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# Future harvesting pressure on European forests

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**Abstract** We provide quantitative insight in the spatial distribution of the future supply of wood as a raw material from European forests (27 countries) until 2060. This supply is tested for two scenarios: 'projection of historical management' and 'new management trends' and compared against a benchmark scenario. The new management trends scenario incorporates influences of issues as nature-oriented management, carbon credits and increased demand for bio-energy. The results of these projections provide insight in the state of the European forests and indicate that under the 'new management trends' supply can still increase to 729 million $m^3$ by 2060 in Europe, whereby almost throughout Europe we allow harvest to be higher than increment for some time. Without linking countries dynamically through international trade, we identify regions where harvesting pressure is highest. Under the new management trends scenario, the harvested volume is reduced with 82 million $m^3$/year (compared to 'projection of historical management') because of stricter management constraints. However, the management regimes as parameterised here allow harvesting pressure to remain highest in Central Europe and some Scandinavian countries, notably Finland and Norway.

**Keywords** European forests · Forest resource · Wood products · Markets · Nature-oriented management · Carbon credits

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## Introduction

European forests without the Russian Federation cover 192 million ha, spread over 36 countries. These forests increasingly have to fulfil a wider variety of demands while at the same time the demand for conventional wood products increases as well (Trømborg et al. 2000; UN-ECE 2005). Despite these increasing demands, the current European forest area and average growing stock is at its highest point since medieval times. The growing stock amounted on average to 143 $m^3$/ha in 1995 (UN-ECE/FAO 2000). However, the long-term availability of wood as a raw material in Europe is still of concern. This concern is driven by a combination of factors:

1. the pulp and paper industry expects structural demand increases in the near future in European countries and thus investments for capacity expansion have to be decided upon;
2. even larger increases in consumption (but in the longer term) are expected in Central European countries with economies in transition;
3. developments in forest management and in competing demand groups indicate that supply to the industry may be restricted in the future. This will notably be because of the following three reasons:
   - trends towards nature-oriented forest management leading to reduced willingness to harvest exacerbated by low stumpage values;
   - the EU policies on energy (European Commission 1997) leading to an extra demand for roundwood for bio-energy needs;
   - the Kyoto Protocol leading to rewarding carbon credits under further build-up of growing stock in the forest.

If these trends continue, a vast resource may develop, with high rates of mortality and a decreasing net increment. This vast resource may show higher levels of biodiversity than today, as the area of forest in the older age classes increases, as well as the amounts of dead wood in the forests. Whether this is the preferred direction to go is mainly a political decision. Therefore, insight in future development of the forest resource, and quantification of spatial and temporal shifts in harvesting pressure are needed. These large-scale analyses allow for strategic choices to be made at the European level.

## Aim

The aim of this study is to provide quantitative insight in the spatial and temporal dynamics of future supply of wood as a raw material (between 2005 and 2060) from European forests.[1]

To do so, the supply is quantified using a forest resource model. This supply is calculated following three scenarios: (a) Benchmark with stable fellings, (b) ‘projection of historical management’ with increasing felling levels and (c) ‘new management trends’ with strongly increasing fellings. The scenarios A and B incorporate management regimes as applied in the 1980s and 1990s as obtained from handbooks and questionnaires to data correspondents. The scenario C incorporates effects of the three issues: nature-oriented management (NOM), bio-energy and carbon credits.

The study looks at the problem from a resource and management perspective. The model does not have any endogenous econometric variables. It is assumed that economic effects can be incorporated through changes in forest resource management.

The main assumption on incorporated management changes is that the impacts of NOM, bio-energy and carbon credits can be translated into changes in management regime by tree species, country and owner class. These management changes are thus exogenously (i.e. not responding dynamically during simulation) determined and they represent forest owner responses to the sum of the three issues.

## Methods, scenarios and data

### Modelling approach

The projections in this study are made with the European Forest Information Scenario Model (EFISCEN), a forest resource assessment model. EFISCEN is described in more detail in Pussinen et al. (2001) and Nabuurs (2001). The projections carried out with this model provide insight into increment, growing stock, age class distribution and actual fellings for tree species and regions in a country. The EFISCEN model uses time intervals of 5 years. The initial state of the forest resource is based on the latest forest inventory data. These input data are structured by forest types, which are defined by country, region, owner, site class and tree species. Each forest type contains the following variables by age classes:

- area (ha);
- average stemwood volume growing stock (overbark, $m^3$/ha);
- stemwood volume increment (overbark, $m^3$/ha/year).

A separate area matrix is set up for each forest type of the inventory data, in this case 4,115 forest types for 132 million ha of forest (including the European part of Russia). The area matrix approach is derived from Sallnäs (1990).

Forest management is controlled at two levels in the model. First, a basic management for each forest type, like thinning and final felling regimes, is incorporated. These regimes are seen as constraints of cutting levels. These regimes are adapted in the current study for the three issues (NOM, bio-energy and carbon credits) (Nabuurs et al. 2003). Secondly, the total required national fellings volume (apparent demand) was specified by country for the tree species groups coniferous, deciduous and coppice for each time period. EFISCEN works such that given the state of the forest resource, it’s growth dynamics and the management constraints, the model tries to fulfil the total required national fellings volume.

Natural mortality is described as a percentage of the area in a cell moving one volume level down in the matrix (Schelhaas et al. 2002).

### Initialisation inventory data

An enquiry was made to all national forest inventory institutes in 2001 in collaboration with the European Forest Sector Outlook Studies of the UN-ECE. New data was received from 18 countries and data from the 1996 enquiry was used for the other 9 countries (Nabuurs 2001). The full database reflects, on average, the state of the forests in 1994. Small deviations between the forest area covered in the present study and the area of Forest Available for Wood Supply (FAWS) (UN-ECE/FAO 2000) are due to the fact that country correspondents were not always able to provide the detailed data for the whole FAWS area (Table 1). These usually small deviations were corrected during the runs by multiplying the area in each forest type of a country by the ratio between FAWS area and the area in our database for that country.

### Scenarios

Three main scenario lines were developed. All underlying assumptions are explained in detail in Sects. ’Demand development in conventional wood commodities’, ‘Nature-oriented management’, ‘Carbon credits’ and ‘Bio-energy’. All countries were run individually (ignoring imports and exports or relocation of roundwood supply between countries during the simulation period).

[1] Europe in this study includes the forests of: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, UK.

**Table 1** Overview of meta-data of gathered inventory data and comparison to UN-ECE 2000 data for area covered

| Country | FAWS (UN-ECE 2000) (1,000 ha) | Initialisation inventory data for current study with the EFISCEN model | | |
|---|---|---|---|---|
| | | Number of forest types | Year of forest inventory | Area covered (1,000 ha) |
| Austria | 3,352 | 192 | 1992–1996 | 2,978 |
| Belgium | 639 | 44 | 1997–1999 | 725 |
| Bulgaria | 3,123 | 270 | 2000 | 3,295 |
| Croatia | 1,690 | 8 | 1980s | 1,443 |
| Czech Republic | 2,559 | 140 | 2000 | 2,493 |
| Denmark | 440 | 35 | 1990 | 442 |
| Estonia | 1,932 | 12 | 1999–2001 | 2,074 |
| Finland | 20,675 | 64 | 1986–1994 | 19,752 |
| France | 14,470 | 660 | 1988–2000 | 13,729 |
| Germany | 10,142 | 117 | 1986–1990/1993 | 9,979 |
| Hungary | 1,702 | 18 | 2000 | 1,860 |
| Ireland | 580 | 35 | 1992–1993 | 329 |
| Italy | 6,013 | 49 | 1985 | 5,757 |
| Latvia | 2,413 | 140 | 2000 | 2,804 |
| Lithuania | 1,686 | 506 | 2000 | 1,960 |
| Luxembourg | 85 | 6 | 1989 | 71 |
| The Netherlands | 314 | 13 | 1995–1999 | 307 |
| Norway | 6,609 | 357 | 1996–2000 | 6,644 |
| Poland | 8,300 | 170 | 1993 | 6,019 |
| Portugal | 1,897 | 7 | 1997–1998 | 2,133 |
| Romania | 5,617 | 36 | 1980s | 6,211 |
| The Slovak Republic | 1,706 | 16 | 1994 | 1,909 |
| Slovenia | 1,035 | 6 | 2000 | 1,152 |
| Spain | 10,479 | 850 | 1986–1995 | 13,905 |
| Sweden | 21,236 | 180 | 1996–2000 | 20,967 |
| Switzerland | 1,060 | 100 | 1994 | 1,140 |
| UK | 2,108 | 84 | 1995–2000 | 2,202 |
| Total | 131,862 | 4,115 | | 132,280 |

For countries in bold a new set of data was received. For the other, data from Nabuurs (2001) was used. For each of the 4,115 forest types, the area, growing stock and increment was usually provided for 12 age classes

*Main scenario lines*

(A) *Benchmark* the total national felling level is assumed to stay at the level of the 1990s throughout the simulation period until 2060. This was run in combination with conventional forest management according to handbooks.

(B) *Projection of historical management* a scenario in which the total requested fellings rise considerably until 2060 (see Sect. 'Demand development in conventional wood commodities') in combination with conventional forest management according to handbooks. It is assumed that the forest area stays the same, the species composition stays the same, and that no strict reserves are established.

(C) *New management trends* this scenario consists of the basic fellings development as in the B scenario (Sect. 'Demand development in conventional wood commodities') plus an extra annual total European fellings of 80 million $m^3$ roundwood by 2030 for bio-energy (Sect. 'Bio-energy'). This total fellings scenario is run in combination with new management trends as given in Sects. 'Nature-oriented management' and 'Carbon credits'. In these sections is dealt with the specific questions in this study; i.e. the severity of the three issues (NOM, bio-energy and carbon credits) and how they are integrated in management. The main assumption on these issues is that impacts of NOM, bio-energy and carbon credits can be translated into changes in management by tree species, country and owner class in EFISCEN. They represent forest owner responses to the sum of the three issues. These owner responses again reflect market and pricing mechanisms, but are not dynamic during the simulation. This scenario also includes assumptions on future forest area expansion and assumptions on losses of FAWS due to the establishment of strict reserves.

*Demand development in conventional wood commodities*

In the present study, the general assumption on demand development was based on literature on forest sector market models. This reflects assumptions concerning Gross Domestic Product development, population development, and, e.g. (international) policies. An analysis of historic consumption and fellings in Europe for the period from 1964 to 2000 showed a 53% increase in consumption in 30 Western and Central European countries (1.2% per year) (Fig. 1). Fellings however, experienced a small increase only: 9% on the same time scale. The fact that fellings did not increase as much as consumption has to do with increased processing efficiency and increased recycling that took place over this period of time. It was not caused by increased imports from outside the EU.

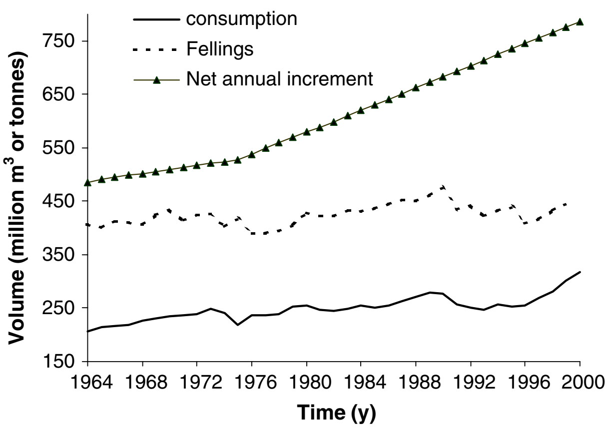



**Fig. 1** Consumption of all commodities (sawnwood, fuelwood, paper and paperboard and panels, in million tonnes), fellings (roundwood overbark, in million $m^3$) and net annual increment (roundwood overbark, in million $m^3$) in European countries excluding Commonwealth of Independent States. Sources for fellings and increment are FAO (1948, 1955, 1960, 1976) and UN-ECE/FAO (1985, 1992, 2000). The source for consumption is the UN-ECE database

Figure 1 shows the strongly increasing trend of net annual increment in European forests. Over this course of time, the ratio of fellings to increment declined from 90% in 1950 to currently 55%.

For the present study, the total demand scenario assumption was based on:

- historic increase in consumption as given in Fig. 1;
- the notion that consumption in countries in transition is just starting;
- the notion that consumption in European countries has not reached its maximum yet;
- a consumption forecast by Trømborg et al. (2000), which show an increase in consumption of wood products in Europe varying per commodity between 0.78 and 2.77% per year between 1994 and 2010;
- a review of 19 projection studies by Weiner and Victor (2002) that show a global demand increase for industrial roundwood of 1.3% per year during the period of 1995–2010;
- an enquiry made by the Confederation of European Paper Industries (CEPI) that shows a 3.4% increase in demand for pulp and paper over the next 5 years (CEPI 2002).

The principle fellings increase for wood products under the B and C scenarios was assumed to develop according to the following scenario: 3.4% per year from 2000 to 2005, then 1.5% per year until 2020 and then 1% per year until 2060. This main scenario was implemented with small deviations between countries.

*Nature-oriented management*

Nature-oriented management generally aims at enhancing nature conservation values in the forest and differs from traditional economic optimisation in forest management in that it is less directed towards wood production. Important vectors for NOM in Europe are for example the Pro Silva movement (European federation of foresters who advocate forest management based on natural processes. PRO SILVA was founded in Slovenia in 1989) and to a certain degree also forest certification processes. In the simplest case, NOM may simply mean choosing different tree species and in its most extreme case, the establishment of strict nature reserves in existing forests.

In the current study, it was assumed that NOM is going to be important for European forestry in the future and will reduce a forest owner's willingness to supply, i.e. as a result of less dependency of the forest owner's income on the forest, and the valuation of other functions the average owner is assumed to supply less at the same stumpage prices. This reduction in supply willingness is incorporated for the 27 European countries as a combination of the following assumptions (based on a review by de Goede 2000):

- longer rotations [20 years for long rotations, and 10 years for short rotation species (< 60 years)]. This was kept rather simple because of a lack of detailed information on how the management of each tree species may change under NOM;
- from total fellings an additional 10% must originate from thinnings/group fellings;
- thinning can only be carried out in forests with growing stocks over 150–300 $m^3$/ha, depending on the forest type. This is based on the assumption that non-commercial thinnings are not being practised anymore;
- a species change towards the more natural/indigenous species is incorporated as a 30–40% chance that species like spruce and pine will be regenerated with species like beech and oak. The accompanying assumption is that sufficient sites are available where this is a logical step;
- set aside from harvesting all beech and oak forests older than 150 years. Initially, this usually affects 1–1.5% of the total forest area in a country. Due to ageing of the forest during simulation, this area may increase to some 6–10% by 2060 depending on management regimes, felling levels, etc. These forest areas remain part of the simulation, but are simply not affected by harvesting anymore.

*Carbon credits*

For the present study two aspects of the Kyoto Protocol are assumed to have impact on the scenario assumptions: (1) the amount of new areas being planted due to Kyoto Protocol measures (Article 3.3 of the Kyoto Protocol) and (2) the likelihood that forest owners will be financially compensated for building up carbon (= growing stock) in existing forests (Article 3.4 of the Kyoto Protocol).

*Amount of new areas being planted due to Kyoto Protocol measures*

Changes in forest areas are already taking place at the moment without any carbon credits being paid. The average annual net changes in the forest area during the period 1983–1993 were highest in France and Spain with, respectively, 61.6 and 86 thousand hectares annually. Belgium, Serbia and Montenegro and Albania had seen an overall decrease in forest area.[2]

However, these are the net changes between the gross increases and decreases in FAWS and forest not available for wood supply (FNAWS). For the 27 countries under study, an average annual increase in FNAWS of 324,200 ha and in FAWS of 103,600 ha has been reported (UN-ECE/FAO 2000). Thus, there is an increase overall in forest area of some 0.3% but only part of it is available for wood supply.

It was assumed that Article 3.3 of the Kyoto Protocol will indeed stimulate the gross FAWS area expansion: from the current +103,000 to 290,000 ha/year (on average over the whole simulation period). This scenario assumption will increase the total FAWS in the 27 European countries from the present 134 million ha (in our database) to 150 million ha. This increase was assumed to take place mainly between 2010 and 2040 and to apply to the present forest area per country with some emphasis on pre-accession countries.

*Likelihood that forest owners will be financially compensated for building up carbon (growing stock) in the existing forest*

Additional carbon credits can be gained from 'forest management' up to the maximum amount individually defined for each Annex I Party (available as annex to UNFCCC 2001). This ceiling is very small for the first commitment period of 2008–2012 when the EU countries must have reduced their total greenhouse gas emissions by 8% compared to 1990, and will easily be accomplished by the present build-up of growing stock (UNFCCC 2001).

Prices paid for credits are in the range of €4.7–11/t $CO_2$,[3] which is roughly equivalent to €4.25–10/m$^3$ of stemwood. This is a significant monetary value in comparison to pulplog stumpage of around €15–20/m$^3$ offered in Scandinavia, and is very high in comparison to pulplog stumpage of €1–5/m$^3$ offered in Central Europe. The question, however, is whether governments are going to choose for Article 3.4, and whether they will subsidise the ongoing carbon build-up in existing forests and if they are actually going to pay these prices. Up to now, no government does, although a majority of EU countries will elect Article 3.4 'forest management' measures in order to achieve their emission reduction commitment. The carbon build-up however, is merely an effect of present undercutting, and is not a deliberate action taken by forest owners to store carbon.

We can therefore assume that this part of the Kyoto Protocol has had no impact on forest owner behaviour up to now. However, this section of the Kyoto Protocol is in line with the management trend under NOM, leading to build-up of growing stock. As it is in line with a strong trend in forestry, owners may be interested in it, provided that it is paid for. Taking all this into consideration, as well as taking into account the high uncertainty level in outcomes of future international climate negotiations, it would be fair to assume that Article 3.4 may lead to a prolongation of rotation lengths by 10 years (irrespective of country or site). However, rotation length prolongation was mentioned under owner behaviour, NOM, and now under Kyoto Protocol issues. If forests were subjected to prolongation under all these issues, it might have resulted in assumed prolongated rotations of an extra 30–40 years. This seemed unrealistic and a total maximum of 20 years prolongation was assumed as a constraint.

*Bio-energy*

In the EU policy on bio-energy (European Commission 1997), the EU aims at doubling the contribution of Renewable Energy Sources (RES) from a current 6–12% by 2010. The European Commission has designated biomass as an important RES on top of the current consumption of roundwood and industrial residues of approximately 40 million m$^3$/year in EU and EFTA countries. Very recent, in December 2005, the European Commission published a Biomass Action Plan (European Commission 2005), followed by a communication on an EU Strategy for Biofuels (European Commission 2006). The Biomass Action Plan aims to increase biomass use to 150 million t oil equivalents (in primary energy terms) in 2010 or soon after.

Due to the above-mentioned RES policy an increase in demand for wood fibres from forest resources for the production of bio-energy has already been recorded and it can be expected to increase further. The increased demand for roundwood, based on the EU Whitepaper, has been calculated to amount to approximately 92 million m$^3$ by 2010 (Dielen et al. 1999; Berndes et al. 2003). Later, Lindner for EEA (2006) assessed an availability of environmentally compatible biomass from forestry of around 39 million t oil equivalent (~200 million m$^3$ from both stemwood and branches).

From the current state of implementation of the RES policy in Europe, it can be concluded that it is unlikely that the RES targets for woody biomass will be met within the intended time span. Adjustment of the time span or of the quantitative targets seem inevitable. An extra felling of 80 million m$^3$ of roundwood by 2025–2030, matches this requirement and is incorporated as an assumption in the 'new management trends' scenario. This additional fellings is distributed over the countries of study with respect to their current share in total fellings (Nabuurs et al. 2003).

## Results

Foremost, the results show that a large increase in supply can be achieved sustainably in European forests. The

[2] This is not completely true anymore according to updated TBFRA data as published by UNECE/MCPFE's State of Europe's Forests, 2003.

[3] €4.7/t CO2 = 17 €/t C. Every cubic meter of stemwood contains 0.25 t C. Thus, the equivalent value per cubic meter of stemwood is 17/4 = €4.25.

supply under 'new management trends' increased from 409 million $m^3$/year in 2005 to 647 million $m^3$/year in 2060. Under the projection of historical management with assumed increased demand, the supply increased to 729 million $m^3$/year in 2060 (Fig. 4). So, despite an 80 million $m^3$ higher demand, the new management trends give a reduction in fellings of 82 million $m^3$. Thus, in total a reduced supply of 162 million $m^3$/year was found despite an increase in forest area of 16 million ha over a time period of 55 years in the new management trends scenario. These large increases in supply are possible while maintaining a slightly increasing average growing stock (Fig. 6).

When keeping the felling level very stable (Benchmark), the average growing stock rises from 188 to 287 $m^3$/ha. Higher rates of mortality were found under these growing stocks.

The high supply levels we found within European forests, because we allow temporarily overharvesting in comparison to increment (Figs. 2, 3). Overharvesting occurs more severely in the 'projection of historical management' scenario. Still the average growing stock increases in this scenario. In all regions where overharvesting occurs (usually starting in 2040), this happens often with an increasing linear trend in time. This in contrast to the 'new management scenario', where overharvesting is severe in some regions in 2030 and 2040, but then declines again in 2050 because of the constraints taking effect, i.e. the available stock is used up in a certain decade.

In the new management trends scenario we quantified the large-scale effect of management constraints. It becomes clear that effects of management changes like setting aside forests for nature reserves, tree species changes, and rotation prolongation have their influence on total fellings mainly in the long term (Fig. 4). Namely only after 2050 the fellings as achieved under 'new management trends' start to decline. Without the afforestations the decline in fellings would have been stronger, but still the afforestations did not fully compensate for the effect of the constraints. Figure 5 also shows that the tree species composition (30–40% of all clearfelled coniferous stands are regenerated as deciduous species) only changes slowly. Although the deciduous forest area

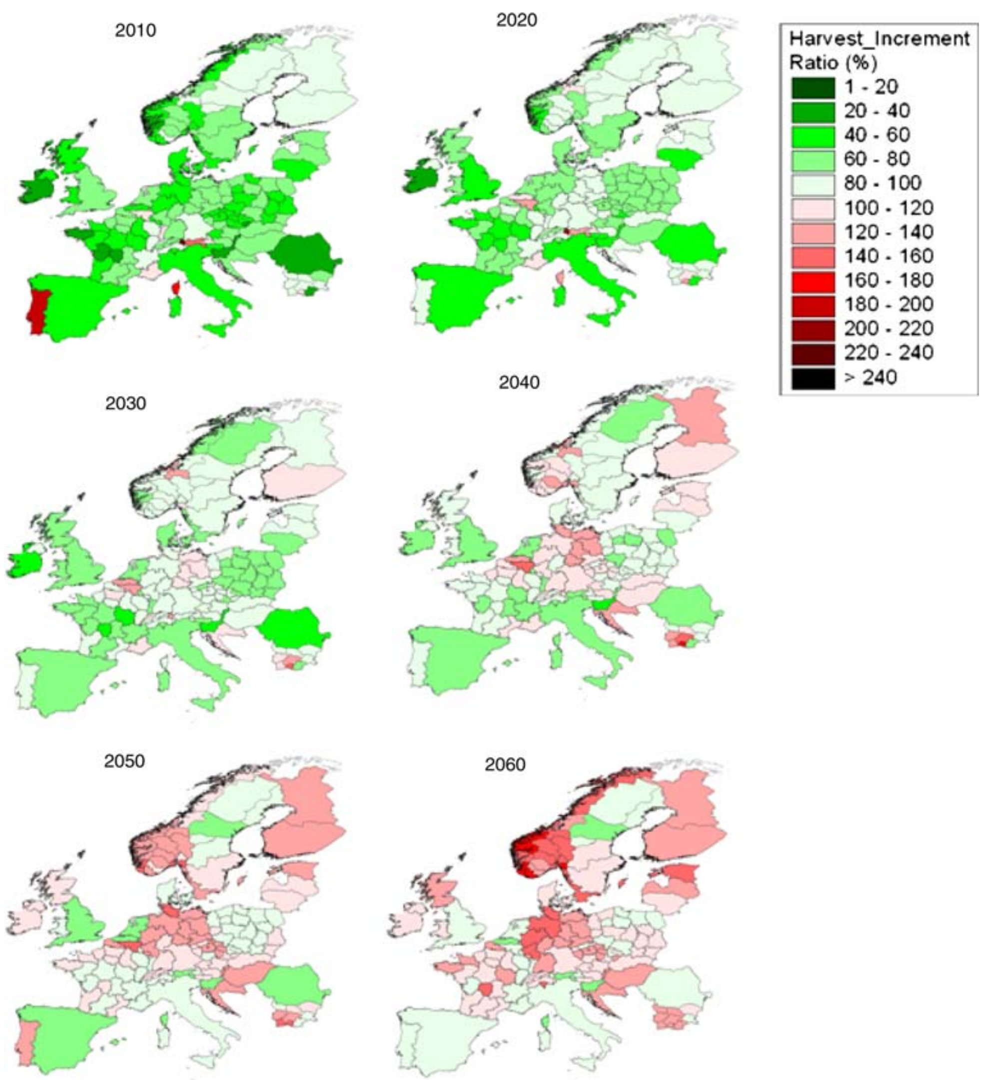
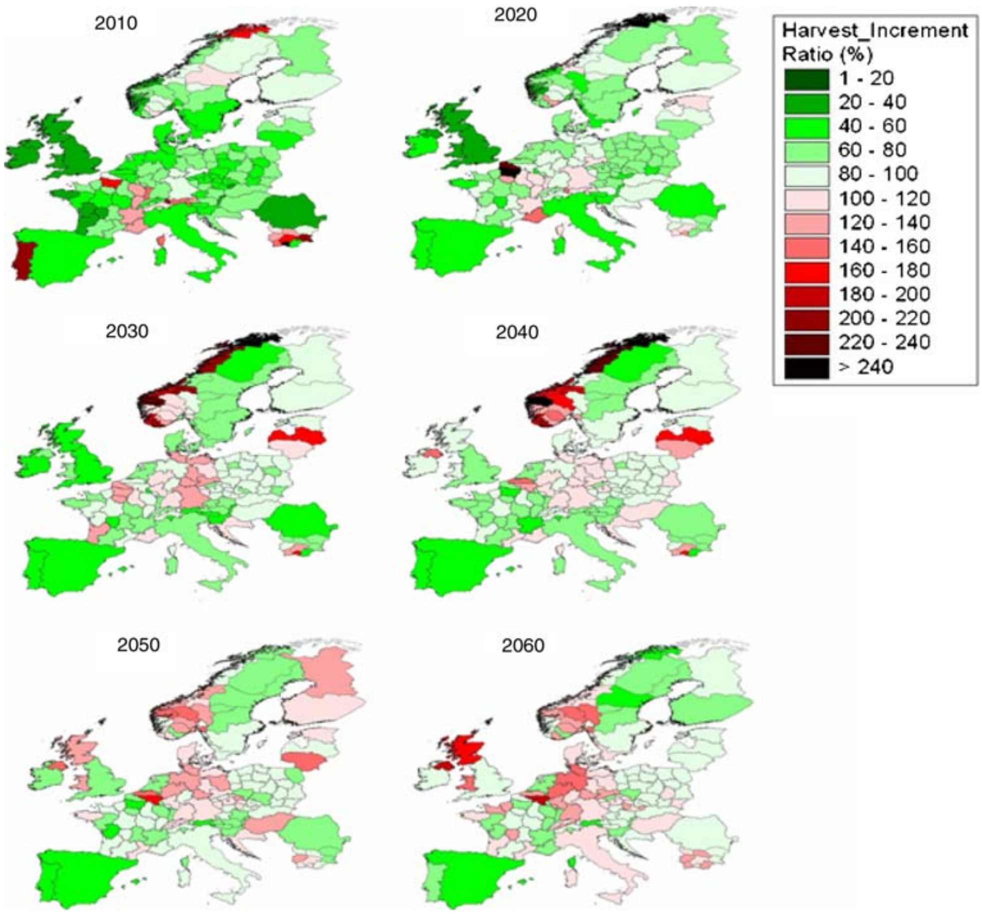



**Fig. 2** Felling over increment ratio in the 'projection of historical management' scenario

Fig. 3 Felling over increment ratio in the 'new management trends' scenario



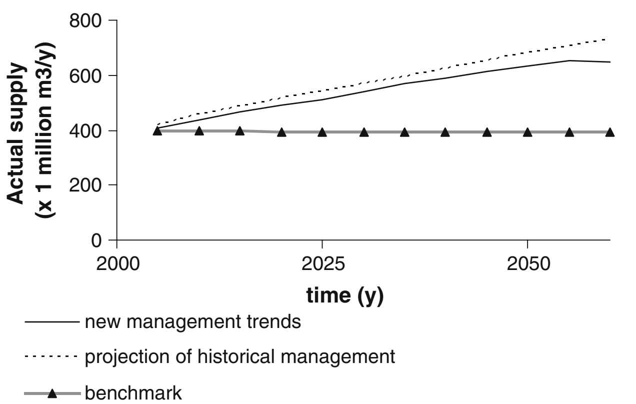




**Fig. 4** Total European roundwood supply from the 27 countries under study

increases considerably with 28% from 46 to 59 million ha in 2060, the coniferous area is very stable between 82 and 86 million ha. The latter is because all coniferous forests that are lost due to species changes, are compensated by new afforestations.

The trend in average growing stock development (Fig. 6) shows only a small difference between the B and C scenarios. So despite quite different scenario assumptions, and quite stringent management rules in the 'new management trends' scenario, the average growing stock is hardly affected. Under the 'projection of historical management' growing stock increases fastest, but peaks around 2040 at 221 m$^3$/ha and then declines. Under the 'new management scenario' the growing stock keeps on increasing to a level of 221 m$^3$/ha in 2060. However, the total effect of management changes is obscured by contrasting effects. For example, under the 'new management trends' harvesting is less, so one would expect much higher average growing stock, but this is counteracted by new afforestations with very low standing volumes, and by conversion of coniferous stands into deciduous stands with lower growth rates.

When keeping the felling level very stable (Benchmark), the average growing stock rises strongest from 188 to 287 m$^3$/ha, and results in a strong decline of the net annual increment (Fig. 7). This benchmark scenario in Fig. 7 shows a strong decline of average increment across Europe from 5.8 m$^3$/ha/year in 2000 to 4.7 m$^3$/ha/year in 2060.

The age class distributions (Fig. 8) also show a combination of effects of different measures. Although the aim of the 'new management trends' scenario was to enhance biodiversity by creating more old forests, this is only partly achieved. We can see in Fig. 8 (bottom) that the area of forests older than 200 years has increased from 1.7 million ha in 2000 to 4.4 million ha in 2060. However, the average age has hardly increased because in this scenario we also try to increase fellings a lot in combination with prolongated rotations. This leads to more forest

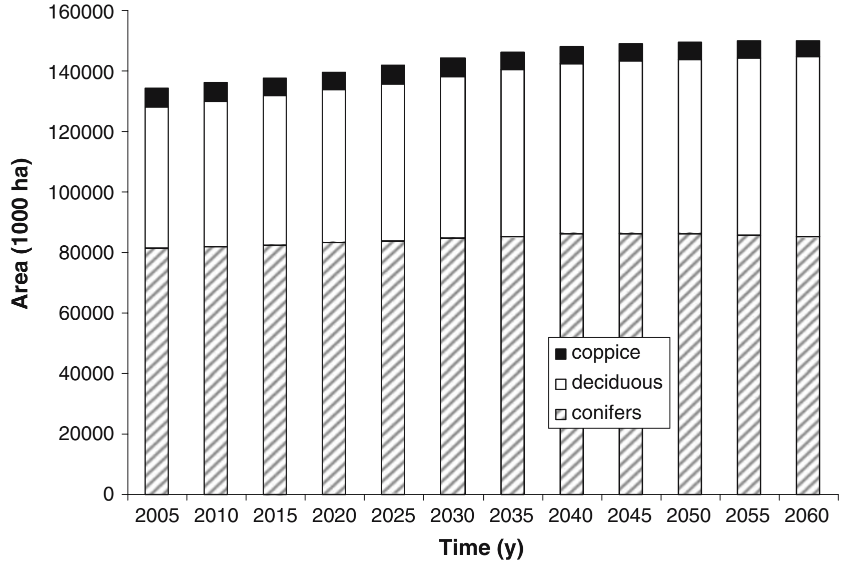



**Fig. 5** European forest area development over time by tree species group under the new management trends scenario

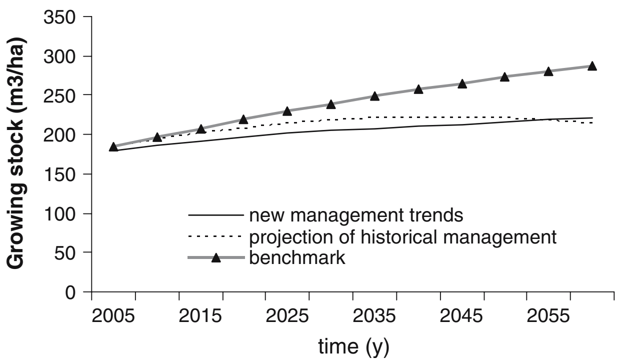



**Fig. 6** European average growing stock development under the three scenarios

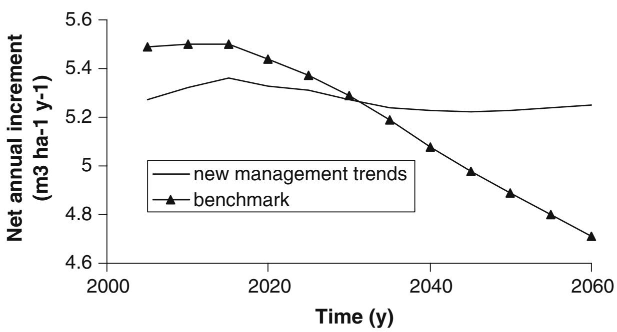



**Fig. 7** Average European net annual stemwood volume increment under the benchmark and the new management trends scenario

area in 2060 in the age classes 100–150, but leads to less forest area in the classes 150–200. That is, prolongating a rotation means that you have to find the same amount of wood, but in the older age classes! Figure 8 (top) shows for the benchmark scenario (with simply a stable and rather low amount of fellings) that the ageing of the forest is much more pronounced in this case in the classes 80–200 years.

## Discussion

This study confirms the notion of ample forest resources in Europe (Spiecker et al. 1996; Bundeswaldinventur 2006; UN-ECE/FAO 2000). We project that large increases in supply are possible. However, in order to achieve this, harvesting rates higher than the net increment are required in many regions. We show that the (often mentioned) sustainability indicator of harvesting versus increment can be breached for some time, while hardly endangering the growing stock. Still, we think that the level of supply as found here will most likely not be achieved, because forest owner show a decreasing trend in willingness to harvest.

Under the B and C scenarios we assumed that demand will continue to increase as it did over the last five decades, and that the processing technology improvements have reached their limits. The combination of these assumptions means that a demand increase linearly translates into a required supply of raw material. This is a rather high demand scenario. This was chosen in order to show the upper limitations of the resource and in order to show the full impacts of the management changes.

If we do not want the sustainability index to be breached (harvesting less than increment), then serious limits to the interpretation of the 'ampleness' of the wood resource need to be taken account of. In the latter case we may be back at the time of the 1950s and 1960s when UN-ECE Timber Committee projections warned of a lack of raw material resource (FAO 1948, 1955, 1960). Later projections (UN-ECE/FAO 1985, 1996) proved that ample supply was possible while at the same time the resource increased. However, these last two projections, as well as Nilsson et al. (1992) showed the impacts of environmental changes on the forest resource and highlighted the effects of acid deposition, climate change and concerns about biodiversity. Now again in

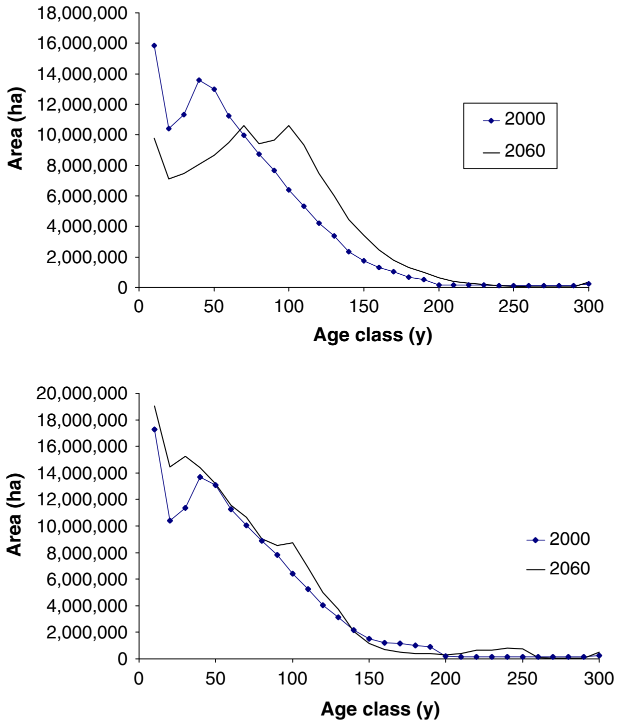



**Fig. 8** Age class distribution in 2000 and in 2060 of all European forests under simulation in the benchmark (*top*) and the new management trends scenario (*bottom*)

the present study, we show the vast potential within Europe's forest resources but we highlight that management changes and competing demands will constrain future use of the resources.

Our analyses do have their limitations, mainly because the model used (EFISCEN) is not a timber market model. Model endogenous adaptation of prices, demand and supply does not occur. Despite the large potential of fellings that we show here, the model shows the limitations of the resource and of the impact of management changes. These two factors are often incorporated in market models in a limited way only.

We have made the assumption that forest owner responses to prices and owner's overall decreasing willingness to harvest, can be taken into account by adapting the management regimes in EFISCEN. This of course has limitations and is only flexible in a way that management rules are dependent on the state of the resource, as was done here. Further limitations are also in the field of international trade in wood products which is not captured in EFISCEN. Incorporation of international trading mechanisms within Europe and beyond would allow to dynamically search for a sustainable wood supply.

The spatial distribution of overharvesting as shown in Figs. 2 and 3 may not give the full dynamic picture. This is partly because we have assigned the demand increases to each country in proportion to its current share of total harvesting in Europe. This is a limited view as some countries may take up larger proportions in the future than others. For example, it can be assumed that countries with large average growing stocks (Switzerland, Austria, Czech Republic), will increase their harvesting, and temporarily choose to overharvest in order to bring down growing stocks. Such policies or management decisions are not well represented in the current study. These dynamic responses between countries may require international trade relations to be incorporated (Nabuurs et al. 2002).

Inclusion of aspects like sustainability and wood procurement will require more dynamic modelling approaches in the future at higher spatial details, possibly based on GIS systems of the plot level data of national forest inventories. In such future versions of EFISCEN, the model may be an integral part of rural development studies. It may be enhanced in addressing wood procurement, economics, international trade, some market modelling aspects and accessibility of the resource. Applications will be in the bio-energy options, biodiversity issues, as well as climate change adaptation.

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