

Chapter 21

Norway

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21.1 Introduction

21.1.1 Forest Resources

Forest covers approximately 37% of the Norwegian land area. The most important tree species with respect to volume and economic value are Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula* spp.). For the 2007–2011 period, the Norwegian National Forest Inventory (NFI) estimated forest area to be 12.2 million ha, with annual volume increment under bark of 25.6 million m³.

Annual fellings have been relatively stable for the last 80 years (around 10 million m³/year), while mean annual increment has doubled during this period. This means that annual harvested volume is considerably less than the potential level, and potential harvest in Norway continues to increase each year. Thus, it is not surprising that current growth is now more than twice as what it was 80 years ago. Growing stock has increased significantly since the first Norwegian NFI, when the growing stock of the Norwegian forest was estimated at slightly more than 300 million m³ (reference year 1925), while the most recent inventory (2010–2014) estimate of volume under bark of Norwegian forests is approximately 920 million m³. This increase is due to better forest management and harvest levels that, over time, have been less than growth.

Approximately 80% of the forest area is privately owned, mainly by farmers who combine small-scale forestry with agriculture. Forest industry and private enterprises own only approximately 4% of the forest area, while the state and the municipalities own approximately 12%.

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Multiple reports have aimed at characterizing the local or national biomass supply situation in Norway (e.g. OED 1997; NOU 1998; Berg et al. 2003; Bernard and Bugge 2006; Vennesland et al. 2006; Hobbelstad 2007a, b; Langerud et al. 2007; Gjølshøj and Hobbelstad 2009; Tomter 2016a, b), but no countrywide projections have been reported on a regular basis. Most of the existing woody biomass resource projections are long-term projections based on the Norwegian NFI and conducted using forest scenario analysis tools such as GAYA [NorFor, SGIS] (Hoen and Eid 1990) and AVVIRK2000 (Eid and Hobbelstad 2000), with a focus on potential harvest (e.g. Eriksen et al. 2006). The last official countrywide projections for Norway were published in 2006 and were based on the eighth NFI (2000–2004). Although countrywide projections for Norway are not conducted on a regular basis, countywise projections are published on a 15-year cycle, which means that some of the projections are very recent and some are 15 years old. These projections use data from the temporary and permanent Norwegian NFI plots, and are long-term maximum sustained yield estimates.

21.1.2 NFI History and Data

The Norwegian NFI dates back to 1919. The first inventories (NFI1 and NFI2) used strip sampling; from 1957 until 1986 the NFI used cluster sampling with temporary plots; and from 1986 until 1993 circular, fixed-area, permanent sample plots were installed in all counties except Finnmark. Starting with the seventh NFI (1994[95]–1999), the NFI became a continuous forest inventory, with 20% of the plots remeasured each year (Tomter et al. 2010).

The first NFI was motivated by concerns related to forest resource development and thus, the main focus of the first inventories was economic exploitation of the forest. In recent inventories, the assessment of environmental values has been increasingly emphasized and now represents a central task for the NFI. Recently also a number of adjustments have been made to the NFI to facilitate carbon reporting for the LULUCF sector.

The NFI sampling design is based on a 3×3 km grid that covers all of Norway and includes about 12,000 plots lying within forest. Certain areas have smaller or larger sampling intensities than produced by the basic 3×3 km grid. Plots above the coniferous forest line are distributed using a 3×9 km grid. The northernmost county of Norway, Finnmark, has traditionally been excluded from the NFI. However, after the first inventory in Finnmark was completed in 2011, Finnmark has been included in the regular schedule of 5-year remeasurements. Most of Finnmark county uses a 9×9 -km grid, except for the coniferous forest area which uses a 3×3 -km grid. Starting in 2012, the protected areas have a greater sampling intensity than the rest of the country.

Detailed tree measurements are obtained for the 250 m² circular plots, while land use and stand characteristics are assessed for a 1000 m² area surrounding each plot.

21.2 Data

21.2.1 NFI Data Usable for Resource Projections

The main source of data for woody biomass resource projection is the NFI permanent and temporary plots. Both permanent and temporary plots are 250 m² circular plots. On each permanent plot all trees with at breast height (*dbh*) of at least 5 cm are measured and their species recorded. On plots with 10 or fewer trees, all tree heights are measured, while for plots with more than 10 trees a subsample is selected proportionally to basal area with a target sample size of 10 trees per plot. For the selected trees, information on damage, discoloration signs, crown color, and crown density is also collected. Stand density and species composition are assessed, among other variables, for a 1000 m² area surrounding the plot. For all trees on the 250 m² plot, *dbh*, species, status, position, and damage are measured. For each plot, other measures are also taken including distance to road, skidding distance, high accuracy GPS coordinates, and slope. Current site index is estimated for the dominant species at each plot in productive forest (annual yield capacity of at least 1 m³/ha of wood including bark), where site index is defined as the average height of the 100 largest trees per ha at age 40. At each re-measurement, treatments carried out in the past 5-year period are recorded. Possible treatments include final fellings, thinnings, selective cuttings, regeneration treatments, early stand tending treatments, drainage and pruning.

Total volume per plot is estimated as the sum of individual volume estimates for all trees with *dbh* of at least 5 cm. Individual tree volumes are estimated with species-specific, individual tree volume models with tree height and *dbh* as independent variables. For trees without measured heights, species-specific height models are used to estimate their basic height (H_{hc}). H_{hc} is then used to estimate the individual tariff tree volumes (V_{Hhc}). To account for differences in the diameter-height relationship between sites, V_{Hhc} is multiplied by a plot- and species-specific correction factor. The correction factor (tariff) is calculated using only trees with measured height as the ratio between the sum of the V_{Hhc} and the sum of the volumes estimated using the measured heights. The individual volumes in both the numerator and denominator of the correction factor are weighted to account for the unequal sampling probability originating from the selection of trees proportional to the basal area for height measurement.

Total biomass per plot is estimated as the sum of the individual biomass components (stump, roots, stem, bark, dead and living branches, and foliage) for all individual trees with *dbh* of at least 5 cm. Individual tree biomass is estimated using species-specific allometric models with tree *dbh* and tree height as independent variables.

21.2.2 *Other Statistical Information Related to Wood Resources and Use Wood*

The Statistics Norway (Norwegian statistics bureau) website (www.ssb.no) publishes information on growing stock (based on NFI), annual increment (based on NFI), roundwood removals, average price per m³ of industrial roundwood for sale, and commercial roundwood removals by assortment group, among other forestry statistics. Some of these data go back to the 1920s.

21.3 Methods

AVVIRK2000 is a deterministic simulation model for large-scale, long-term (100 years) forestry scenario analyses. AVVIRK2000 and its predecessor AVVIRK3 have been the main tools used for long-term management planning and forestry scenario analysis in Norway in recent decades. The time scope of the system focuses on strategic planning with projections made for a fixed period of 100 years, divided into 10 periods of 10 years. All treatments are considered as having occurred at the midpoint of each 10-year period.

Growth projections are based on the development of the “average tree”, i.e., the development of a tree with diameter at breast height equal to the basal area mean diameter (D_{ba}), and with height equal to the mean height weighted by basal area, also known as Lorey mean height, (H_L). The basal area mean diameter, also known as quadratic mean diameter, is calculated for each plot as the diameter of the tree of

average basal area, that is $D_{ba} = \sqrt{\frac{4BA}{N}}$, where BA is the plot basal area (e.g. 2 m²),

and N is the number of trees on the plot. The empirical models used to describe the state of the forest and stand dynamics in AVVIRK2000 are fitted with data from experimental permanent sample plots. The core of the growth model consists of three sets of models: diameter increment models (Blingsmo 1984), height development models (Strand 1967; Tveite 1967, 1976, 1977; Braastad 1977) and a mortality model (Braastad 1982). The volume of the “average tree” is estimated using models developed by Braastad (1966, 1974, 1980), Brantseg (1967) and Vestjordet (1967), and the volume per hectare of the stand is estimated as the product of the volume of the “average tree” and the number of trees per ha, N. In young stands, site index, age and number of future trees and tree composition are the basis for yield estimation. No volume or volume increment is estimated until the dominant height of the stand has reached 9 m. At this time, mean basal area is estimated according to Braastad (1975, 1977, 1982), and then “average tree” diameter and height are estimated.

Timber value and the proportions of pulpwood and saw timber are estimated using the Blingsmo and Veidahl (1992) models which use tree species, D_{ba} and H_L as independent variables.

Four harvest strategies are available: (1) a non-declining harvest path or net income path for the period of 100 years, (2) a user-defined harvest level or net income level for any number of 10-year periods up to 10, (3) a harvest path according to user-defined harvest ages for all stands, or (4) a harvest path according to removal of stands with relative annual value increment lower than a user-defined percentage. Several environmental restrictions such as an “ecologically orientated regime”, where no treatments are allowed until the forest reaches a user-defined maturity, can also be selected.

Because AVVIRK2000 estimates are based on the development of the “average tree” and the number of trees per ha, all results are at stand- or forest-level:

Forest-Level

- volume of fellings distributed by thinning and final cutting,
- volume of fellings distributed by tree species and assortments (sawlogs, pulpwood),
- income,
- regeneration cost,
- area distribution by site classes and development classes,
- volume distribution by site classes and development classes, and
- increment distribution by site classes and development classes.

Stand-Level

- volume, income, cost for cutting (thinning, clear cutting, seed tree cutting etc), regeneration, tending etc. for all treatments estimated in the stand for each 10-year period,
- state of the stand, for example, age, number of trees, tree species composition, mean diameter, mean height, volume, increment, etc.

In addition, for each forest/stand, the net present value is calculated as well as the soil expectation value for a newly established stand.

The most common biomass models for Norway are the Swedish models, Marklund (1987) and Marklund (1988) for the aboveground biomass and Petersson and Ståhl (2006) for belowground biomass. Although AVVIRK2000 does not estimate biomass, GAYA, a similar forest scenario analysis tool that uses the “average tree” approach, does estimate biomass using the Swedish individual tree models.

21.3.1 Value of the Timber

In AVVIRK2000 all prices and costs are assumed constant over time, i.e., the discount rate is a real rate, and it is defined by the user. Timber value is estimated using models (Blingsmo and Veidahl 1992) with tree species, D_{ba} and H_L of each estimation unit as independent variables. The models are standardized, i.e., the initial values are adjusted according to existing or assumed timber prices and assortment

distribution. The model also provides an option that permits the user to specify the timber value per m^3 for the stand, reflecting the timber value of all assortments in the stand jointly.

21.3.2 Costs

Variable costs can be determined according to manual or mechanized logging systems. The model handles clear cutting, harvests when seed trees or shelterwood are established and phased out, and thinnings. For both systems, the costs rely on variables such as tree species, D_{ba} and H_L , as well as variables such as transport distance and cost factors. The net present value of a silvicultural regime is determined by the cash flow originating from the estimated timber values and harvest costs, and from the costs for silviculture. Fixed costs (administration, planning, etc.) are included in the net present value.

21.3.3 Uncertainty

Up to now uncertainty analysis have not been part of any of the woody biomass projections for Norway.

21.3.4 Dissemination

The Norwegian NFI regularly reports on growing stock and biomass resources for the country as a whole, for regions (i.e. several counties), and for individual counties. Results for smaller geographical units than a county are usually not reported because the requirements for maximum standard errors may be violated due to the low numbers of sample plots.

21.4 Discussion

AVVIRK2000 growth projections are based on the development of the “average tree”. This means that the variability within and between stands with similar D_{ba} , H_L and number of trees per ha, is ignored. Furthermore, mixed-species stands are assumed to grow as if they were mono-species stands. The reality of the Norwegian forest is that uneven-aged stands with multiple species are not uncommon. Also, diversified tree structures including multi-layered canopies are not uncommon. Neither of these types of stands is correctly represented by the “average tree”.

As a result of Norwegian forestry history, the current area of over-mature forest is relatively small. Hence, over-mature forests are barely represented in the NFI data and in the datasets used to fit AVVIRK2000 models. Because the current woody biomass projections are made for a period of 100 years, and some areas are restricted from harvesting, estimates for some are extrapolations beyond the limits of the AVVIRK2000 growth models. Most over-mature forests in Norway are currently on low productivity sites, so gathering data on growth of very old stands that cover the wide range of forest conditions across Norway is difficult. An alternative to solve this issue would be establishment of international networks with the aim of sharing data on over-mature forest growth and yield.

Norway reports potential harvest levels. These potential levels do not reflect what might be realistically available in the market. For example, for the 2007–2012 period, the annual potential harvest was estimated to be more than 19 million m³, while the annual felling volume in Norway has been approximately 10 million m³ for the last 80 years.

Current published results lack any measure of uncertainty. Potential sources of uncertainty that could be considered include sampling variability, model prediction uncertainty, the effects of climate change on growth, mortality, and regeneration, and uncertainties related to owner behavior, economic parameters, and catastrophic events such as wind or fires.

A new framework for forest development scenarios, called “sitree”, is being developed in Norway. The new framework will include both new and old individual tree forest growth and yield models. The new framework will also include modules for estimating vegetation and soil carbon, and a module for life cycle analysis. The framework will allow for estimation of uncertainty through Monte Carlo simulations.

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