Chapter 1
Introduction

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1.1 Background

For millennia, forests have been a strategic resource for mankind, providing building material for houses, ships, and mining; household and industrial fuel; hunting grounds and grazing opportunities for cattle. Despite its strategic importance, forest management was often not sustainable. Many European countries have a long history of deforestation and overexploitation of forest resources. North America has also seen substantial deforestation since European colonization. The principles of sustainable forest management were formulated around 1700 by Von Carlowitz in Germany (1713). Centuries later the concept of sustainability became popular under the term "sustainable development" as coined by the Report of the World Commission on Environment and Development: Our Common Future, also known as the Brundtland report (http://www.un-documents.net/our-common-future.pdf). On larger scales, around 1990 with the meetings of the Ministerial Conference on the Protection of Forests in Europe (MCPFE, now known as Forest Europe) the

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principles of sustainable management were established as guidelines for the stewardship of forests as natural resources. At national and regional scales, the idea of sustainable wood supply was the basic principle behind forest management and the restoration of forests in Europe since the middle of the nineteenth century. Many European countries have seen an expansion of their forest areas in the past 100–150 years due to active afforestation and natural expansion of forests on waste lands and marginal agricultural lands (Mather 2001). This phenomenon has also been observed in the southern United States of America (USA) during the period 1935–1975 by Rudel (2001) who describes how smaller yields on marginal agricultural lands led to conversion of these lands to forest.

Concerns about possible shortages of wood and overharvesting were major reasons that many countries began implementing forest resource monitoring systems. The first nation-wide assessments were initiated in the early twentieth century, mostly in Northern Europe. Additionally, many countries established research trials to investigate growth and yield in relation to forest management, resulting in the production of yield tables for the most commonly used tree species. These yield tables were an important tool for assessing forest productivity and harvesting possibilities, mostly at the stand scale. As a logical next step, governments and industries asked for projections of future wood availability and allowable harvest levels. In response, many countries developed projection systems that featured a wide array of mostly country-specific tools, models and simulators.

Over recent decades, societal appreciation has increased for the many functions and services that forests provide: nature conservation, recreation, protection of infrastructure and protection of soil and water resources. However, demands for these functions and services sometimes conflict with the wood production function and, therefore, must be included in studies on potential wood supply.

The situation with respect to forests and forestry within Europe varies enormously. Forest cover ranges from 1.9% in Iceland to 76% in Finland. Countries with large forest areas generally have well-developed forest industries, while the focus in countries with relatively little forest is more on conservation and recreational use. A large array of forest management systems is used, including the traditional clear-fell and replant system, shelterwood systems, group-and individual tree selection systems, coppicing and strict nature reserves. The number of tree species in the boreal zone is limited, but is much greater in mid-and southern Europe. Western European countries with little forest cover often have active forest area expansion policies, while area expansion in southern and eastern countries occurs spontaneously on abandoned agricultural lands.

Since the beginning of the twenty-first century, climate change has been considered the most important environmental issue in many European and North American countries. While forests are thought to be impacted by future climate change, at the same time they are seen as part of the solution. Forests play an important role in the global carbon cycle. Large quantities of carbon are exchanged every day between forests and the atmosphere, and large amounts of carbon are stored in biomass, soil and wood products. Among the six economic sectors identified by the United Nations Framework convention on Climate Change as sources of anthropogenic greenhouse gas (GHG) emissions, the Land Use, Land Use Change and Forestry (LULUCF) sector is the only terrestrial sector with the potential to remove GHG emissions from the atmosphere. Besides acting as a carbon sink, wood products can substitute for energy-intense materials such as aluminium and concrete and can easily be recycled. When used for generating energy, woody biomass can replace fossil fuels such as gas or coal. If sourced from sustainably managed forests, wood can be regarded as a renewable resource that contributes to reducing fossil carbon emissions.

European countries have adopted ambitious renewable energy standards with the aim of providing 20% of total energy consumption by 2020 from renewable resources of which 40–50% is expected to be delivered by bioenergy (Muys et al. 2013). The proposal for increasing the use of wood in strategies for mitigating the impacts of climate change raised the question of wood availability in Europe. Currently, the European annual harvest is about 66% of the annual increment (FOREST EUROPE 2015), theoretically indicating the possibility for increased harvesting. However, it is questionable how much of this unused potential is really available because of multiple challenges such as fragmented ownership, conflicts with other forest uses, accessibility, economic constraints, and discrepancy between required and available species and dimensions. Projections using European level forest scenarios with different sets of constraints point to considerable deficits in wood supply by 2020 when compared to expected wood demand (Mantau et al. 2010). In recent years, the role and importance of woody biomass has grown steadily, resulting in large imports of wood pellets from North America (Goh et al. 2013).

Overall, the pressure on European and North American forests is rising. Wood demand is increasing due to developments in the bioenergy sector and also in the bio-economy sector which is expected to consume more biomass in the future. At the same time, forests are expected to fulfil a multitude of other functions. The impacts of climate change on forests are expected to range from increased growth due to higher temperatures and longer growing seasons to increased mortality due to changes in precipitation patterns, shifts in tree species' ranges and/or changes in disturbance regimes. Forest resource projections can be used to investigate these impacts and to provide insight into the consequences of intended future policies. In this book we provide an overview of available projection tools and assess the degree to which they can respond to the challenges posed.

1.2 Forest Resources in Europe and North America

In Sects. 1.2.1, 1.2.2, 1.2.3, and 1.2.4 unless otherwise noted, all European estimates are from the 2015 FOREST EUROPE report (FOREST EUROPE 2015), all Canadian estimates are from State of Canada's Forests report (NRC-CFS 2015), and all estimates for the USA are from a report on the Forest Resources of the United States, 2012 (Oswalt et al. 2014).

1.2.1 Forest Area and Forest Available for Wood Supply

In 2015, Europe excluding the Russian Federation had an average forest cover of 32%, the same percentage as in the USA in 2012 but less than the nearly 35% of Canada that is covered by forests. For environmental, economic and social reasons, not all forests are available for wood supply. Central-West and Central-East Europe are the regions with the greatest volumes of growing stock (8.8 and 7.9 billion m^3, respectively) and the greatest (94%) and least (70%) shares of Forests Available for Wood Supply (FAWS), respectively. European forest area is 215 million ha, of which 150 million ha is available for wood supply. In the USA, of the 310 million ha of forests, 29.7 million ha (9.6%) of forests are classified as "Reserves" where timber harvesting is legally prohibited. Canada has 347 million ha of forest and reports 59% of their forest to be minimally affected by human activities (primary forests). These areas include protected forests and inaccessible forests.

1.2.2 Afforestation and Deforestation Trends

In Europe, total forest area expanded by nearly 700 thousand ha per year between 1990 and 2015, while the area available for wood supply expanded by about 50 thousand ha per year in the same period. Afforestation of agricultural land unsuitable for agriculture is one of the policy objectives most frequently reported in FOREST EUROPE 2015. The report on the State of Canada's Forest 2015 indicates a decline in forest area of about 0.33% from 1990 until 2010, mostly as a result of forest land converted to agricultural and urban uses. Most Canadian forests originate from natural regeneration, although planting initiatives are underway for a small proportion of the total forest area. In the USA, after the severe deforestation observed in the period 1630–1910, forest area has not only stabilized but since 2007 has been trending upward at a rate of about 1% per year.

1.2.3 Growing Stock and Fellings

The average growing stock in Europe increased from 126 m^3/ha in 1990 to 163 m^3/ha in 2015. In 2015, the total growing stock was 35 billion m^3 of which 84% is available for wood supply. In the USA, the growing stock distributions of softwood and hardwood vary by region. In the Northeast and Southeast regions hardwoods comprise most of the timber volume (6.9 and 6.3 billion m^3, respectively), whereas in the Rocky Mountains and Pacific Coast (including Alaska and Hawaii) regions, softwoods comprise most timber volume (4.02 and 7.03 billion m^3, respectively). Overall, since 2007 softwood growing stock has experienced a modest increase of approximately 3% (15.5 billion m^3). Canada's most productive species are found in the

Pacific Maritime ecozone with an average growing stock of 432 m^3/ha, whereas the forests in the Taiga Shield and Hudson Plains ecozones have the slowest growing species with 61 m^3/ha and 36 m^3/ha, respectively.

The balance between Net Annual Increment (NAI)[1] and annual fellings is traditionally among the most frequently used criteria for assessing the sustainability of forests in Europe. According to the FOREST EUROPE 2015 report approximately 66% of the NAI is utilized by fellings. The greatest felling rates were reported for Austria (94%) and Sweden (102%), while the smallest rates were reported for Ukraine (29%), Turkey (37%) and Italy (39%). In 2010, increments amounted to 839.7 million m^3 and fellings to 582.3 million m^3. Between 1986 and 2006, growing-stock removals in the USA remained fairly stable and totalled 364 million m^3 in 2011. Softwoods accounted for 235.5 million m^3 (65%) of growing stock removals in 2011, and hardwoods accounted for 128.4 million m^3 (35%). In Canada, harvests are regulated by Allowable Annual Cuts (AACs) calculated for the provinces and territories and have been relatively constant since 1990s. In 2013, the total volume of timber harvested was 148 million m^3, only two-thirds of the AAC.

1.2.4 Ownership and Landowner Characteristics

About half of European forests are publicly owned, but the share varies from 3% in Portugal to 90% in some Eastern European countries. A little more than half the forest land in the USA (58%) is privately owned, while the remaining 42% is controlled by Federal, State, and local governments. Ownership patterns also vary across the country with private ownerships dominating in the Northeast and Southeast and public ownerships dominating in the Rocky Mountains and along the Pacific Coast. Conversely, only 6% of Canada's forests are privately owned. Canadian provinces and territories own 90% of the forests and have responsibility for ensuring compliance with forest management plans. The remaining 4% represents forest lands owned by the federal government (Natural Resources Canada 2016).

In Europe the number of private holdings has increased over time to 18% in the period 1990–2015, probably as a result of active afforestation on private lands in Western Europe, restitution and privatisation processes in countries with formerly centrally planned economies and fragmenting of properties at inheritance. The average size of private holdings is much smaller than the public holdings, with the majority of the private holdings less than 10 ha.

The USA has an estimated 11 million private forest landowners, the majority of whom own properties of less than 4 ha. However, 67% of forest land is in holdings of at least 40 ha, and 22% is in holdings of at least 4000 ha and is owned by less than 1% of the owners, primarily corporations or investment organizations and primarily managed for commercial purposes.

[1] The net annual increment is the average annual volume over the given reference period of gross increment less that of natural losses on all trees to a minimum diameter of 0 cm (*dbh*). (According to UNECE: http://www.unece.org/forests/fra/definit.html)

1.3 Production and Consumption of Wood in Europe and North America

Europe and North America are major producers of roundwood. Together they produce about 1 billion m^3 annually (Fig. 1.1), 35–40% of the world total. The majority of the removals are industrial roundwood (82%), while fuelwood accounts for only 18%. Felling levels in the USA and Canada have been rather stable since 1990, but the 2008 recession caused a reduction of more than 25% and felling levels have yet to recover. In Europe, the felling level gradually increased over time until the recession. Thereafter it mostly stabilised, but fuelwood increased from 80 million m^3 in 1990 to 131 million m^3 in 2013. Due to the increased demand for bioenergy in Europe, the USA and Canada substantially increased their exports of wood pellets in recent years.

For the period 2010–2030, the European Forest Sector Outlook Study II (EFSOS II, UNECE/FAO 2011) projects a doubling of wood-based energy demand as a consequence of the policy targets for renewable energy, while demand for products is projected to increase only by 5–10% in the same period. To fulfil the extra bioenergy demand from domestic sources, in addition to harvesting more stemwood, mobilisation of harvesting residues (tops, branches and stumps) must be increased enormously. Other potential sources of biomass are short-rotation coppices and trees outside forests. The supply can be further increased if more post-consumer wood is mobilized. However, increased dependence on imports is likely. The North American Forest Sector Outlook Study (NAFSOS, UNECE/FAO 2012) projects industrial roundwood to return to pre-recession levels for Canada, and to increase above those levels by 10–20% by 2030 for the USA. Fuelwood production in the USA until 2030 is projected to triple or even quadruple.

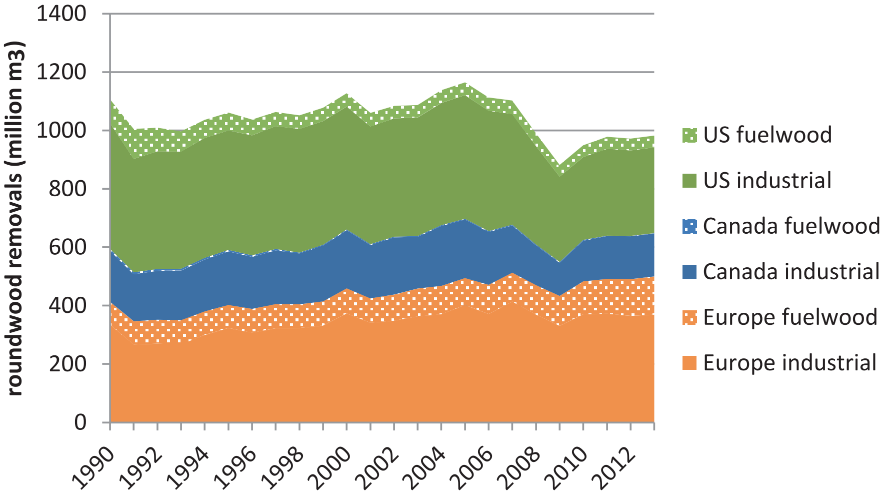

Fig. 1.1 Roundwood removals in Europe (excluding Russian Federation), USA and Canada for the period 1990–2013 (UNECE/FAO 2016)

Europe as a whole has been largely self-sufficient for the last 50 years, but there has been extensive trade in wood and wood products with other regions. The same is true for the USA, with domestic supply equal to 96% of industrial wood consumption (Oswalt et al. 2014). Canada is a net exporter of wood and wood products, with the USA as its largest trading partner followed by China (NRC-CFS 2015).

Harvest in Canada is mostly concentrated in the western parts of the country. In the USA, the harvest pattern has changed over time. While most wood was traditionally harvested in the Pacific Northwest region of the country, the Southeast is now the greatest supplier. Main harvesting regions in Europe are southern Sweden, southern Finland and the Baltic States, large plantations of *Pinus pinaster* in south-western France, plantations of Eucalypt in Portugal, and Central Europe where Norway spruce is an important commercial species.

1.4 Forest Inventory

Concerns for overharvesting produced the need for accurate information on the state of the forest and the rates at which the forest was growing and was being harvested. Forest inventory programs were established to satisfy this information demand. Early attempts at basic forest inventories had already been conducted by the end of the Middle Ages. The first forest inventories were local and aimed at assessing available timber resources for specific purposes. However, these inventories were not suitable for compiling information to assist forest policy and decision making at national levels. National-level inventories were started in the early twentieth century and have traditionally collected information about the status of the forest in terms of tree species composition, age class distribution and growing stock volume.

In the 1980s, the impact of air pollution on forests became evident. In Europe, forest health and crown condition monitoring networks were established on separate sampling grids, e g., Level I monitoring of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (known as ICP Forests, http://icp-forests.net). Moreover, the increasing significance of ecological functions of forests such as biodiversity required new monitoring concepts and studies. Thus, forest monitoring can be understood to cover all forest features beyond the target variables of traditional forest inventory with special emphasis on interactions between forest ecosystems and the environment. However, the separation between production-oriented forest inventories and environmentally-oriented monitoring programmes has become less distinct. The changing role of forests, combined with national and international reporting requirements, has altered the demand for forest information. In recent years ecological variables have been also included in traditional forest inventories, as well as variables aimed at quantification of carbon stocks and other forest functions.

Nowadays, nation-wide inventories are conducted in North America and in most European countries. In both Europe and North America, projection systems have been developed that rely on forest inventory data to characterize the initial state of the forest and often to develop and/or calibrate growth models around which the projection systems are built. Therefore, the detail and accuracy of the forest data generated by the inventory systems are crucial for the quality of the projections. Here we describe the two most commonly used methods for compiling nation-wide forest estimates: the Standwise Forest Inventory (SFI) approach and the sample-based National Forest Inventory (NFI) approach.

1.4.1 Standwise Forest Inventory

The idea of sustainability gradually emerged during the eighteenth century and finally led to the establishment of regular forest management. The theoretical and practical concepts of forest management planning were developed by the early German forest academics (e.g. Hartig 1795; Cotta 1804; Hundeshagen 1826). At that time, wood production was the main purpose of forestry. Management planning requires quantitative information on wood resources at the stand level in terms of growing stock volume and site productivity. Thus, the assessment of forest conditions was closely related to the elaboration of Forest Management Plans (FMP). Hence, management planning was established as an instrument to ensure sustainable utilization of forests, and Standwise Forest Inventory (SFI) was a basic principle for management planning.

Forest management implies the spatial division of forest areas into districts, compartments and stands. The area unit of an FMP inventory is normally the stand, which is considered to be reasonably homogeneous with respect to species composition, age, and site characteristics and is subject to specific management and silvicultural treatment. Standwise management is often closely linked to yield table-based assessments of growing stock, growth and yield. Hence, yield tables are also used for updating growing stocks without measurements. SFI includes a wide spectrum of methods ranging from visual assessment to sample-based surveys. The inventory cycle is normally 10 years; thus, every year about 10% of the forest area of an ownership is inventoried and the allowable cut for the subsequent 10-year period is calculated. Allowable cut is an implicit assessment of future wood supply at the stand level. Data obtained from standwise inventories, especially those based on ocular estimates, are regarded as less reliable than data from statistical inventories because they provide no estimates of uncertainty and may be subject to systematic deviations (e.g. Kangas et al. 2004; Haara and Leskinen 2009; Šmelko et al. 2008).

Small scale, stand-by-stand forest inventories were established in most European countries during the 19th and early 20th centuries. Depending on forest legislation, forest management planning was implemented in different manners according to ownership. FMPs were systematically implemented by the forest authorities, especially in state and communal forests.

Historically, forest management planning evolved differently in different regions of Europe. After World War II, most forests in the Eastern European communist countries were under state control. Forest management was subject to central planning which required a uniform forest management planning system to cover as much forest area as possible. In these countries, SFI became the basis for the preparation of FMPs for state forest enterprises (administrative units). Thus, forest authorities managed forests countrywide with uniform standards. Hence, it became possible to compile nationwide forest inventory data at the forest enterprise level for estimating total forest area. After the end of the communist era in the 1990s, centrally planned economies were abolished and economic and administrative structures changed substantially. Forests formerly under centralized state control were reprivatized, and organizational structures were adapted to include forest services. However, forest data continues to be stored in centralized databases under state supervision: Hungary, National Forestry Database NFD; Estonia, Forest Register FR; the Czech Republic, FMP database. Such databases are used to aggregate forest statistics at higher levels (regional units, national) and may be linked to other geo-referenced spatial data that provide additional information value, e.g., thematic maps of forest characteristics. With the political changes, responsibilities for implementing FMPs also changed to varying degrees among countries. In Hungary, state forest authorities are responsible for forest management planning as well as for supervision of forest management in private forests, whereas in Estonia, the state is only responsible for granting management planning licenses and only licensed companies are allowed to carry out forest management planning. In all cases, forest management planning instructions and rules are regulated by law and are under state inspection. Conversely, in other European countries, FMPs remain owner-specific instruments.

1.4.2 National Forest Inventory

National Forest Inventories (NFI) typically use systematic sampling designs based on grids placed over a forest map of the country and establish field sample plots at grid intersections with forest cover. The sample plots are usually in the form of concentric circles with fixed radii where smaller trees are measured only on the smaller radii circles. A few countries use variable radius sampling, also called angle count or Bitterlich sampling. Measurements on individual trees on sample plots always include tree species, diameter at breast height (*dbh*), and often additional variables such as height, log quality, and visual damage. Individual sample plots typically represent areas of 100–2000 ha, depending on the grid used. Methodologically, the advantages of NFIs are the uniform protocols applied nationwide which, in combination with proper quality assurance measures, provide consistent and comparable data. The statistical design allows use of unbiased estimators of totals and means for important forest attributes and uncertainty measures that facilitate calculation of confidence intervals. Another great advantage of NFIs is that they typically cover all lands that satisfy the country's forest definition, regardless of ownership or other cadastral categories. Data may be collected at defined intervals, often 5 or 10 years, although more commonly nowadays a proportion of plots are measured each year. Tomppo et al. (2010) provides a detailed description of NFI systems including ranges of grid dimensions, plot sizes and configurations, and minimum diameter thresholds characteristic of European and North American NFIs.

National Forest Inventories (NFI) were established in the early twentieth century in the Nordic countries: Norway in 1919, Finland in 1921, and Sweden in 1923. At that time forestry was a very important economic sector and there was a great need for information on the state and development of the forests as a natural resource at the national level. Other European countries followed after World War II. In the USA sample-based inventories date from 1928, although they were often implemented at state and regional levels which inhibited consistent and timely reporting across all states. However, in the 1990s the Forest Inventory and Analysis (FIA) program of the U.S. Forest Service standardized inventories with respect to plot configuration, sampling design, measurement protocols, and reporting requirements for the entire the country. Eastern European countries traditionally used SFI approaches, although recently NFIs have also been established in most of these countries; some countries maintain both inventory systems. However, for national and international wood availability studies the SFI data are still preferred as input data for projections.

1.5 International Reporting, Harmonisation Efforts and the Role of the USEWOOD Cost Action

NFIs have been the source of forest information for decades for purposes of assisting forestry and environmental planning, forest policy and industrial investment decisions. The desire to monitor the sustainable use of forests triggered the implementation of NFIs in central Europe (Tomppo et al. 2010). Deforestation, biodiversity losses, acid deposition, GHG emissions, and unsustainable forest management have all contributed to development of other monitoring programmes such as FOREST EUROPE (2015). Most European countries joined international treaties such as the United Nations Framework Convention on Climate Change (UNFCCC 2010) and the Kyoto Protocol and are obliged to monitor and report net carbon stock changes and GHG emissions by sources and sinks in the LULUCF sector. Over the years, good practice guidance documents have been prepared to assist countries in developing accurate and comparable inventories for the LULUCF sector. Notwithstanding, international reporting requirements revealed that the use of harmonized sets of definitions was required. For this reason considerable effort has been committed to developing methods for harmonized reporting in Europe. The European National Forest Inventory Network (ENFIN) has been the motivation underlying multiple European funded projects focused on harmonized reporting. These efforts have produced considerable progress that has motivated countries to voluntarily revise their definitions and their measurement protocols to minimize data differences resulting from different sampling designs, plot configurations, definitions and measurement protocols. Primary results have included development of common reference definitions and methods for producing harmonized estimates despite different national inventory features.

Recent renewable energy and climate change policies are expected to drive an increase in European consumption of wood for energy production. A reasonable question is whether European forests can sustainably produce sufficient woody biomass. Multiple studies on supply potentials have been carried out, but the approaches, terminology, constraints, assumptions and therefore the estimates and conclusions, vary considerably among studies. One difficulty in comparing results at the international level is that national definitions of wood categories vary widely because they depend on the species, the industry and the market. Simultaneously, a vast number of projection systems used for providing estimates of future wood availability have been developed in response to country-specific problems and national forest policy requirements. Some countries developed their projection systems; others adapted existing systems, while others rely on European simulators to carry out such analyses.

COST Action FP1001 (USEWOOD) facilitated research cooperation and coordination among European researchers focusing on NFIs, wood availability and projection of wood resources. USEWOOD included three Working Groups (WG): (1) WG1 focused on techniques for assessing and estimating the state of and changes in wood resources based on NFI data, definitions and harmonization; (2) WG2 focused on improving wood resources' estimates by integrating remotely sensed and NFI field data; and (3) WG3 focused on predicting the use of wood resources. The scope of WG3 included describing both the data used for projecting the potential supply of tree biomass under economic, social and ecological conditions and the different methods used. The descriptions will lead to clearer interpretations of projection results through a deeper understanding of the mechanisms behind the projections, their required inputs, underlying assumptions, scenario simulation capacity and limitations. Similar descriptions are also reported for data and methods currently used by Canada and the USA.

1.6 Organization of Book Contents

Part 1 of this book aims to synthesize current approaches for projecting wood availability with discussions ranging from the concept of wood availability to the challenges ahead. Part 2 includes a series of chapters describing the national approaches used in some European countries and North America (Fig. 1.2).

After the introduction (Chap. 1), Chap. 2 focusses on the concept of wood availability and the challenges in transferring forest inventory information to market availability. Chapter 3 provides descriptions of the types of growth models and additional simulation modules, how they are combined into forest simulators and their specific features. The chapter also presents an overview of the different projection systems described in more detail in the second part of the book. Chapter 4 describes the simulators that are currently used in Europe and discusses approaches for carrying out European-wide studies. Finally, Chap. 5 summarizes the driving forces affecting woody biomass availability and its projection, discusses the advantages and disadvantages of choosing each of the approaches described and the future challenges ahead.

Fig. 1.2 Map of Europe and North America showing country contributions in *dark grey*

References

Cotta H (1804) Systematische Anleitung zur Taxation der Waldungen. Johann Daniel Sander, Berlin

FOREST EUROPE (2015) State of Europe's Forests 2015

Goh CS, Junginger M, Cocchi M et al (2013) Wood pellet market and trade: a global perspective. Biofuels Bioprod Biorefin 7:24–42. doi:10.1002/bbb.1366

Haara A, Leskinen P (2009) The assessment of the uncertainty of updated stand-level inventory data. Silva Fennica 43(1):87–112. doi:10.142/4/Sf.219

Hartig GL (1795) Anweisung zur Taxation der Forste, oder zur Bestimmung des Holzertrags der Wälder. Heyer, Gießen

Hundeshagen JC (1826) Die Forstabschätzung auf neuen wissenschaftlichen Grundlagen. Heinrich Laupp, Tübingen

Kangas A, Kangas J, Heikkinen E, Maltamo M (2004) Accuracy of partially visually assessed stand characteristics: a case study of Finnish forest inventory by compartments. Can J For Res 34:916–930. doi:10.1139/x03-266

Mantau U, Saal U, Prins K, et al. (2010) EUwood - Real potential for changes in growth and use of EU forests. Final report. Hamburg, Germany: University of Hamburg, Centre of Wood Science. http://www.egger.com/downloads/bildarchiv/187000/1_187099_DV_Real-potential-changes-growth_EN.pdf. Accessed 5 July

Mather A (2001) The transition from deforestation to reforestation in Europe. In: Angelsen A, Kaimowitz D (eds) Agricultural technologies and tropical deforestation. CAB International, Wallingford

Muys B, Hetemäki L, Palahi M (2013) Sustainable wood mobilization for EU renewable energy targets. Biofuels Bioprod Biorefin 7:359–360. doi:10.1002/bbb.1421

Natural Resources Canada (2016) Forest land ownership. https://www.nrcan.gc.ca/forests/canada/ownership/17495. Accessed 15 July 2016

NRC-CFS, Natural Resources Canada, Canadian Forest Service (2015) The State of Canada's forests. Annual report 2015, p 76

Oswalt SN, Smith WB, Miles PD, Pugh SA (2014) Forest resources of the United States, 2012: a technical document supporting the forest service update of the 2010 RPA assessment, US Forest services, USDA

Rudel KT (2001) Did a green revolution restore the forests of the American South? In: Angelsen A, Kaimowitz D (eds) Agricultural technologies and tropical deforestation. CAB International, Wallingford

Šmelko Š, Šeben V, Bosela M, Merganič J, Jankovič J (2008) National forest inventory and monitoring of the Slovak Republik 2005–2006. National Forest Centre – Forest Research Institute, Zvolen

Tomppo E, Gschwantner T, Lawrence M, McRoberts RE (2010) National Forest Inventories Pathways for Common Reporting Springer Heidelberg ISBN 978-90-481-3232-4

UNECE/FAO (2011) The European Forest Sector Outlook Study II (EFSOS II). 2010–2030. UNECE/FAO, ECE/TIM/SP/28

UNECE/FAO (2012) The North American Forest Sector Outlook Study 2006–2030. UNECE/FAO, Geneva, ECE/TIM/SP/29

UNECE/FAO (2016) Forestry production and trade database. http://faostat3.fao.org/download/F/FO/E Accessed 15 July 2016

UNFCCC (2010) Report of the conference of the parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Part One: Proceedings http://unfccc.int/resource/docs/2009/cop15/eng/11.pdf Accessed 15 July 2016

von Carlowitz H (1713) Sylvicultura Oeconomica oder haußwirthliche Nachricht und Naturgemäßige Anweisung zur Wilden Baum-Zucht, Leipzig: Johann Friedrich Braun (2 Bände)