantial amounts of biomass may be present in non-tree below-ground biomass. In such cases a country may choose to include that pool as well. In many countries biomass expansion functions or factors are available for the estimation of below-ground biomass of trees. Tree stumps should not be included in this category, but in the above-ground pool. The limit is the ground level (the top of the humus layer).

48. Dead wood ☺

We propose to deviate slightly from the basic definition given in the Good Practice Guidance (GPG) report. “The dead wood pool includes above-ground non-living woody biomass, either standing or lying. The pool includes standing trees, snags (broken standing trees), and downed woody material. The threshold diameter is 10 cm; to be included a piece of dead wood must have at least a 1.3 m long section coarser than 10 cm.” The definition of deadwood corresponds to that one used in other cases for different purposes (within COST Action E43) and thus a distinct non-case specific definition can be used. The major difference between the proposed definitions and that of the Good Practice Guidance (GPG) report is that dead roots are not included in our definition of dead wood. Dead roots should instead be counted within the soil organic carbon pool.

49. Litter ☺

Good Practice Guidance (GPG) definition includes all non-living biomass with a diameter less than a minimum diameter chosen by the country (e.g. 10 cm), lying dead wood, in various states of decomposition above the mineral or organic soil. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.

In soil science Litter is a well-defined soil layer. The definition of Litter as used in the Good Practice Guidance (GPG) report is not consistent with that one used by soil experts and in soil typologies of different EU countries.

We propose to deviate from the definition in the Good Practice Guidance (GPG) report. Our recommendation is to report Litter and other organic horizons together with the other soil organic matter. In the reporting tables the notation "included elsewhere" should be used.

50. Soil organic matter ☺

The definition of Good Practice Guidance (GPG) gives no clear distinction between humus/litter and mineral soils. Due to the reasons mentioned under Litter above, it is recommended to report Soil organic carbon and litter as one entity, as Soil organic matter. It comprises fine woody debris, litter (as traditionally defined in soil science), all potential humus layers, and carbon in mineral soils down to a depth of 30 cm below the humic layer. Live fine roots of less than 2 mm are included with soil organic matter.

The pool also comprises dead roots.

Forest Management and Managed Forest

According to the UNFCCC reporting agreements, emissions and removals of greenhouse gases are only to be reported for managed areas (forests). Further, the Kyoto Protocol article 3.4 provides a possibility for Parties to account for emissions and removals of greenhouse gases due to forest management, which is stated to be the "process of planning and implementing practices for stewardship and use of the forest (forest land) aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner".

51. Managed forest (terminology) ☺

Regarding the two basic terms we propose the following definitions, based on the conclusions from an expert meeting at FAO (in spring 2005):

- Forest management is the formal or informal process of planning and implementing practices aimed at fulfilling relevant environmental, economic, social, and cultural functions of the forest.
- A Managed forest is a forest subject to forest management.

With these definitions, areas under Forest management and Managed forest areas will be the same, although "technical" deviations in the Kyoto Protocol reporting may occur since all areas once included in the forest management category must remain in this class, even if land use is changed. Likewise, afforestation and reforestation will increase the area of managed forest, but those two categories are reported separately.

The second issue concerns the definition of what areas should be considered Managed forest. While the concept of forest should follow the general definition (provided by WG 1 within COST Action E43), it remains to be decided what kinds of management activities should be included.

52. Managed forests (areas) ☺

Managed forest includes all forests subject to fulfilling relevant environmental, economic, social, and cultural functions. The category comprises all forest areas that are accessible to society, regardless of whether or not land use is visible.

Thus, the important issue is whether or not a forest area is accessible. If it is, a formal or informal decision regarding its use has been made. Specifically, forest in (accessible) reserves should be included as managed forest.

Working Group 3 Definitions

Forest biodiversity is a complex concept and it is usually non object of direct measures. It is instead monitored and assessed trough the use of a number of different indicators.

The aim of WG3 was to identify those forest biodiversity indicators that may be calculated in an harmonised way on the basis of data acquired by NFIs.

General Definition of Forest Biodiversity

53. Forest biodiversity ☺

Forest biodiversity pertains to the variety, abundance and spatial distribution of ecosystem attributes.

Such ecosystem attributes were classified following different approaches:

1. Lévêque (1994) and Gaston (1996) identified genetic, taxonomic, and ecosystem level.
2. Whittaker (1971) identified three spatial types of diversity:
   – Alpha diversity, which refers to ecosystem diversity
   – Beta diversity, which refers to the change in diversity between ecosystem
   – Gamma diversity, which refers to the overall diversity for different ecosystems within a region
3. Noss (1990) identified three components: compositional, functional, which relates to ecological and evolutionary processes; and structural, which relates to physical organization of the pattern of elements.

In the WG3 we focus mainly on the definition of Noss (1990).

For *forest* we refer to the adopted reference definition 24 from WG1. For *composition* we refer to present species composition of trees, shrubs and other vegetation components. For *site factors* we refer to environmental parameters such as altitude, aspect, slope, soil parameters, etc.

Essential features of forest biodiversity can be identified for which the use of NFI data is more relevant to calculate biodiversity indicators (Winter et al., 2008): forest categories, forest structure, deadwood, tree and forest age, ground vegetation, natural forest, regeneration.

Definitions of Forest Biodiversity Essential Features

54. Forest categories ☺

A forest category is "a category of forest defined by its composition, and/or site factors (locality), as categorised by each country in a system suitable to its situation." (The Montreal Process, 2007).

Forest category (or forest types) classification systems are a flexible approach to collect and organise forest information according to a typology that is useful for understanding differences in forest biodiversity indicators (Barbati et al. 2007).

For *forest* we refer to the adopted reference definition 24 from WG1. For *composition* we refer to current species composition of trees, shrubs and other vegetation components. For *site factors* we refer to environmental parameters such as elevation, aspect, slope, soil characteristics, etc.

A scheme for a standard classification of forest types at European level was proposed by the European Environmental Agency (2006). The category level of that system (14 European forest categories) was adopted by WG3 of COST Action E43 as a reference.

55. Forest structure ☺

The forest structure relates to the physical organization of the forest elements described in terms of composition and complexity. It is the combination of three components: tree species composition, horizontal forest structure and vertical forest structure.

56. Dead wood ☺

For dead wood we consider the volume (over bark) of all above-ground parts of dead woody plants.

It does not include dead parts attached to living plants or litter. The distinction between dead wood and litter is defined on the basis of decay stages. When dead wood is more decayed than the most decayed class, it is no longer a part of dead wood and becomes a part of litter.

This reference is independent from the dimensional definitions of dead wood pieces but at the moment can be considered equivalent to reference 37 from WG1.

57. Tree age ☺

The tree age is the time in years elapsed since the germination of the seed, or the budding of the sprout or cutting from which the steam tree developed.

58. Forest age ☺

Forest age is based on the age of the trees that are part of the forest.

Since forest age is interesting to evaluate the level of potential biodiversity of the forest or the ecological distance from old growth condition, it is generally calculated on the basis of the tree age of the oldest trees. Two indicators were defined to quantify forest age: (1) dominant age, (2) stand age.

59. Dominant tree age ☺

The dominant tree age is the mean tree age of the one hundred tree with the largest dbh on an hectare of forest area.

60. Stand age 😐

The stand age is the mean age of the dominant trees per hectare of forest area.

A dominant tree is an individual tree steam of the upper layer of the canopy (Helms 1998).

61. Ground vegetation ☺

Ground vegetation comprises all plants excluding tree species.

Ground vegetation is characterised by the following layers categories:

1. Shrub layer: layer including ligneous plants >0.5 m and lower than 5 m. It can comprise regeneration (seedlings and saplings), shrubs and climbers. Palms shrubs are also included.
2. Herb layer: all non-ligneous and ligneous <0.5 m; layer can comprise shrubs, herbs, ferns.
3. Bryophyte layer: all bryophytes and lichens growing on the ground.

Shrub is woody perennial of a species typically not forming a single main stem and not having a definite crown.

Herbs are non-woody vascular plants, which die when they have fruited (annual) or those which stems die but parts of the plant survive under or close to the ground (biennial or perennial).

Ferns are seedless vascular plants classified in the division of Pteridophyta.

Bryophytes are nonvascular, terrestrial green plant, including mosses, hornworts, and liverworts (National Vegetation Classification Standard, 1997, Vegetation Classification Standard).

Lichens are organisms consisting of a symbiotic association of a fungus with a photosynthetic partner.

62. Natural forest ☺

A natural forest has only vegetation native species and has no human disturbances. Naturalness is measured on a scale ranging between primary virgin forests and artificial forest plantations with non-site native species.

Without human impact means without visible/detectable/measurable human impact on the composition, structure and functions of the forest.

Index