Chapter 5
Future Challenges for Woody Biomass Projections

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5.1 Understanding the Driving Forces Affecting Woody Biomass Availability and Its Projection

The importance of forests for satisfying social, economic, and ecological demands continues to increase. National Forest Inventories (NFIs) are the main tool for responding to the information requests related to these demands. National and international reporting obligations mirror these needs for information, but due to a lack of political coordination, NFIs use a huge variety of data collection protocols and reporting formats including non-matching terms and definitions. These circumstances characterize the challenges linked to international information requests for estimates of future wood and biomass supply.

Woody biomass supply information is crucial for the wood processing industry and for environmental policy makers. Decisions are made on several levels, from the local scale where the decisions on biomass supply are strongly determined by forest management, to the regional, national, and European scales where support is

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needed for forest and forest-related policies on issues such as bioenergy targets, incentives, and subsidy policies. The simplest and often requested approach is based on the assumption that recent Net Annual Increment (NAI) is the best parameter for estimating future wood and biomass supply; however, this approach can be misleading (Chap. 2). Although it has been common knowledge in forest management planning for more than 100 years that NAI is just one among several variables for estimating future wood supply, conveying this knowledge to the decision makers outside the expert community has been challenging. Obviously, the driving forces that cause major deviations between NAI and the future supply are very complex and interlinked, and an exhaustive study is necessary to understand them fully.

First, a sound definition and a procedure for estimating the area of Forests Available for Wood Supply (FAWS) is important. The latest State of European Forests Report clearly showed that a definition for FAWS with a commonly accepted interpretation is still lacking (FOREST EUROPE 2015; Vidal et al. 2016; Alberdi et al. 2016). Some European countries have a small area of FAWS when compared to the total forest area. For example, in Bulgaria the share of FAWS is only 58% of total forest area. Other countries such as Switzerland consider nearly all forests as FAWS and report a share of 97%. It is unlikely that these deviations originate from actual differences in the structure of the forest. At least a portion of the deviations can be attributed to differences in the national definitions. The land use class FAWS is not used in the United States of America (USA) or Canada, although the concept is expressed in other land use classes. In the USA, one criterion for the land use class characterized as timberland is that these lands must not be withdrawn from timber utilization. More than 210 million ha (60%) of the 330 million ha of forest land in the USA is classified as timberland of which 70% is in private ownerships (Oswalt et al. 2014). In Canada, more than 234 million ha (56%) of the 417 million ha of forested territory is classified as commercial forest, nearly all of which is in public ownerships and of which 0.4% is annually harvested (Natural Resources Canada 2015). For future projections we must acknowledge that any FAWS estimate might change over time due to nature protection measures on one hand, and to forest road building in remote and previously inaccessible areas on the other hand.

Multiple factors influence the potential future woody biomass supply. Classical influences are the distributions of age and yield classes which are included in all national projection systems (Chap. 3). In addition, differing ownership structures and differing management regimes among different categories of forest owners affect the future supply. Although most projection systems recognise different ownership classes, it remains a challenge to model the behaviour of owners, especially small private owners. Also, market behaviour on both the demand and supply sides resulting from external influences (e.g., small forest owners or economic crisis) affect wood prices and harvest costs which, in turn, might be influenced by changes in harvesting technologies. However, there are only a few national projection systems that are able to estimate harvesting costs, and even fewer that are actually coupled to a market model that includes future demand and trade (Chap. 3). Because forest growth and development are strongly linked to climate conditions, climate change could be considered a source of variability over time. The effects of future temperature and precipitation changes are relatively easy to handle in modelling, whereas the potential for increasing storm and fire events are more difficult to accommodate in a scientifically robust manner. However, at the moment most national projection systems do not include direct effects of climate change on tree growth (Chap. 3). Empirical models are not very reliable for predicting future interactions between soil and climate variables for which there are no historical observations. Process-based models would be more suitable for such a task, but so far only Netherlands reported the use of a process-based model (see Chap. 20). Nevertheless, application of country-wide projection systems based on eco-physiological models is particularly demanding because these models often require a wide range of soil and climate data that are not available for the locations of inventory plots that serve as the source of most other input data. Finally, tree species composition changes in response to changing climate should be included in long-term wood supply projections. Although many projection systems allow replanting with other species after final felling, almost none of them model natural regeneration under a changing climate (Chap. 3).

Although the foregoing list of influences on future wood supply is not complete, the challenging character of the mission to include all these effects and their interrelations in the political discussions is bold and demanding. Even for experts, inclusion of all these driving forces into tools for estimating future woody biomass supply is challenging. Therefore, the preferable approach is to focus on scenario analyses under defined conditions rather than simple growth and mortality predictions.

5.2 Woody Biomass Scenario Analyses

Approaches to scenario analyses are quite diverse in both Europe and North America. One reason is that countries individually choose which of the previously mentioned factors to include in or exclude from their projection systems (see also Chap.3). Often the main forces driving the choices can be traced to the motivation for the tool development and/or to the types of growth models and additional modules (e.g., modules for the simulation of forest management or disturbances) available in each country. For instance, in some countries projection systems emphasize future forest carbon stocks in response to Kyoto Protocol commitments (e.g. Iceland, Italy, Canada), whereas in other countries the tools were primarily developed to project wood availability for industry and were only later augmented to estimate biomass available for bio-energy and carbon stocks (e.g. Finland, Sweden, Portugal).

Another source of differences is climatic gradients that are evident from northern to southern Europe. One result is that northern climatic conditions inhibit the greater diversity in forest types and ecosystems that occur naturally in the south of Europe. Thus, whereas the Nordic countries have been able to develop advanced tools for simulating scenarios for their forests, the much greater complexity of southern European forests has often precluded development of similar tools. Therefore, approaches that include all forest ecosystem varieties are often lacking at the country level for these regions. For example, in Spain as many as 175 different tree species are assessed by the NFI, of which 30 cover a significant share of the total forest area (see Chap. 24). Such complexity has led to the development of stand level simulators for the most important tree species in specific regions of the country. If national estimates are needed, simpler approaches albeit with greater uncertainties are possible solutions.

Approaches to European forest management also differ with a general trend featuring more clear-cutting in the north and more coppice forests in the south. Superimposed on this trend are previous east-west differences in political systems that strongly affect approaches to both forest management and monitoring. Some eastern countries continue to use stand-wise forest inventories as the basis for forest management plans and as the source of data for input to projection systems that usually make projections based on NAI (Chap. 3).

The large range of environmental conditions for natural forest development and approaches to forest management throughout Europe has produced a tremendous variety of general approaches and methods for wood and biomass resource scenario analyses and interpretations of the results. The challenge of how to obtain the best pan-European estimates can be met in several ways (Chap. 4). Depending on the harmonisation strategy, approaches can range from a pure "bottom-up" approach, accommodating all differences in natural and socio-economic conditions and using only national tools, to a "top-down" approach, ignoring much of the natural and socio-economic variability, and using a centralised methodology based on NFI data and a common tool, producing comparable results.

These two approaches are linked through the trade-off between the most accurate descriptions of national and regional conditions but with little comparability among country results when using the "bottom-up" approach, or greater comparability of results but disregarding the topographic, climatic, vegetative and socio-economic conditions that are unique to countries and regions when using the "top-down" approach.

In North America, both Canada and the USA are large countries that span the continent and, therefore, have large numbers of biomes, each of which represents a different combination of topographic and climatic conditions and each of which is dominated by different forest types. Thus, construction of a single, all-inclusive projection system that would encompass the entire scope of these conditions would be nearly impossible. The two countries take somewhat different approaches to resolving this difficulty. In Canada, nearly all the commercial forest land is in public ownerships, and the provinces and territories have responsibility for managing these lands. One result is that management practices and policies and inventory programs vary considerably across the country, further compounding the difficulty of developing a common projection system. Canada's National Forest Carbon Monitoring Accounting and Reporting System (Kurz and Apps 2006), although national in scope, deals with biome differences by using provincial and territorial forest inventory data and growth and yield data to forecast future timber supply. In the USA, although most productive forest land is in private ownerships with potentially greatly varying management practices, all forest lands in all ownerships are covered by the country's nationally consistent inventory program. An important result is that nationally consistent data in a common format can be supplied to any projection system. The most widely used projection system, the Forest Vegetation Simulator (Crookston and Dixon 2005), uses these inventory data with a suite of biome-level growth and mortality models that are incorporated into a common software framework with a common user interface.

5.3 The Challenges

European countries use a large variety of approaches to model future woody biomass supply (Chap. 3). Even countries with similar ecological conditions have developed different approaches driven by differences in the economic importance of the forest sector, differences in the aims of the tools, and differences in inventory systems. As a basis, several steps could be taken towards harmonisation of national projection systems:

- Knowledge sharing to reduce the "noise" in different methodological approaches that are not based on different natural or management conditions
- Use of a common output format
- Harmonisation of the input and output variables for the national tools to the degree possible
- Use of a common general modeling structure and a common software structure
- Work towards common tools for countries with similar general conditions

In addition, all countries face similar challenges with respect to inclusion of climate change effects on increment and tree species composition, uncertain owner behaviour and modelling future demand of wood and wood products. Development of common approaches for these issues seems very useful. Such approaches need to be generic so they can be combined with different types of projection systems. Examples are the development of a method for integrating diverse owner behaviours into projection systems by Rinaldi et al. (2015), and the role of forestry mitigating the effects of climate change (Lundmark et al. 2014).

Despite attempts to better align the national simulators, there is a clear need for harmonised projections at the European scale. Several simulators have been developed that can produce such projections (Chap. 4). The challenge is to combine national data, expertise and modelling systems in a manner that maximises harmonisation. A prerequisite here is continued collaboration between national and European experts to exchange information on methods and assumptions that contribute to differences among approaches. A comparison between national and European simulators and projection studies would be a useful first step in this direction. Furthermore, projection systems in the USA and Canada may provide inspiration for solving some of the European issues with regard to the variety of ecological conditions that need to be covered.

Within the United Nations Economic Commission for Europe (UNECE), there is also the request to further harmonise projections between Europe and North America. It is unlikely that the same resource projection tools will be used for both continents, but current discussions focus on using the same global market models and harmonising economic scenarios between European and North American Forest Sector Outlook Studies (respectively EFSOS III and NAFSOS II). Another major challenge with respect to these studies is the inclusion of the Russian Federation in a comparable way.

Another challenge relates to "customization" of the results and information produced by different projection systems. There is often a lack of mutual understanding among supply side experts and demand side experts (i.e. wood industry) resulting in misunderstandings about availability of woody biomass (Chap. 2). The only way to overcome these communication problems is to work intensively together. The ITOC model (Inventory to Consumer biomass availability) (Mantau et al. 2016) is an example of a methodology for transforming forest inventory data to consumer biomass availability that facilitates the exchange of data among experts in different fields and increases mutual understanding.

Last but not least, estimation of the quality of information obtained from wood and biomass supply studies has not yet been rigorously or scientifically addressed. Global interrelationships among systems cause policy decisions to have all-embracing consequences. Policymakers decide on the policies to be implemented to meet stakeholders' objectives and preferences, while scientists are expected to assess the outcomes of alternative policies. In the case of woody biomass projection systems, the links, flows and relationships among all the elements comprising the system must be evaluated and the corresponding uncertainties must be assessed (Walker et al. 2003). Because simulation systems are composed of multiple modules (e.g. regeneration, growth, mortality) their complexities and the multiple error sources make uncertainty difficult to assess (Kangas 1999; McRoberts and Westfall 2014). One cause is that error propagates from trees to stands (e.g. Zhang et al. 1997; Cao 2006; Mäkinen 2010); a second cause is that uncertainty increases with greater prognosis length (Holm 1981; Kangas 1997); another cause is that deterministic projection systems force decision making to be based on mean predicted values but without appropriate knowledge of the risk (Fortin and Langevin 2012; Fortin et al. 2009; Antón-Fernández and Astrup 2012). Estimators based on likelihood or pseudo-likelihood functions (Lindstrom and Bates 1988; Wolfinger and O'Connell 1993; Pinheiro and Bates 1995, 2000; McCulloch and Searle 2001) facilitate accounting for the different error components, as well as the error structure within the sub-models that comprise individual-tree models. When coupled with a Monte Carlo approach, these estimators can simulate multiple error components and enable assessment of uncertainty related to the stochasticity of the processes. Multiple studies of the precision of growth projections have been conducted (e.g. Gertner and Dzialowy 1984; Mowrer and Frayer 1986; Gertner 1987; Mowrer 1991; Kangas 1997; Fortin et al. 2009; Fahlvik et al. 2014; Fortin et al. 2016). Unfortunately not all the projection systems described in this book have undergone similar analyses. However, the use of large-scale projection systems in decision-making processes, including the upcoming international negotiations on climate change, urge the importance of uncertainty assessment. In particular, the IPCC good practice guidance specify criteria related to both bias ("neither over- nor underestimates so far as can be judged") and precision ("uncertainties are reduced as far as practicable") (Penman et al. 2003). Sensitivity analyses have been performed for some tools, but a comprehensive approach that takes into account multiple sources of uncertainty is lacking. Such uncertainty analyses should start at the measurement level and include investigation of both sampling and modeling prediction errors. Finally, such analyses should also address whether the data and the models are adequate for the types of questions to be answered.

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