CERE

CERE Working Paper, 2015:5

# Increasing forest biomass supply in Northern Europe – Countrywide estimates and economic perspectives

Göran Bostedt, Mika Mustonen, Peichen Gong



SLU

UMEÅ UNIVERSITET

Department of Economics, Umeå University, S-901 87, Umeå, Sweden

www.cere.se

# Increasing forest biomass supply in Northern Europe – Countrywide estimates and economic perspectives

Göran Bostedt*
European Forest Institute, North European Regional Office, SLU, S-901 83 Umeå, Sweden, and
Dept. of Forest Economics, SLU, S-901 83 Umeå, Sweden, and
Dept. of Economics, Umeå University, S-901 87 Umeå, Sweden
Tel.: +46-90-786 5027, goran.bostedt@slu.se

Mika Mustonen
Natural Resources Institute Finland (Luke), P.O. Box 18 (Jokiniemenkuja 1),
FI-01301 Vantaa, Finland
Tel.: +358 29 5325450, mika.mustonen@luke.fi

Peichen Gong
European Forest Institute, North European Regional Office, SLU, S-901 83 Umeå, Sweden, and
Dept. of Forest Economics, SLU, S-901 83 Umeå, Sweden
Tel.: +46-90-786 8492, peichen.gong@slu.se

*Corresponding author

**Abstract**

Woody biomass is the largest source of renewable energy in Europe and the expected increase in demand for wood was the stimulus for writing this paper. We discuss the economic effects of biophysical capacity limits in forest yield from a partial equilibrium perspective. Opportunities to increase the supply of forest biomass in the short- and long-term are discussed, as well as environmental side effects of intensive forest management. Focusing on northern Europe, national estimates of potential annual fellings and the corresponding potential amounts, simulated by the European Forest Information Scenario model (the EFISCEN model) are then presented, as well as reported fellings. For the region as a whole, there seems to be substantial unused biophysical potential, although recent data from some countries indicate underestimated annual felling rates. There is a need to discuss strategies to ensure that demand for wood resources in northern Europe can be accommodated without large price increases. However, using a larger proportion of the biophysical potential in northern Europe than at present will entail trade-offs with environmental and social values, which means that strategies are needed to protect and account for all the benefits of all forms of ecosystem services.

Keywords: Forest biomass, biophysical capacity, intensive forest management, European Forest Institute

## Introduction

Besides being a source of raw material for the forest industry, in the future, forests are expected, increasingly, to contribute to the production of energy as well as providing a wide range of environmental and social services.

Woody biomass is by far the largest source of renewable energy in Europe, accounting for almost 50 % of the renewable energy consumption in the European Union (Pelkonen *et al.*, 2014). Projections in the European Forest Sector Outlook Study II (UN 2011) indicate that if wood is to play its part in reaching renewable energy targets, the supply of woody biomass in Europe would have to increase significantly: by 2030 the annual supply must increase by nearly 50 %, or by more than 400 million $m^3$. The widely cited EUWood study's (Mantau *et al*. 2010) intermediate scenario estimates a 73% increase in forest biomass demand and a gap of 316 million cubic meters in 2030. On the other hand, studies taking into account recent structural changes in forest product markets, international trade, and market price adjustments according to economic theory project that the demand for forest biomass in the EU could be significantly lower than this (Solberg *et al*. 2014). However, the shift towards a post-petroleum bioeconomy-based society can be expected to boost the demand for wood as a raw material. Hence, as an example, although the future of graphic papers is bleak, the board and packaging segment of the paper industry – supported by trade, internet shopping, urbanization, the need to store food properly, and energy prices – is generally considered to have a better future (e.g., Donner-Amnell, 2010).

The stimulus for writing this paper[1] is this expected increase in demand for wood. EU countries all aim to reduce emissions of greenhouse gases. These targets are known as the "20-20-20" targets and state that the EU should: reduce greenhouse gas emissions from 1990 levels by 20 %, raise the share of EU energy consumption produced from renewable resources to 20 %, and improve the EU's energy efficiency by 20 % by 2020. This implies that energy intensive sectors in northern Europe that are able to move away from non-renewable fuels will probably do so. This potential increase in demand for wood to be used in energy production is of great interest to forestry and forest industries in northern Europe, due to its impacts on sales income from forestry, wood prices, and rural employment.

[1] Which is based on Jonsson *et al*. (2013).

Given the expected increase in demand, an important issue is whether this can be met without sharp increases in roundwood prices. Ultimately, forest growth is limited by its biological production potential, controlled by the availability of light, water and nutrients and based on where the boundaries on a given site are. Within this framework, forest owners will manage forests to maximize their benefits, given the limits set by society to safeguard non-timber values.

The aim of this paper is to discuss the economic effects of biophysical capacity limits on forest yield from a partial equilibrium perspective, and to present, for countries in northern Europe, a compilation of previous estimates of these biophysical limits. The intention is to clarify what role these biophysical limits play in northern Europe, and to determine the need to increase harvest potential in the region. Our analysis focuses on the interaction between forest growth, harvest and prices given the current economic and political situation.

The geographical scope of this paper is the countries in northern Europe, i.e. Denmark, Estonia, Finland, Germany, Iceland, Ireland, Latvia, Lithuania, northwest Russia, Norway, Poland, Sweden and the United Kingdom (UK).

The next section includes general data pertaining to the countries in northern Europe, e.g. data on forest area, growing stock, annual increment and final fellings. We also present data on the use of renewable energy. In section 3 we then apply a partial equilibrium economics perspective to the question of forest yield capacity limits. Section 4 presents national estimates of potential annual fellings and the corresponding potential simulated by Jonsson *et al*. (2013) using the European Forest Information Scenario model. In the final section of the paper, we discuss the differences between potential and actual fellings and the extent to which increases in demand for wood resources in northern Europe can be accommodated within the region without large price increases.

## Forest resources and forestry in Northern Europe

The region under focus in this study has a total forest area of 182.3 million hectares, almost half of which is found in northwest Russia. The average growing stock per hectare is 134 $m^3$. It is worth noting that only Sweden reports annual fellings that exceed 80 % of the annual increment (Table 1). However, data on both annual increment and annual fellings from several countries may be unreliable. For instance, forest growth in forest reserves that is not harvested may be left out of estimates of annual increments for some countries.

Table 1: Forest area, growing stock, increment and felling: estimates for 2010.

| | Forest area (mill. ha.) | Forest area available for wood supply (mill. ha.) | Growing stock (mill $m^3$ OB) | Growing stock per hectare ($m^3$) | Annual increment (mill. ha.) | Annual increment/ growing stock (%) | Growth per ha and year ($m^3$) | Annual fellings (mill. $m^3$) |
|---|---|---|---|---|---|---|---|---|
| Denmark | 0.6[1] | 0.6[1] | 113.4[1] | 199[2] | 5.8[1] | 5.1 | 10.0[5] | 2.4[1] |
| Estonia | 2.2[1] | 2.0[1] | 441.4[1] | 203[2] | 11.2[1] | 2.5 | 5.6[5] | 5.7[1] |
| Finland | 22.1[1] | 19.9[1] | 2207[1] | 99[2] | 91[1] | 4.1 | 4.6[5] | 59.4[1] |
| Germany | 11.1[1] | 10.6[1] | 3492[1] | 315[2] | 107[1] | 3.1 | 10.1[5] | 59.6[1] |
| Iceland | 0.03[1] | 0.03[1] | 0.45[1] | 15[2] | 0.02 | 4.4 | NA | NA |
| Ireland | 0.7[1] | NA | 74.3[1] | 101[2] | 5.4 | 7.3 | NA | 2.8[1] |
| Latvia | 3.4[1] | 3.1[1] | 633[1] | 189[2] | 25.3[7] | 2.0 | 5.0[5] | 12.4[1] |
| Lithuania | 2.2[1] | 1.9[1] | 479[1] | 218[2] | 16.0[1] | 3.3 | 5.7[5] | 8.6[1] |
| Norway | 10.2[1] | 6.4[1] | 997[1] | 98[2] | 21.9[1] | 2.2 | 3.4[5] | 11.0[1] |
| Poland | 9.3[1] | 8.5[1] | 2304[1] | 219[2] | 70.0[6] | 3.0 | 8.0[5] | 40.7[1] |
| NW Russia | 89[3] | NA | 10096[3] | 114[3] | 134[3] | 1.3 | 1.5[3] | 46.9[4] |
| Sweden | 28.6[1] | 20.6[1] | 3243[1] | 119[2] | 96.5[1] | 3.0 | 4.7[5] | 80.9[1] |
| UK | 2.9[1] | 2.4[1] | 379[1] | 132[2] | 20.7[1] | 5.5 | 8.6[5] | 10.5[1] |
| Total | 182.3 | - | 24 459.6 | - | 591.9 | 2.4 | - | 340.9 |

Sources: [1]UNECE % FAO (2010), data are estimates made by each respective country for 2010, based on averages for 2008 and 2009. [2]FAO (2010), data are estimates made by each country for 2010. [3]Karvinen et al. (2011), compilation of data in regional plans with reference years 2008 to 2010 except for the Leningrad and Pskov Regions 2003. [4]Rosleshoz official statistics (reference year 2010). [5]UNECE & FAO (2011), data are estimates made by each respective country for 2010. [6]Gerasimov (2013), reference year 2011. [7]UNECE & FAO (2011b), estimate by country for 2010, based on average for 2008 and 2009.

On average, 75 % of the forest land in the region is conifer-dominated. However, on the southern boundary of the area, i.e. in the UK, Denmark, Germany, and the Baltic countries (Estonia, Latvia, and Lithuania), the broadleaved share of the forest is between 40 and 50 % (FAO 2010). Exotic tree species generally comprise small proportions in the region, but are not uncommon in Denmark, Iceland, Ireland and the UK.

The typical ownership pattern in the region is that the majority of the forest area is publicly owned, mainly due to the fact that public ownership is extremely high in Russia, but also in Poland and Lithuania. Other countries with more than 50 % of the forest in public ownership are Estonia, Latvia and Ireland. The privately owned forest land is mainly held by small non-industrial forest owners, except in Sweden and Finland, where large forest companies own large parts of the private forest land.

Directive 2009/28/EC defines the accounting criteria and 2020 targets for the share of energy from renewable sources in terms of *gross final consumption of energy* for each Member State. The states are, however, allowed independently to define the renewable sources consumed and the promotion measures used to achieve the targets. The starting point and target figures vary significantly by country (Table 2). Those that have the furthest to go before they reach their 2020 renewable-energy target – i.e., the need to increase the share by approximately 10 percentage points or more – are the countries situated in the Atlantic part of northern Europe: the United Kingdom and Ireland. Estonia and Sweden have already achieved and exceeded the defined target, with Lithuania close to reaching the target. For Sweden, where around one third of renewables consists of hydro power, the set target is the highest for the EU member states: almost half of its gross final energy consumption should be covered by renewable energy. For Latvia, this share is 40% and for Finland 38%. In Norway the national target for renewable energy is two thirds, and around 90 % of the renewables is accounted for by hydro power (Eurostat).

Table 2: Share of renewable energy in gross final energy consumption for north European countries (2004-2012)

| Area / State | 2004 | 2006 | 2008 | 2010 | 2011 | 2012 | Target 2020 | Need to be increased 2020/2012, % |
|---|---|---|---|---|---|---|---|---|
| EU (28) | 8.3 | 9.3 | 10.5 | 12.5 | 12.9 | 14.1 | 20 | 6 |
| Denmark | 14.5 | 15.9 | 18.6 | 22.6 | 24.0 | 26.0 | 30 | 4 |
| Germany | 5.8 | 7.7 | 8.5 | 10.7 | 11.6 | 12.4 | 18 | 6 |
| Estonia | 18.4 | 16.1 | 18.9 | 24.6 | 25.6 | 25.8 | 25 | |
| Ireland | 2.4 | 3.1 | 4.0 | 5.6 | 6.6 | 7.2 | 16 | 9 |
| Latvia | 32.8 | 31.1 | 29.8 | 32.5 | 33.5 | 35.8 | 40 | 4 |
| Lithuania | 17.2 | 17.0 | 18.0 | 19.8 | 20.2 | 21.7 | 23 | 1 |
| Poland | 7.0 | 7.0 | 7.8 | 9.3 | 10.4 | 11.0 | 15 | 4 |
| Finland | 29.2 | 30.1 | 31.3 | 32.4 | 32.7 | 34.3 | 38 | 4 |
| Sweden | 38.7 | 42.6 | 45.2 | 47.2 | 48.8 | 51.0 | 49 | |
| United Kingdom | 1.2 | 1.6 | 2.4 | 3.3 | 3.8 | 4.2 | 15 | 11 |
| Norway | 58.1 | 60.2 | 61.8 | 61.2 | 64.6 | 64.5 | 67.5 | 3 |

Iceland: Not available

Data source: Eurostat

Given the targets, an increased use of woody biomass for energy purposes can be expected in the near future; the extent to which woody biomass is used for energy purposes in the region today then becomes an interesting issue.

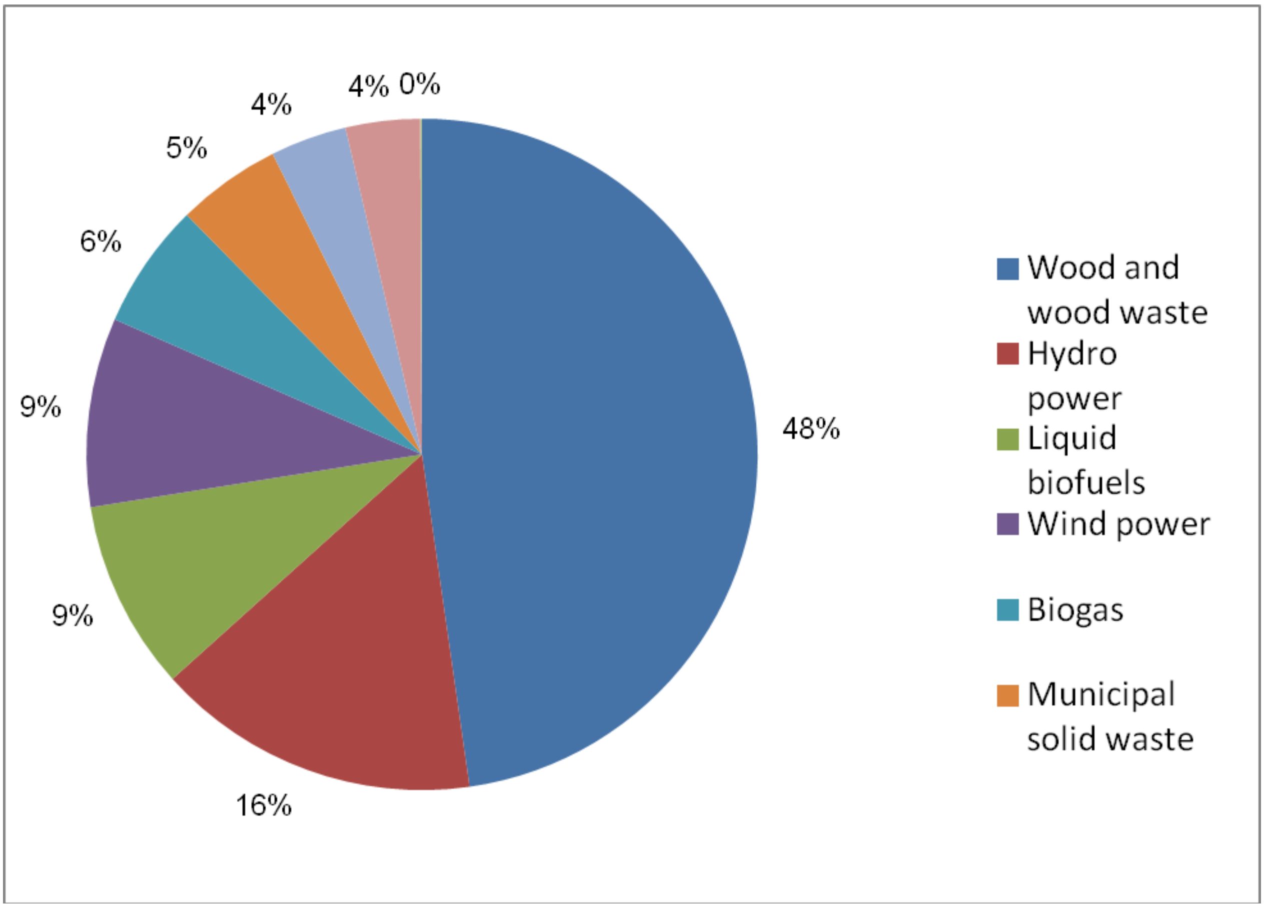


Figure 1: Share of renewable energy sources in gross inland consumption of renewable energy in the European Union (2011). Data source: Eurostat

According to Eurostat, the share of renewable energy in the *Gross inland energy consumption* of the EU Member States was approximately 10%, or 7,077 petajoules, in 2011. Since 2000, this share has increased by 4 percentage points. The most important source of renewable energy is wood fuel (wood and wood waste), which covered 48%, 3,378 petajoules, of the total consumption of all renewable energy in the EU in 2011 (Figure 1). Since 2000, the consumption of wood fuels has increased by more than 50%. Their share of all renewable energy has, however, simultaneously decreased by seven percentage points. This is due to the relatively higher rate of growth of other renewable energy sources (e.g. liquid biofuels, wind power, biogas and solar energy) (Pelkonen *et al.*, 2014).

The share of wood fuels as part of the renewable energy used by EU member states is presented in Figure 2. In 2011, the share of wood fuels within the national consumption of all renewable energy in the EU was most significant in some of the Baltic and Nordic countries. In Estonia, 95% of all renewable energy consumed consisted of wood fuels. The share exceeded 80% in Lithuania, Finland and Poland. Germany, which accounts for approximately one-seventh of the total EU consumption, is the largest single consumer.

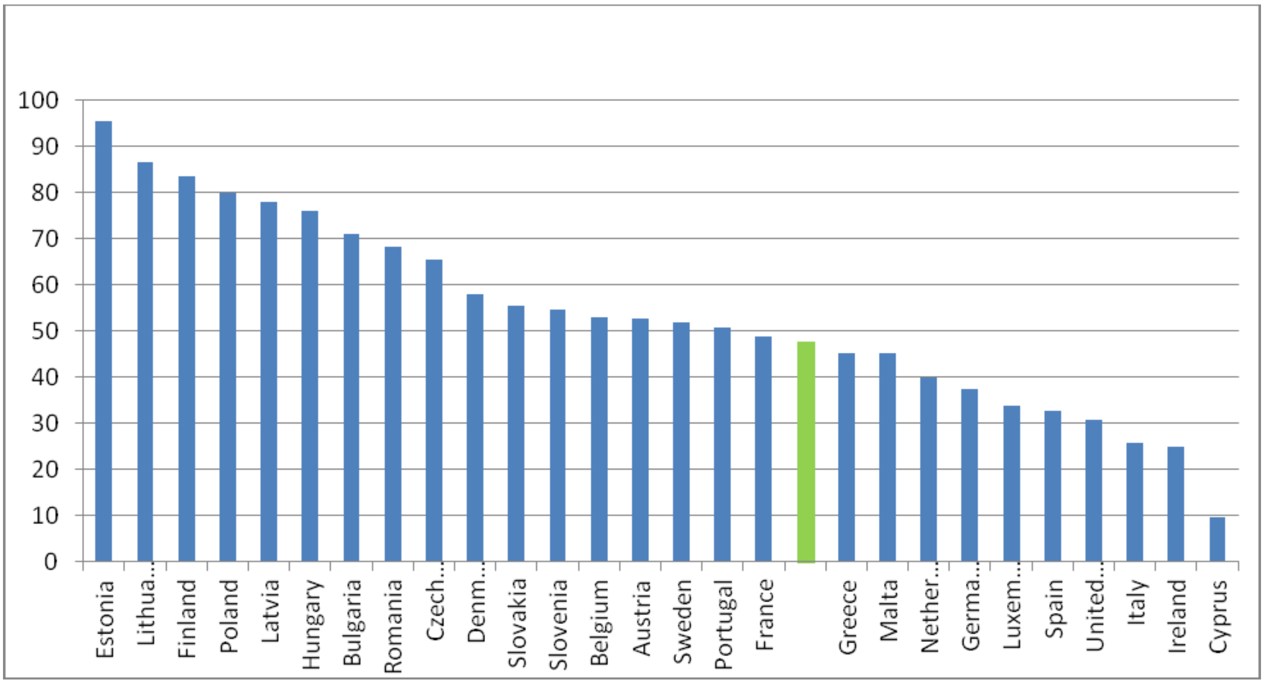


Figure 2: Share of wood and wood waste in gross inland consumption of renewable energy in the European Union (2011) by Member States. Data source: Eurostat.

## Theoretical aspects

If economics is ignored, biophysical capacity limits to forest yield are the only obstacle – one that has to be pushed to its limit if society's ambition is to increase the use of woody biomass for energy purposes. Applying a partial equilibrium economics perspective to the question of forest yield capacity limits, allows the issue to become nuanced.

The forest sector in northern Europe has been subject to a number of econometric analyses; some recent ones for Sweden include Ankarhem (2004) and Geijer *et al*. (2011). With respect to the demand and supply of forest products, the results of both these studies come to the same qualitative conclusion, that own price elasticities have the expected characteristics, i.e. the amount of a specific forest product (e.g. roundwood) landowners would like to harvest and supply to the market is increasing, and the amount demanded is decreasing, with respect to its own price. This econometric result is also confirmed in several similar studies from other countries with large forest sectors. Thus, we can fairly safely say that, in the neighbourhood of the equilibrium price and quantity, the supply function will be positively sloped and the demand function negatively sloped for roundwood price (see Figure 3), as microeconomic theory would predict. This means that, as demand for roundwood increases (meaning that the demand curve shifts upwards to the right), the equilibrium price and quantity will increase.

The increase in the harvest of roundwood encouraged directly by a price increase is achieved by increasing the harvest intensity in forests already managed for timber production and/or by extending harvest to previously unmanaged forest lands. In northern Europe (perhaps with the exception of Russia), unmanaged forests that could legally be used for timber production are typically found on marginal lands where timber production is not profitable because of poor soil quality or excessively high management and logging costs. An increase in timber price enhances the profitability of timber production in such forests, and hence leads to larger areas of forests being used for production; this has positive effects on the supply of forest biomass both in the short term and in the future. Increasing harvest intensity in currently managed forests can only result in a temporary increase in timber harvest, however. The reason is that, other things being equal, an increase in the harvest now will reduce the amount of timber available for harvest in the (near) future in these forests.

Timber harvest would also increase if the supply curve shifted downwards to the right. In contrast to the effect of increasing demand, an increase in supply (i.e. the supply curve shifts downwards to the right) will lead to a larger amount being harvested but attracting a lower price. The driving forces underlying the shift of the supply curve as well as the magnitude of the shift varies with the time frame under consideration. In the short term (so short that one cannot increase the total forest inventory), timber supply would increase if a sufficient number of landowners anticipate a decrease in future demand (and thus price) of timber. Given the background and the purpose of this paper, however, this possibility is excluded from further discussion. Liberalization of harvest regulations could also cause the short-term supply to increase, although the effect in the long run could be positive or negative. In general, harvest regulations are implemented to enhance the ecological services of forests and to secure sustained yield of various forest products. It is not a plausible option to increase timber supply at the cost of reducing the ecological services and the sustainability of forestry. Therefore, we will not discuss the potential of increasing supply through liberalization of harvest regulations.

A third possibility is to improve the accessibility and the profitability of timber production on marginal forest lands with the help of public support. This would result in an increase in the total land area used for timber production, and thus could increase the supply both temporarily and in the long run. The potential increase in supply through this measure depends on the area and quality of forests that are currently not used for timber production due to a lack of economic incentives.

A fourth possibility to increase supply in the short-term is to improve the recovery rate at forest harvest. Presumably, the potential effect of this option on timber supply is small. However, it could lead to a substantial increase in the supply of forest biomass because a somewhat large share of forest biomass was traditionally regarded as harvest residuals and was not used. The increase in demand for forest biomass for energy purposes would make it profitable for land owners to collect and sell harvest residuals (tops, branches and perhaps also stumps), which would lead to increased supply of forest biomass without increasing harvest intensity. The potential increase in supply is proportional to the amount of timber harvested, but is subject to restrictions of related regulations.

In addition to the two possibilities mentioned above (harvesting from marginal land and increasing the recovery rate at harvest), the supply of forest biomass could be further increased by increasing the total area of forest land (e.g. through afforestation of abandoned agricultural land) or by improving the productivity of existing forest land and forest growth, if a longer time period is considered. Either way, the full effects on the supply of forest biomass can only be achieved gradually over a very long time period. In other words, the potential for increasing the supply of forest biomass changes over time – the further in the future, the larger (and more uncertain) the potential increase is.

Within the EU 2030 framework for climate and energy policies, afforestation of abandoned agricultural land could result in increased supply of forest biomass if short-rotation energy forests are established. Other than applying fertilizer to mature stands, silvicultural measures aimed at improving the productivity and growth of forests are unlikely to have any significant effect on the supply of forest biomass within this time frame. Experiences from the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) show that fertilization of mature stands on mineral soils can increase stem wood growth by, on average, about 30% during a 10-year period. This means that in about 10 years the harvest of stem volume can be increased by 10-20 $m^3$ per ha in areas which are fertilized today.

In the long-run, many more options are available to increase forest growth and thus the supply of forest biomass. Examples include fertilization of young forests, tree breeding and the use of genetically improved seeds/seedlings in regeneration, and the introduction of exotic species. In Sweden, the average mean annual increment has increased by about 65% since the 1950s (from 3.1 $m^3$/ha/year during 1953-1957 to 5.1 $m^3$/ha/year during 2008-2012), which has allowed a steady increase in both the growing stock of timber and timber harvest. During this period, the total harvest increased by over 70%, while the total growing stock of timber increased by about 50%. These figures give some idea about the long-term potential increase in forest biomass supply.

There is a complex dynamic interaction between the increase in demand and increase in supply. Increase in demand leads to higher prices (at least temporarily), which in turn leads to more investment in (more intensive) forest management and a larger area being used for forest biomass production. At the same time, increases in prices have negative effects on the timber stock per unit area and most likely also the sustained yield.

Disregarding trade in roundwood for a moment, we take a nation by nation perspective on what happens when the demand for forest biomass increases and on the effect of the biophysical capacity limits. As price increases, intensive forest management (IFM) techniques are likely to become increasingly relevant. IFM techniques refer to practices well described in the scientific literature i.e. using high quality breeding material, fertilization, maintenance of ditch networks, short-rotation forestry using broadleaved fast-growing tree species, clonal forestry, and using highly productive exotic tree species. Such techniques focus on increasing forest productivity on existing forestlands and/or on reforesting previously abandoned agricultural land. Studies undertaken in Sweden (Larson *et al*. 2009) suggest that these techniques will be increasingly applied in the future. In fact, given that it is already profitable for private companies, and based on existing roundwood prices as noted in Brännlund *et al*. (2012), and the fact that many of the intensive cultivation measures are already allowed in Sweden today (to some limited extent), it is surprising that IFM techniques are not already widely used. Brännlund *et al*. (2012) suggest several possible explanations: deeply rooted traditions about how a forest should be managed, a general scepticism towards the possible benefits of this new method, or a denial by forest owners that positive economic outcomes are indeed possible. However, this conservatism and scepticism will probably decline as the profitability of IFM techniques increase with increasing roundwood prices.

In Figure 3 below, which disregards export and import of roundwood, *q* is the harvested quantity of roundwood, *p* is the roundwood price, D is the inverse demand function for roundwood, while S is the supply function for roundwood. Implementation of IFM techniques will increase supply in a given country. Graphically, this is shown in the figure as a shift from $S_0$ to $S_1$ in response to an increase in demand, illustrated as a shift in the demand curve from $D_0$ to $D_1$. The IFM techniques with the lowest marginal cost will be implemented first. As price continues to increase, IFM techniques associated with higher marginal costs and smaller effects on yield will be put into use. However, supply is contingent on a biophysical capacity limit to forest yield (BCL in the figure). In reality, the biophysical capacity limit, BCL, will never be reached. For instance, in the figure the realized harvest before the shift in demand will be $q_0$, while the realized price will be $p_0$. Increases in demand and implementation of IFM techniques will, however, bring the realized harvest closer to the BCL (denoted $q_1$ in the figure). The effect is that the supply function for roundwood for a typical country in northern Europe will be increasing at an increasing rate and approach the biophysical capacity limit in forest yield asymptotically, i.e. for very high prices of roundwood the actual supplied quantity will be very close to the biophysical potential for that country.

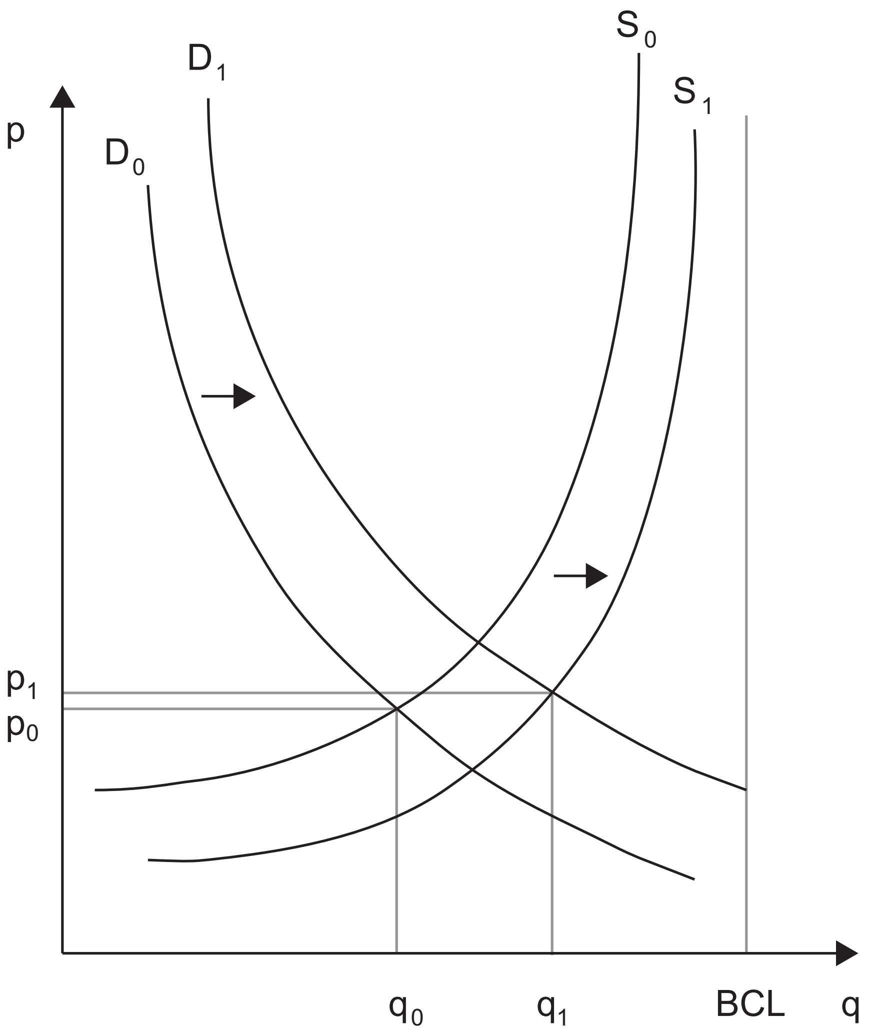


Figure 3: Partial equilibrium in the roundwood market with biophysical capacity limit (BCL) in forest yield.

This analysis, as mentioned earlier, completely ignores international trade in roundwood. In fact, in northern Europe there are significant exports and imports of roundwood, as shown in Table 3, below.

Table 3: Total roundwood production, imports and exports in northern European countries, average 2009-2013

1000 m³ (u.b.[1])

| | Production | Imports | | | Exports | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | Roundwood | Roundwood | Chips and particles | Wood residues | Roundwood | Chips and particles | Wood residues | **Imports** | **Exports** | **Net imports** |
| **Denmark** | 2646 | 740 | 492 | 820 | 706 | 142 | 36 | 2052 | 883 | 1169 |
| **Estonia** | 6898 | 319 | 80 | 60 | 2434 | 433 | 302 | 459 | 3169 | -2711 |
| **Finland** | 49685 | 5841 | 3295 | 491 | 671 | 280 | 262 | 9627 | 1212 | 8415 |
| **Germany** | 52836 | 7227 | 882 | 2373 | 3700 | 1946 | 1694 | 10482 | 7340 | 3141 |
| **Iceland** | 4 | 1 | 30 | 3 | 0 | 0 | 0 | 34 | 0 | 34 |
| **Ireland** | 2604 | 180 | 14 | 40 | 301 | 45 | 37 | 234 | 383 | -148 |
| **Latvia** | 12210 | 548 | 39 | 31 | 4548 | 2426 | 439 | 618 | 7413 | - 6794 |
| **Lithuania** | 6707 | 301 | 298 | 201 | 1569 | 149 | 199 | 800 | 1917 | -1117 |
| **Norway** | 10358 | 1202 | 883 | 221 | 1399 | 109 | 646 | 2306 | 2154 | 152 |
| **Poland** | 36476 | 2490 | 627 | 215 | 1926 | 73 | 372 | 3332 | 2371 | 962 |
| **Sweden** | 69520 | 6979 | 1352 | 1398 | 1022 | 304 | 129 | 9730 | 1455 | 8275 |
| **UK** | 9852 | 337 | 143 | 192 | 768 | 203 | 72 | 671 | 1043 | -372 |

[1]u.b. – under bark

NW Russia: Not available

Data source: FAOSTAT

The table shows figures for total trade in roundwood, comprising here roundwood (industrial wood and wood fuel), wood chips (wood reduced to small pieces), as well as wood residues (by-products from wood industries) that can be used either in forest industries or as a fuel. The large net importers in the region are Finland and Sweden. Also Germany and Denmark are clearly net importers, Germany both imports and exports remarkable volumes of roundwood. Latvia, Estonia and Lithuania have large exports of roundwood, especially in relation to their respective total production. Wood is also traded in the form of wood pellets used for heating. Large importers of pellets are the United Kingdom with 3.4 million tons and Denmark with 2.3 million tons in 2013. Latvia also exports pellets: 1.1 million tons in 2013 (FAOSTAT). However, imports of roundwood to the region are small compared with total production, suggesting that the region is more or less self-sufficient.

How can we model exports and imports in this fairly simple graphical framework? For a net exporter, the quantity demanded from other countries shifts the demand curve to the right, increasing price and quantity, and thereby increasing the implementation of IFM techniques (see Figure 4).

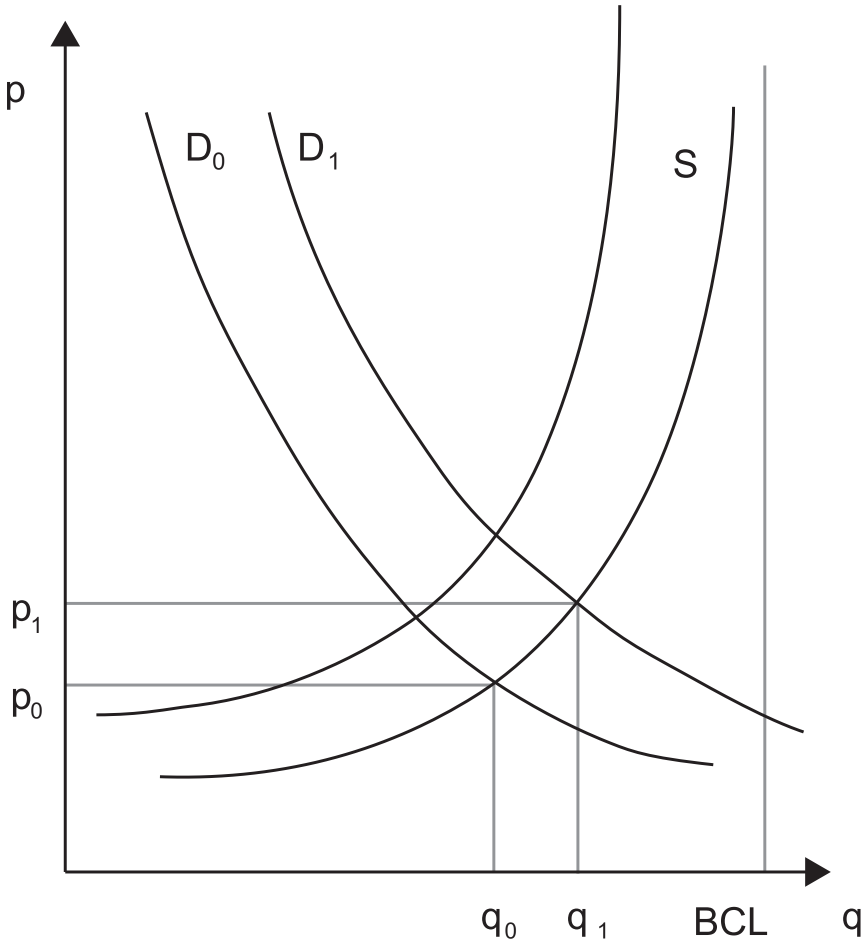


Figure 4: Partial equilibrium in the roundwood market with increased export demand and a biophysical capacity limit (BCL) in forest yield.

For a net importer, the quantity supplied from other countries shifts the supply curve to the right, see Figure 5, below. This will increase equilibrium quantity (in the figure from $q_0$ to $q_1$) and reduce equilibrium price. Note that the supplied quantity from domestic production will decrease (in the figure from $q_0$ to $q_{1d}$). Note also that the supply curve S1 is not restricted by the domestic BCL in forest yield.

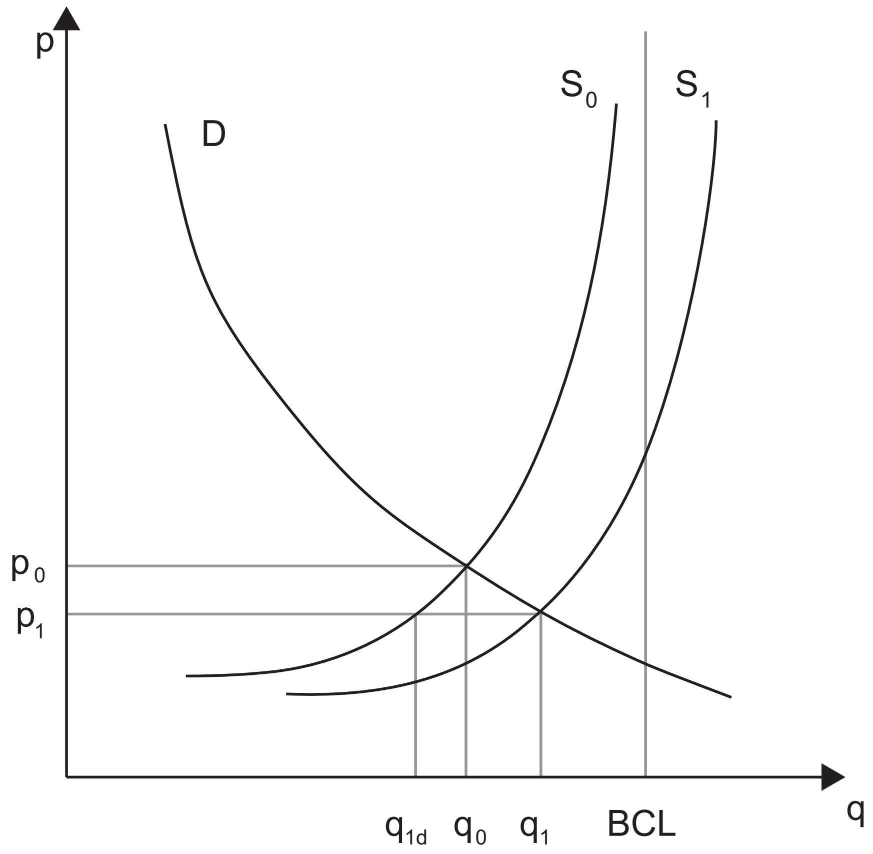


Figure 5: Partial equilibrium in the roundwood market and the effects of import shifting supply and a biophysical capacity limit (BCL) in forest yield.

The driving force behind exports and imports is, of course, price. As shown by Toivonen *et al*. (2002) the Law of One Price (LOP) seems to hold between Sweden and Finland. The LOP says that, for two regions belonging to the same competitive market, the local prices of a homogeneous product should differ exactly by the transportation costs between these regions. Given the relatively low transport costs in the studied region, the LOP can be expected to hold. However, as noted in Toppinen & Kuuluvainen (2010), cross country comparisons of LOP in the timber markets in Europe are rare. One effect of trade is that the issue of BCL in forest yield should really be viewed not on a national level, but on the regional level. However, if there is a general increase in demand for woody biomass for energy purposes in the region, we will climb up the supply curve in several countries in the region and IFM techniques will be more widely used.

This raises the issue of the environmental effects of intensive forest management. These are addressed for Sweden in a unique study by Brännlund *et al*. (2012) which lists the following effects:

*Climate effect:* IFM has an impact on the carbon cycle by affecting a forest's capacity to act as a carbon "sink", but also by having substitution effects, since bioenergy can replace fossil fuels.

*Acidification and nutrient loading*: Acidification is caused by deposition of sulphur and nitrogen, combined with an increase of the removal of wood residues from forest land. IFM techniques, through the use of more nitrogen fertilizer, also lead to an increase in acidification, the reason being that the uptake of nitrogen by trees and other organisms is not complete, leading to "nitrogen leakage" which can adversely affect groundwater, lakes, waterways, and marine environments. Brännlund *et al*. (2012) estimated the cost per hectare to be somewhere between 48 and 192 SEK/year.

*Landscape changes and recreation:* Intensive forest management on previously abandoned agricultural land or low-value forestlands can lead to aesthetic impacts on the landscape, which may adversely affect social values. These landscape impacts can be significant at the local level. Open agricultural landscape is lost when previously abandoned fields are used for IFM. Brännlund *et al*. (2012) estimated this loss based on Drake (1992, 1999), resulting in a WTP per hectare for preservation of the Swedish agricultural landscape amounting to 1838 SEK/year at 2008 prices.

Intensive cultivation also leads to other landscape effects. For example, some conventionally managed forests will subsequently transition to intensively cultivated areas, leading to potential recreational impacts.

*Biological diversity:* IFM techniques can also affect biological diversity. One obvious effect is that increased nitrogen will disproportionally benefit certain vegetation (Swedish Board of Forestry, 2007). However, Brännlund *et al*. (2012) did not attempt to estimate this effect, arguing that the net effect is uncertain. Some species will benefit while others will suffer. No known study includes an estimation of the monetary effect of IFM on biological diversity.

Brännlund *et al*. (2012) present three scenarios for the net societal effect of implementing IFM on 3.5 million hectares of forest land and on 0.4 million hectares of abandoned agricultural land in Sweden. Scenario C is assumed to illustrate the effect of higher timber prices due to an increased demand for bio-fuel driven by climate and energy policy, and gives a net benefit (including environmental effects) ranging from -17,900 to 20,000 million SEK at 2008 prices, depending on the social cost of carbon. Thus, the welfare effects of IFM are characterized by high levels of uncertainty. This is a cause for concern, since increased application of IFM techniques can have severe environmental side effects.

## Prospects for increasing forest yield

### *Methods*

Given that increased application of IFM techniques is a likely effect of an increased demand for bio-fuel driven by climate and energy policy, it becomes interesting to analyze further the potential for increasing forest yield. Put another way, how large is the difference between current annual fellings and the biophysical capacity limit in forest yield? Potential fellings presented in the following section are derived from three sources: i) national estimates as provided by national representatives ii) the study by Karvinen *et al*. (2011) as regards Northwest Russia and, iii) results (Reference scenario) from simulations with the EFISCEN model (Verkerk and Schelhaas, In press) for the European Forest Sector Outlook Study (EFSOS) II (UN 2011). Thus, the study uses existing assessments and no modelling or other independent assessment of potential fellings have been undertaken in the current study. In the following, “reported fellings” are the fellings reported to Forest Europe (UNECE & FAO 2010), some of which have been updated by national representatives.

The EFISCEN model is a large-scale forest scenario model that assesses the availability of wood and projects forest resource development on the regional to European scale. A detailed model description is given by Schelhaas *et al*. (2007). In the EFISCEN model, the state of the forest is described using an area distribution over age- and volume-classes in matrices, based on forest inventory data for the forest area available for wood supply. Transitions of areas between matrix cells during a simulation represent different natural processes and are influenced by management regimes and changes in forest area. Growth dynamics are simulated by shifting area proportions between matrix cells. In each 5-year time step, the area in each matrix cell moves up one age-class to simulate ageing. Part of the area of a cell also moves to a higher volume-class, thereby simulating volume increment. Growth dynamics are estimated by the model’s growth functions, the coefficients of which are based on inventory data or yield tables.

Management scenarios are specified at two levels in the model. First, a basic management regime defines the period during which thinnings can take place and a minimum age for final fellings. These regimes can be regarded as constraints on the total harvest level. Thinnings are implemented by moving the area to a lower volume class. Final fellings are implemented by moving the area outside the matrix to a bare-forest-land class, from where it can re-enter the matrix, thereby reflecting regeneration. Second, the demand for wood is specified for thinnings and for final felling separately and EFISCEN can simulate felling the required wood volume if available.

To assess biomass of branches, coarse roots, fine roots and foliage, stemwood volumes are converted to stem biomass using basic wood density (dry weight per green volume) and to whole-tree biomass, using age- and species specific biomass allocation functions. During thinnings and final fellings, logging residues are generated. These residues consist of stemwood harvest losses (e.g. stem tops), as well as branches and foliage that are separated from the harvested trees. In addition to these logging residues, stumps and coarse roots are produced. In the model, it is possible to define the share of the residues and stumps/coarse roots that are removed from the forest during thinning and final fellings.

The forest inventory data that were used to initialize the EFISCEN model were collected by Schelhaas *et al*. (2006). They were based on detailed National Forest Inventory (NFI) data on species and forest structure and provided the theoretical biomass potentials from broadleaved and coniferous tree species separately from:

- stemwood;
- logging residues (i.e. stem tops, branches and needles);
- stumps;
- early thinnings (thinning in very young stands; also referred to as precommercial thinnings).

To compare the estimates provided by the EFISCEN model, national estimates of potential annual fellings were obtained for the following countries:

*Estonia*

For Estonia the optimum cutting level was calculated for the year 2010 for three different scenarios. For every scenario, three cutting levels were calculated (low, moderate and active). The level presented in the results represents the optimum scenario at the moderate level. The felling calculation covered forest areas which will reach maturity in future 10-year periods.

*Finland*

The maximum sustainable roundwood removal is defined by maximizing the net present value with a 4 % discount rate subject to non-declining periodic total removal, saw log removal and net income (for forests available for wood supply). There are no sustainability constraints concerning tree species, cutting methods, age classes or the growth/drain -ratio in order to utilize the dynamics of forest structure efficiently. The calculation time was 50 years and it is divided into five 10-year periods. The forest data for the calculations are based on field measurements from the National Forest Inventory of Finland.

*Germany*

In the case of Germany, there is no defined national annual allowable cut, because there is no national authority to implement it, due to the autonomy of the Bundesländer. However, the political feeling on the national level is that the timber harvest is sanctioned up to the maximum average annual growth. The calculation of the potential annual fellings is therefore based on the maximum average annual growth.

*Ireland*

The calculation of the potential annual fellings for Ireland is based on the All Ireland Roundwood Production Forecast 2011-2028 (Phillips, 2011).

*Lithuania*

The annual allowable cut for state forests is approved by the order of the Lithuanian Minister of Environment. Private forest owners are requested to prepare forest management plans for 10- or 20-year periods, but the total allowable cut in private forests is not defined. In state forests the maximum allowable cut was judged to be 4 mill. $m^3$ per year for the years 2009-2013. The actual cut in private forests varied from 2 to 3.6 mill. $m^3$ per year for the years 2001-2010. The annual allowable cut in state forests is calculated by the OPTINA methodology, a dynamic programming model developed by the Lithuanian Forest Research Institute, which includes the security of a sustainable wood supply. Decision makers also have the opportunity to influence the calculated optimal solution at each step by changing ratio coefficients that can decrease or increase the annual final cutting budget. A distribution model calculates the priority indexes for each mature, over-mature, or damaged stand.

*Norway*

The calculations concern the annual sustainable yield for a 100-year perspective, and the maximum possible cut is calculated with the constraint that fellings must be able to be sustained in the subsequent 10-year period. In addition, subtractions are made for the volume “lost” due to set-aside areas, including both strictly protected areas and areas requiring some retention according to certification schemes (i.e. buffer zones beside mires, streams and water bodies). A general practice has also been to apply a 0.95 correction factor to the model predictions due to uncertainty about whether the “average” forest adheres to model-based predictions.

*Poland*

The majority of forests in Poland are managed by the State Forests Holding (SF) and for each forest district a 10-year mandatory forest management plan is drawn up. In the plans, the volumes of thinnings and final cuttings are defined. The potential fellings presented below refer to the volume of wood which can be harvested in a given year, taking into account the volume prescribed in the management plan. This is calculated every year for all the forest districts, taking into account the volume of wood that was harvested in previous years within each 10-year period, the allowable cut according to the management plan, and the number of years left till the end of the 10-years of a specific forest management plan.

*Northwest Russia*

This region is defined as the Northwest Federal District of the Russian Federation, including the Arkhangelsk, Kaliningrad, St. Petersburg, Murmansk, Novgorod, Pskov and Vologda regions, Republics of Karelia and Komi, city of St. Petersburg and Nenets Autonomous Okrug. The data come from Karvinen *et al*. (2011).

*Sweden*

The potential annual fellings come from Svensson (2008), who reports the results from the project Skogliga Konsekvensanalyser (Forest Consequence Analysis), SKA-VB 08. The figures were calculated using the so-called Hugin system (see eg. Bengtsson *et al*. 1989), a complete system for forest consequence calculations developed in Sweden from the 1980s. The Hugin system means that the forest's future development can be determined based on the growth of individual trees. An assessment of the uncertainties involved in the Hugin calculations is presented by Claesson (2008). It should be noted that the positive growth effects of climate change are included in the calculations for all scenarios. The figure is based on the SKA-VB 08 scenario, called the “Reference”. This scenario describes the development assuming current ambitions in forest management, environmental policy, adopted in 2010 and a likely change in the climate. Furthermore, the scenario assumes that the Swedish government environmental quality objective “Sustainable Forests” will be fulfilled. The concept of potential logging refers to a harvest whose size in each period is such that harvesting in the subsequent period is not significantly less.

*Results*

Table 4, below, presents annual fellings reported for Forest Europe (UNECE & FAO 2010) in the studied region and comparisons to national estimates for potential annual fellings and the corresponding potential simulated by the EFISCEN model (UN 2011), i.e. empirical estimates of the BCL. Regarding NW Russia the figures are from the study by Karvinen et al. (2011). Some of the reported fellings have been updated by national representatives.

Table 4 Reported and potential annual fellings (million $m^3$) for 2010

| Country | Reported fellings | Potential – national calculations | Potential – EFISCEN model | Comments on national calculations |
|---|---|---|---|---|
| Denmark | 2.4 | n/a | 3.2 | No national calculations undertaken. |
| Estonia | 5.7 | 12-15 | 10.2 | Calculation based on national forest inventory and current management restrictions. |
| Finland | 59.4 | 71.4 | 73.5 | Calculation based on on national forest inventory and the MELA model. |
| Germany | 59.6 | 100 | 90.3 | National calculations of potential based on maximum annual growth. |
| Ireland | 2.8 | 3.7 | 2.5 | National calculations of potential based on All Ireland Roundwood Production Forecast. |
| Latvia | 12.4 | n/a | 17.9 | No national calculations undertaken. |
| Lithuania | 8.6 | 4 | 9.5 | National calculations of potential based on the OPTIMA model for state forests. |
| Norway | 11.0 | 16-17 | 14.0 | Two national calculations of potential taking environmental considerations into account. |
| Poland | 40.7 | 32.4 | 54.1 | National calculations of potential based on 10-year plans for state-owned forests. |
| NW Russia | 46.9 | 112.7 | n/a | National calculations of potential based on silvicultural regulations. |
| Sweden | 80.9 | 94.7 | 92.1 | National calculations of potential based on calculations undertaken every 5 to 10 years. |
| UK | 10.5 | n/a | 12.2 | No national calculations undertaken. |

For most countries there is considerable evidence of convergent validity in the sense that the national calculations of potential are fairly close to the calculations of potential based on the EFISCEN model. For Estonia, Germany, Ireland, Norway and Sweden the national estimates exceed the EFISCEN estimates, while the converse holds for Finland, Lithuania and Poland. Large relative differences (in excess of 35%) exist for Estonia, Ireland, and Lithuania

In Table 5 the reported fellings are presented in relation to the most conservative of the calculations of potential presented in Table 4. In the case where this percentage exceeds 100, one can suspect a flaw in the calculation of potential. In some cases this flaw is obvious – the potential is calculated for some subset of all productive forests in the country, usually the state-owned forests (Lithuania and Poland). In these cases the table also includes another estimate of national potential.

Table 5 Reported fellings as a percentage of potential annual fellings for 2010

| Country | Reported fellings (% of potential) |
|---|---:|
| Denmark | 75 |
| Estonia | 56 |
| Finland | 83 |
| Germany | 66 |
| Ireland | 112 (76) |
| Latvia | 69 |
| Lithuania | 215 (91) |
| Norway | 79 |
| Poland | 125 (75) |
| NW Russia | 42 |
| Sweden | 88 |
| UK | 86 |

In Finland, Ireland, Lithuania, Poland and Sweden the reported fellings are close to the respective national potential, implying that increases in demand for wood are hard to accommodate domestically due to increasing marginal costs. Large differences between actual and potential fellings exist in Estonia, Germany and, above all, northwest Russia. On the surface, Russia has a large potential in the short to medium term to accommodate increases in wood demand for energy production without large price increases due to increased marginal costs, and exports from Russia to the EU have great potential to play an increasing role. However, actual supply from northwest Russia depends on bottlenecks such as infrastructural shortcomings, notably the lack of forest roads.

Another relevant factor is future Russian trade policy. It should also be noted that large areas in northwest Russia are currently not under any form of forest management.

## Discussion

This study has shown that there is a striking variation in the intensity of utilization of the wood resources in northern Europe. For the region as a whole, there seems to be a substantial unused biophysical potential. However, recent data from some countries indicate that annual felling rates may be underestimated (cf. Jonsson et al. 2013). Given the increased demand for wood-based energy, and if felling rates in some countries are higher than currently recognized, there appears to be a need to discuss strategies for implementation of more intensive forestry practices to ensure that increases in demand for wood resources in northern Europe can be accommodated within the region without large price increases.

Different ways to increase the timber harvest are discussed in the paper. Increasing harvest intensity in currently managed forests can only result in a temporary increase in output since an increase in the harvest now will reduce the amount of timber available for harvest in the (near) future. Other alternatives include increasing the total land area used for timber production by improving the accessibility and profitability of timber production on marginal forest lands. Another option is to improve the recovery rate at forest harvest. As this paper shows, price increases will make intensive forest management techniques increasingly relevant over time. This is comparable with other types of resource use, like extraction of oil. In the 1980s, some thirty years ago, no one deemed it viable to extract crude oil from tar sands. However, with increasing oil prices, open pit mining of tar sands has become a profitable business. Similarly, with increasing timber prices previously underutilized wood resources, e.g. in northwest Russia with its huge forests resources that currently are not managed, will be increasingly viable.

The comparison with oil extraction highlights two other aspects of increased use of wood resources: the importance of the international perspective and rising opportunity costs as forest management is intensified. Concerning the international perspective, it is important to see the question of wood supply in northern Europe as a part of a global market for wood products. This raises the question of whether biophysical capacity limits in northern Europe really are a problem for the region given a globalized market for wood products. Today, the public debate on the issue often takes a very narrow self-sufficiency perspective, as if every country was an island without the ability to trade.

Concerning opportunity costs, it should be obvious that using a larger proportion of the biophysical potential than at present in northern Europe will entail trade-offs with environmental and social values of the forests. This means that strategies for ensuring and combining all values from all forms of ecosystem services need to be discussed and developed. Hence, policy instruments are needed that provide incentives for forest owners to intensify forestry, while at the same time safeguarding environmental and social values from the forests. Here it should be noted that in countries with a large number of private non-industrial forest owners with low awareness of how to manage their forests, the ownership structure is a challenge when implementing policies at the landscape level. The trade-offs and demands of different ecosystem services may decrease the forest area available for production of woody biomass in the future in many countries, making the increased use of intensive forest management techniques in managed forests even more relevant.

**Acknowledgements**

We are grateful for additional information about how national calculations about potential fellings were calculated from the following national forestry experts: Erik Sollander, Sweden; Aksel Granhus, Norway; Eugene Hendrick, Ireland; Thomas Nord-Larsen, Denmark; Adam Kalizewski, Poland; Heino Polley, Germany; Pat Snowdon, UK; Mati Valgepea, Estonia; Toms Zalitis, Latvia; Olli Salminen, Finland; and Vilis Brukas, Lithuania.

## References


Ankarhem M. 2004. Effects of Increased Demand for Biofuels: A Dynamic Model of the Swedish Forest Sector. In: Ankarhem,M., *Bioenergy, Pollution, and Economic Growth* [dissertation], Umeå Economic Studies No. 661, University of Umeå.

Bengtsson G, Holmlund J, Lundström A, Sandewall M. 1989. *Avverkningsberäkning 1985, AVB 85*. Umeå (Sweden): Report 44, Dept. of Forest Survey, SLU.

Brännlund R, Carlén O, Lundgren T, Marklund P-O. 2012. The Costs and Benefits of Intensive Forest Management. *J Benefit-Cost Anal*. 3: 2152-2812.

Claesson S. 2008. *Skogliga konsekvensanalyser 2008 – SKA-VB 08*. Jönköping (Sweden): Report 25, Swedish Forestry Board.

Donner-Amnell J. 2010. *New Rules, New Players or a New Setting? New Factors Changing the Character of Forest Related Activities in the Nordic Countries*. Uppsala (Sweden): Paper presented at the 1st Nordic Conference on Forest Policy Science.

Drake L. 1992. The Non-Market Value of Agricultural Landscape, *Eur Rev Agric Econ*, 19(3), 351-361.

Drake L. 1999. The Swedish Agricultural Landscape – Economic Characteristics, Valuation and Policy Option, *Int J Social Econ*. 26: 1042-1060.

Eurostat. 2014. Energy Statistics [Internet site]. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database.

FAO. 2010. *Global Forest Resources Assessment 2010*. Main Report, Rome (Italy): FAO.

FAO. 2014. FAOSTAT Forestry [Internet site]. Available at: http://faostat3.fao.org//faostat-gateway/go/to/download/F/*/E .

Geijer E, Bostedt G, Brännlund R. 2011. Damned if You Do, Damned if You Don't – Reduced Climate Impact vs. Sustainable Forests in Sweden. *Resour Energy Econ*. *33*: 94-106.

Gerasimov Y. 2013. *Atlas of the Forest Sector in Poland*. Joensuu (Finland): Working Paper 268, Finnish Forest Research Institute.

Jonsson R, Mustonen M, Lundmark T, Nordin A, Gerasimov Y, Granhus A, Hendrick E, Hynynen J, Kvist Johannsen V, Kaliszewski A, et al. 2013. *Conditions and Prospects for Increasing Forest Yield in Northern Europe*. Vantaa (Finland): Working Paper 271, Finnish Forest Research Institute.

Karvinen S, Välkky E, Gerasimov Y, Dobrovolsky A. 2011. *Northwest Russian Forest Sector in a Nutshell*. Joensuu (Finland): Finnish Forest Research Institute.

Larsson S, Lundmark T, Ståhl G. 2009. *Möjligheter till intensivodling av skog, slutrapport från regeringsuppdrag*, Umeå (Sweden): Jo 2008/1885, SLU (Summary in English).

Mantau U, Saal U, Steierer F, Verkerk H, Lindner M, Anttila P, Asikainen A, Oldenburger J, Leek N, Prins K. 2010. *EUwood – Real Potential for Changes in Growth and Use of EU Forests*. Hamburg (Germany): EUwood.

Phillips H. 2011. *All-Ireland Roundwood Production Forecast 2011 – 2028*. Dublin (Ireland): COFORD, Department of Agriculture, Fisheries and Food.

Pelkonen P, Mustonen M, Asikainen A, Egnell G, Kant P, Leduc S, Pettenella D. (Eds.) 2014. *Forest Bioenergy for Europe. What Science Can Tell Us 4*. Joensuu (Finland): European Forest Institute.

Schelhaas MJ, van Brusselen J, Pussinen A, Pesonen E, Schuck A, Nabuurs GJ, Sasse V. 2006. *Outlook for the Development of European Forest Resources. A Study Prepared for the European Forest Sector Outlook Study (EFSOS)*. Geneva (Switzerland): Geneva timber and forest discussion paper 41. ECE/TIM/DP/41. UNECE/FAO Forestry and Timber Section.

Schelhaas MJ, Eggers-Meyer J, Lindner M, Nabuurs G-J, Päivinen R, Schuck A, Verkerk PJ, van der Werf DC, Zudin S. 2007. *Model Documentation for the European Forest Information Scenario Model (EFISCEN 3.1.3)*. Wageningen (Holland) and Joensuu (Finland): Alterra report 1559 and EFI technical report 26. Alterra and European Forest Institute.

Solberg B, Hetemäki L, Kallio AMI, Moiseyev A, Sjølie HK. 2014. *Impacts of Forest Bioenergy and Policies on the Forest Sector Markets in Europe – What do we Know?* Joensuu (Finland): EFI Technical Report 89, European Forest Institute.

Swedish Board of Forestry. 2007. *Kvävegödsling av skogsmark*, Jönköping (Sweden): Meddelande No. 2, 2007, Skogsstyrelsen (in Swedish).

Toivonen R, Toppinen A, Tilli T. 2002. Integration of Roundwood Markets in Austria, Finland and Sweden. *Forest Policy Econ. 4*: 33-42.

Toppinen A, Kuuluvainen J. 2010. Forest Sector Modelling in Europe—The State of the Art and Future Research Directions. *Forest Policy Econ. 12:* 2-8.

UN. 2011. *European Forest Sector Outlook Study II: 2010-2030*. Geneva (Switzerland): United Nations, UNECE/FAO Timber Branch, Geneva Timber and Forest Study Paper 28, (Available at: http://www.unece.org/efsos2.html).

UNECE & FAO. 2010. *Forest Europe*. Oslo (Norway): National Reports, Forest Europe, Liaison Unit Oslo.

UNECE & FAO. 2011. *Forest Europe*. Oslo (Norway): National Reports, Forest Europe, Liaison Unit Oslo.

UNECE & FAO. 2011. *State of Europe's Forests 2011. Status and Trends in Sustainable Forest management in Europe*. Oslo (Norway): Forest Europe, Liaison Unit Oslo.

Verkerk H, Schelhaas MJ. Forthcoming 2015. *European Forest Resource Development - A Contribution to EFSOS II*. Geneva (Switzerland): Geneva Timber and Forest Discussion paper, ECE/TIM/DP/61. UNECE.