# Forest Resource
# Scenario Methodologies for Europe

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# TABLE OF CONTENTS

Preface ........ 5

Introduction ........ 7

Large Scale Forestry Scenario Models Used in Europe ........ 9

A Basic Review Of ETTS V ........ 11
- Forest Resource Assessment 1990 and ETTS V Basic Data ........ 11
- Forest balance method and ETTS V results ........ 11
- ETTS V increment scenarios and climate potential ........ 14

EFISCEN Modelling Approach and ETTS V ........ 17
- EFISCEN model structure ........ 17
- Analysis of country level output ........ 18
  - Austria ........ 18
  - Bulgaria ........ 20
  - Finland ........ 20
  - Germany ........ 23
  - Hungary ........ 23
  - Ireland ........ 26
  - Turkey ........ 26

Discussion ........ 29

References ........ 30

# PREFACE

This paper presents two main methodologies for assessing future European forest resources. One is the methodology used by UN-ECE with country correspondents and the other is a methodology currently being developed at the European Forest Institute. The latter methodology consists of a common harmonised dynamic modelling approach for all countries. The aim of this paper is to evaluate the consistency in the ETTS V scenarios and to assess whether a harmonised dynamic modelling approach will yield comparable results as ETTS and whether it may provide additional information.

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# INTRODUCTION

The objective of the European Timber Trend Studies V (ETTS V) is to present an outlook for European demand for forest products and supply of roundwood (FAO/UN-ECE 1996). The outlook assesses the balance between supply, demand and trade in forest products on the one hand and forest resource dynamics on the other. One of the unique and valuable contributions of European Timber Trend Studies (ETTS) is the fact that it integrates country-level expert knowledge of forest sector conditions with systematic, multi-country qualitative analysis. Methodologically, ETTS V is similar to previous ETTS studies, for example, in the way in which timber supply forecasts are derived from experts' opinions (Pajuoja 1995). In the final report of ETTS V, however, more dynamic demand models to predict future demand were used as well (Baudin and Brooks 1994).

One of the problems with the ETTS approach is that it takes many years to compile the data and scenarios from different countries. This process is time consuming and administratively complicated. The models used in different countries vary as well as the requirements on input data. For these reasons, JOINT FAO/ECE Working Party on forest economics and statistics after its twenty-first session, 21-23 May 1997 reported:

"On the basis of the recommendations of an informal group, the Working Party endorsed the following recommendations:

- there is a need for a continuing, rather than episodic, programme on European outlook studies, which would address both short term improvements to the existing ETTS V study and development over the longer term of methods and data in preparation for future studies
- there is a need for formal and long term cooperation on outlook studies between FAO/ECE and other institutions with relevant expertise."

In the present study, different scenario methodologies for the European forests are assessed country-wise. First we analyze the input data which have been used in ETTS V forest scenarios. Next, the consistency of the ETTS scenarios is evaluated by applying two rather general methods: the balance method and the comparison of increments against the Paterson climate potential index (Chapter 3). Then the application of the European Forest Information Scenario Model (EFISCEN), which is used at the European Forest Institute to make European scale projections, is used to run the ETTS V country scenarios (Chapter 4). The basic idea in testing the EFISCEN model is to investigate if could also be used for ETTS scenario making.

The first tests of running the ETTS V scenarios with EFISCEN are then discussed. We focus on and analyze in more detail the comparisons of different scenarios for seven countries: Austria, Bulgaria, Finland, Germany, Hungary, Ireland and Turkey. Although

EFISCEN can currently be run for 27 countries (Nabuurs 1996), we have made a small selection, mainly based on geographical distribution over Europe. At this stage of the development of forest models, we want to emphasize that because of the difference in the basic resource data, silvicultural regimes, and growing conditions in different countries, the scenarios may differ from the actual development of the forest resources. Therefore the scenarios presented in this paper should not be considered as strict forecasts but merely as illustrative examples of the research and development in this field.

# LARGE SCALE FORESTRY SCENARIO MODELS USED IN EUROPE

In the 1960s and 1970s, several European countries developed forestry scenario analysis tools for their national forest area, e.g. MELA for Finland, FOSIM for Germany, HUGIN for Sweden, HOPSY for The Netherlands (Englert and Sasse 1994, Hinssen 1994,

**Table 1.** Overview of scenario models or studies available in Europe.

| Model | Country | Remarks | Author |
|---|---|---|---|
| FOHOW | Austria | forest sector scenario model | Schwarzbauer |
| | Belgium | Norway spruce forestry scenario model | Rondeux |
| FORE-PROB | Czech Republic | forest dynamics scenario model | Kouba |
| FSCE | Czech Republic | forestry scenario model | Kupka |
| PEB | Denmark | forestry scenario model | Tarp |
| ETTS | Europe | combination of static national large scale forestry scenario models | FAO/UN-ECE |
| IIASA | Europe | forestry scenario model | Nilsson, Sallnäs |
| MELA | Finland | forestry scenario model | Siitonen |
| KUHA | Finland | forestry scenario model | Päivinen |
| TMM | Finland | forest sector model | Mykkänen |
| FFF | France | forestry scenario model | Guinaudeau |
| FIBRE | France | forest sector model | Peyron |
| PCSIMUL | France | forestry scenario model | Pignard |
| FOSIM | Germany | forestry scenario model | Englert |
| | Germany | forestry scenario model | Hradetzky |
| | Hungary | forestry scenario model | Király |
| | Ireland | forestry scenario model | Coillte |
| | Italy | financial resource allocation system | Bernetti |
| HOPSY | Netherlands | forestry scenario model | Hinssen & Edelenbosch |
| AVVIRK | Norway | forest scenario model | Hobbelstad |
| GAYA-JLP | Norway | forest sector model | Hoen |
| NTM | Norway | forest sector model | Solberg |
| | Poland | static inventory projection | Rykowski |
| | Portugal | forestry scenario model for Maritime pine timber supply | Bento |
| | Russia | static inventory projection | Isaev |
| FRM | Russia | forestry scenario model | Korovin |
| HUGIN | Sweden | forestry scenario model | Söderberg, Bengtsson |
| | Sweden | forest sector model | Lönnstedt & Peyron |
| | Switzerland | static inventory projection | Brändli |
| | United Kingdom | static forestry scenario model | Whiteman |


Forest Resource Scenario Methodologies for Europe
Gert-Jan Nabuurs, Heikki Pajuoja, Kullervo Kuusela and Risto Päivinen

Lundström and Söderberg 1996, Siitonen and Nuutinen 1996). Table 1 gives an overview of the available models and studies. Outside Europe such modelling systems have been developed e.g. in the USA (SPECTRUM) and New Zealand (FOLPI) (Camenson et al. 1996; Manley et al. 1991). The modelling tools are usually rather traditional forestry analysis tools which focus on the timber value of the forest. Each national model has also been designed to deal with specific national circumstances and national forestry related problems. In countries where these tools are still under development, there is a trend towards more complexity, a higher level of detail, spatial analysis and multiple-use analysis (Nabuurs and Päivinen 1996). There is also a trend in which forest sector models and forestry scenario models are becoming more dynamically connected.

In Europe, there are large scale forestry scenario models for national scale analysis which can be rated reasonable to good in Austria, Czech Republic, Finland, Germany, Hungary, Ireland, The Netherlands, Norway, and Sweden. They cover about half of the European forest resources. There are usually no such national scale forestry scenario models in Southern and Eastern Europe, both representing regions with complex forestry issues. Furthermore, there are two European scale approaches: the IIASA model developed for the IIASA Forest Study (Nilsson et al. 1991) and the European Timber Trend Studies (UN-ECE 1996) carried out by the UN-ECE/FAO. The IIASA model developed in the mid-1980s is still the only dynamic model that can deal with these projections at the European scale. EFISCEN model is based on the IIASA forest model and it still has the same core dynamics.

Harmonisation of these models at the European level would not only be desirable from the viewpoint of output comparison, but also because most European countries have a limited forest area with little influence on the wood markets. Harmonisation at the European level would make it possible to study the countries' influence on the wood market and vice versa. Such harmonised results would make it possible to work towards European level scenario studies, based on the available national expertise. Harmonisation at the European level would also enable studies in e.g. wood production shifts between countries when one country decides to set aside forests for nature.

# A BASIC REVIEW OF ETTS V

## FOREST RESOURCE ASSESSMENT 1990 AND ETTS V BASIC DATA

The first general review of consistency in ETTS scenarios is on basic input data. Therefore, the area of exploitable forest, growing stock, net annual increment and removals as reported in the ETTS scenarios and UN-ECE/FAO Forest Resource Assessment 1990 (UN-ECE/FAO 1992) are compared in Table 2. Also the total removals (i.e. including those from unexploitable forest) in the FAO Forest Product statistics as the mean of 1989-1991 and those presented by FRA 1990 and ETTS are presented in Table 2. The table shows that values differ mainly for net annual increment and removals. The explanation for the differences in increment values are threefold: firstly, ETTS values might be based on more recent inventories i.e. the methodologies for assessing increment are improving and that causes differences in increment levels or the growth itself may have changed. Second, the values have been reported by different authorities who may have used other data sources. Third, FRA 1990 reports values from measurements while countries may have used growth models for the ETTS studies.

Differences in removal data also originate from possible different basic data sources, and alternative interpretations of definitions for removals and fellings, varying base years, and in- or excluding the unexploitable area.

## FOREST BALANCE METHOD AND ETTS V RESULTS

In order to check the mathematical consistency of the country scenarios, the final growing stock volume can be calculated by adding the increment during the period of 1990 to 2040 to the initial volume in 1990 and deducting from the sum the fellings during the same period. In order to get the periodic increment and fellings, the mean annual increment and fellings are calculated from the values presented in the scenario tables and multiplied by 50 (the number of years in the forecast period). The growing stock volume, $m^3$/ha, calculated this way is called the balance value and is compared with the respective values presented in Table 3.

The percentage of removals, under bark (u.b.), with respect to fellings, calculated from the scenario values 1990, are presented in Table 3. Removals, u.b., are fellings minus logging residues minus bark from the removals, o.b. By taking into account the fact that the actual bark percentage is about 15 and if the logging-residue percentage is about 5, the removals u.b./fellings ratio for whole Europe is 81. Large deviations from this value are questionable.

**Table 2.** Some attributes of forest resources presented in UN-ECE/FAO Forest Resource Assessment (UN-ECE/FAO 1992), the ETTS V basic data of resources in 1990 (Pajuoja 1995) and FAO Forest Products Statistics (FAO 1992).

| Country | Exploitable forest | | | |
|---|---|---|---|---|
| | Area 1000 ha | | Growing stock, mill. $m^3$ | |
| | FRA | ETTS V | FRA | ETTS V |
| Albania, secr. | 910 | 909 | 73 | 71 |
| Austria | 3 330 | 3 330 | 953 | 967 |
| Bel-Lux | 702 | 702 | 110 | 110 |
| Bulgaria | 3 222 | 3 222 | 405 | 405 |
| former Czechoslovakia | 4 491 | 4 605 | 991 | 1 000 |
| Denmark | 466 | 419 | 54 | 55 |
| Finland | 19 511 | 19 511 | 1 679 | 1 790 |
| France | 12 460 | 13 535 | 1 742 | 1 800 |
| Germany | 9 852 | 10 225 | 2 674 | 2 809 |
| Greece | 2 289 | 2 289 | 149 | 149 |
| Hungary | 1 324 | 1 626 | 229 | 280 |
| Ireland | 394 | 320 | 30 | 31 |
| Italy | 4 387 | 4 390 | 743 | 744 |
| Netherlands | 331 | 287 | 52 | 50 |
| Norway | 6 638 | 6 638 | 571 | 630 |
| Poland | 8 460 | 8 470 | 1 380 | 1 385 |
| Portugal | 2 346 | 2 309 | 167 | 149 |
| Romania | 5 413 | 5 413 | 1 202 | 1 202 |
| Spain | 6 506 | 6 395 | 450 | 462 |
| Sweden | 22 048 | 22 048 | 2 471 | 2 556 |
| Switzerland | 1 093 | 1 196 | 360 | 365 |
| Turkey | 6 642 | 6 642 | 759 | 759 |
| United Kingdom | 2 207 | 2 325 | 203 | 246 |
| former Yugoslavia | 7 768 | 7 740 | 1 056 | 1 063 |

**Table 3.** Comparison between the mean volume of growing stock in 2040 from ETTS V (Pajuoja 1995) and as calculated by the forest balance method. Also the ratio between the removals, u.b. and the fellings is given.

| Country | Growing stock 2040, ($m^3$/ ha) | | ETTS V/ Balance | Removals u.b./ Fellings (%) |
|---|---|---|---|---|
| | ETTS V | Balance | (%) | |
| Europe | 199 | 204 | 98 | 81 |
| Albania, secr. | 34 | 34 | 100 | 95 |
| Austria | 454 | 453 | 100 | 86 |
| Belgium, secr. | 236 | 236 | 100 | 91 |
| Bulgaria | 199 | 198 | 101 | 68 |
| Croatia | 214 | 243 | 88 | 91 |
| Czech Republic | 313 | 316 | 99 | 86 |
| Denmark | 166 | 163 | 102 | 79 |
| Estonia | 184 | 176 | 105 | 91 |
| Finland | 209 | 220 | 95 | 80 |
| France | 149 | 151 | 99 | 82 |
| Germany, secr. | 330 | 322 | 102 | 71 |
| Greece, secr. | 64 | 64 | 100 | 74 |
| Hungary | 176 | 180 | 98 | 80 |
| Ireland, secr. | 111 | 170 | 65 | 82 |

**Table 2.** (continued)

| Exploitable forest | | | | Total removals | | |
|---|---|---|---|---|---|---|
| Net annual increment 1000 m³ | | Removals 1000 m³ | | 1990 1000 m³, u.b. | | 1989-91 1000 m³, u.b. |
| FRA | ETTS V | FRA | ETTS V | FRA | ETTS V | FAO |
| 1 001 | 1 293 | 1 466 | 2 008 | 1 850 | 2 062 | 2 306 |
| 21 980 | 30 410 | 14 988 | 16 230 | 15 098 | 17 530 | 16 200 |
| 5 121 | 5 121 | 3 311 | 3 313 | 3 401 | 3 315 | 5 066 |
| 8 870 | 10 577 | 3 526 | 3 242 | 3 525 | 3 243 | 3 999 |
| 31 032 | 30 232 | 18 142 | 16 700 | 18 142 | 16 700 | 17 234 |
| 3 515 | 3 200 | 1 810 | 1 816 | 1 945 | 1 951 | 2 228 |
| 69 664 | 81 625 | 44 626 | 44 004 | 45 812 | 44 004 | 41 738 |
| 65 855 | 67 941 | 43 200 | 43 476 | 43 476 | 47 145 | 44 758 |
| 67 546 | 83 757 | 42 652 | 48 000 | 42 716 | 48 171 | 56 485 |
| 3 317 | 3 317 | 2 496 | 2 496 | 2 496 | 2 498 | 2 510 |
| 8 231 | 9 669 | 4 847 | 5 662 | 6 720 | 6 288 | 6 078 |
| 3 294 | 3 450 | 1 411 | 1 203 | 1 411 | 1 205 | 1 598 |
| 17 475 | 13 600 | 7 256 | 7 256 | 7 256 | 7 256 | 8 425 |
| 2 394 | 2 280 | 1 063 | 1 120 | 1 251 | 1 220 | 1 295 |
| 17 633 | 20 721 | 10 095 | 11 659 | 10 908 | 11 659 | 11 535 |
| 30 464 | 30 398 | 22 137 | 18 310 | 23 142 | 19 133 | 18 788 |
| 11 286 | 11 300 | 7 758 | 8 469 | 8 015 | 8 910 | 10 837 |
| 31 594 | 31 594 | 14 226 | 14 226 | 14 850 | 14 228 | 14 409 |
| 27 750 | 28 969 | 12 136 | 12 593 | 14 910 | 15 455 | 16 403 |
| 91 005 | 91 300 | 47 963 | 52 400 | 50 105 | 54 000 | 53 758 |
| 5 820 | 5 900 | 4 500 | 6 100 | 4 900 | 6 500 | 5 184 |
| 20 090 | 19 751 | 11 099 | 11 099 | 18 100 | 21 069 | 15 511 |
| 11 088 | 12 232 | 6 405 | 5 141 | 6 405 | 5 491 | 6 413 |
| 27 654 | 28 481 | 14 984 | 13 516 | 15 353 | 13 896 | 13 281 |

**Table 3.** (continued)

| Country | Growing stock 2040, (m³/ ha) | | ETTS V/ Balance | Removals u.b./ Fellings (%) |
|---|---|---|---|---|
| | ETTS V | Balance | (%) | |
| Italy | 175 | 235 | 74 | 84 |
| Latvia, secr. | 174 | 174 | 100 | 81 |
| Lithuania | 241 | 232 | 104 | 79 |
| Luxemburg, secr. | 429 | 429 | 100 | 79 |
| Netherlands | 293 | 294 | 100 | 76 |
| Norway | 177 | 178 | 99 | 86 |
| Other Yugoslavia, secr. | 162 | 162 | 100 | 76 |
| Poland | 168 | 169 | 99 | 79 |
| Portugal | 66 | 66 | 100 | 72 |
| Romania, secr. | 367 | 367 | 100 | 89 |
| Slovakia | 185 | 310 | 60 | 81 |
| Spain | 144 | 144 | 100 | 81 |
| Sweden | 194 | 193 | 101 | 84 |
| Switzerland | 280 | 276 | 101 | 82 |
| Turkey, secr. | 134 | 134 | 100 | 65 |
| United Kingdom | 103 | 100 | 103 | 79 |

The scenario values of the growing stock volumes in 2040 are considered to be biologically feasible if the mean volume is kept under the level where the increasing age and density of growing stock do not lead to mortality which decreases the growing stock and its net increment to an extent that they prevent the possibility to reach the scenario volume. On the basis of these assumptions, the growing stock volumes and biological unfeasibility seem to be quite high in Austria, Finland, Luxembourg and Romania. However, note that the ETTS V/ Balance ratio for these countries is 100. The balance method indicates questionable results in the ETTS scenarios for Croatia, Ireland, Italy, and Slovakia.

Referring to Table 3, there are country scenarios in which the volume of bark is neglected and the levels of removals, u.b., are too great. In the case of Bulgaria and Turkey the percentages may be unrealistically small in the conditions where the portion of fuel wood is relatively great in removals.

## ETTS V INCREMENT SCENARIOS AND CLIMATE POTENTIAL

A climate related potential growth index (CVP) was developed by Paterson (1956) to describe the climatic potentials for every country to grow trees. Paterson based the index on the hypothesis that the stem volume is primarily the function of the parameters in areas where the climate has had enough time to develop soils. The index consists of independent parameters like the mean temperature of the warmest month, the range between the mean temperature of the warmest and coldest month, the mean annual precipitation and the growing season in humid months.

The CVP-index is based on yield information available in the early 1950s and the current climatic conditions differ from those days. It is still worth comparing the recorded and scenario increments in respect to the Paterson’s climatic potentials when the development of the European forest resources in 1950-1990 is analysed. CVP-index offers a frame of reference, when increments are evaluated (Kuusela 1994).

Since the early 1950s, the recorded increments have increased and become nearer to Paterson’s climatic potential estimates. The increase has partly been caused by the improved accuracy of the increment estimates (Kuusela 1994), but may have been caused by site productivity changes as well (Spiecker et al. 1996). The European mean net annual increment was 52% in 1950, 83% in 1990 and forecast to be 91% of the climatic potential in 2040. The climatic potential amounts to gross increment. If the natural losses, recorded in 1990, 35 mill. $m^3$ (Kuusela 1994) are added to the ETTS increment in 2040, the gross annual increment is 5.19 $m^3$/ha, i.e. 95% the climatic potential.

The increment estimates recorded in 1990 exceed the climatic potential mostly in those countries where the effective management regimes have been applied and are below in those countries where the recorded increment is an obvious under-estimate or the silvicultural quality of forests is poor.

**Table 5.** ETTS V net annual increment compared to estimates calculated by using Paterson's climate potential index*. In 2040 estimated net annual increment for whole Europe is in ETTS V 5.05 $m^3$/ha and when based on Paterson's index, 5.44.

| Country | ETTS V increment relative to Paterson | Paterson $m^3$/ha | ETTS V $m^3$/ha |
|---|---|---|---|
| Albania, secr. | | | 1.42 |
| Austria | High | 6.2 | 10.54 |
| Belgium, secr. | | 7.2 | 7.19 |
| Bulgaria | Low | 5.2 | 3.76 |
| Croatia | | | 4.43 |
| Czech Republic | | | 6.47 |
| Denmark | High | 5.2 | 8.00 |
| Estonia | | | 4.40 |
| Finland | High | 3.8 | 6.26 |
| France | Low | 6.8 | 5.03 |
| Germany, secr. | High | 6.1 | 7.72 |
| Greece, secr. | Low | 5.3 | 1.45 |
| Hungary | | 6.0 | 6.63 |
| Ireland, secr. | | 10.0 | 11.10 |
| Italy | Low | 7.1 | 3.41 |
| Latvia, secr. | | | 3.12 |
| Lithuania | | | 4.17 |
| Luxemburg, secr. | High | 6.2 | 8.10 |
| Netherlands | High | 6.2 | 8.43 |
| Norway | | 5.3 | 4.89 |
| Other Yugoslavia, secr. | | | 3.81 |
| Poland | Low | 5.8 | 3.10 |
| Portugal | Low | 7.4 | 5.21 |
| Romania, secr. | | 4.8 | 5.84 |
| Slovakia | High | 3.9 | 5.17 |
| Spain | | 3.9 | 4.81 |
| Sweden | | 4.3 | 4.22 |
| Switzerland | Low | 7.3 | 4.92 |
| Turkey, secr. | Low | 6.4 | 2.97 |
| United Kingdom | Low | 8.7 | 5.93 |

* Ratio ETTS/Paterson: 80-120% no remark; 60-80 and 120-140 low /high; < 60 and > 140 very low / very high

# EFISCEN MODELLING APPROACH AND ETTS V

## EFISCEN MODEL STRUCTURE

The European Forest Information Scenario Model (EFISCEN) is a model which was developed in the early 1980s by Sallnäs (1989) and later used for the IIASA forest study for European forests (Nilsson et al. 1992). It was specifically designed to deal with data on evenaged forests and later a module for unevenaged forests was added. EFISCEN, which is an area matrix model, was also specifically designed to deal with general forest inventory data, not requiring too many variables. It requires area, volume and increment data per age class, by as many forest type as a country can distinguish. It is therefore flexible in the applied level of detail per country. Furthermore, expertise on forest management regimes is required.

The model generates projections of growing stock, increment, timber harvest volumes, age class development over time by country, region, and species. It does not predict the total demand, but the user specifies future development of demand at the national level and possible afforestations. Based on growth dynamics, age class distributions, and theoretical management regimes, the model calculates if and where to harvest. Although the model was designed to represent rather traditional forest management, it also has some possibilities to take into account nature-oriented forest management (Päivinen et al. 1998).

The EFI baseline study, from which 7 countries were selected for this report, is based on a new data set compiled from the information provided by all national forest inventory institutes in Europe.

**Table 6.** The development of exploitable forest area, growing stock, net annual increment and fellings in selected countries according to EFISCEN model.

| Country | Area 1000 ha | | Growing stock m³/ha | | Net annual increment, m³/ha | | Fellings, mill. m³ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| Austria | 2 934 | 3 014 | 309 | 447 | 10.1 | 8.77 | 16.76 | 21.02 |
| Bulgaria | 3 198 | 3 455 | 118 | 194 | 3.88 | 3.33 | 4.74 | 7.36 |
| Finland | 19 621 | 19 621 | 93 | 128 | 3.63 | 3.27 | 54.98 | 52.09 |
| Germany | 9 874 | 9 874 | 265 | 315 | 8.69 | 7.02 | 64.60 | 69.80 |
| Hungary | 1 604 | 1 964 | 191 | 175 | 6.35 | 5.78 | 8.56 | 11.36 |
| Ireland | 322 | 633 | 108 | 91 | 9.55 | 6.61 | 1.40 | 3.83 |
| Turkey | 5 405 | 5 405 | 152 | 200 | 3.74 | 3.28 | 14.22 | 14.22 |


Forest Resource Scenario Methodologies for Europe
Gert-Jan Nabuurs, Heikki Pajuoja, Kullervo Kuusela and Risto Päivinen

## ANALYSIS OF COUNTRY LEVEL OUTPUT

The comparisons between ETTS V scenarios and EFISCEN model outcomes are based on a model run, where the level of total national fellings was taken from ETTS V scenarios. We then validated EFISCEN outcome mainly on the development of growing stock and net annual increment. EFISCEN also shows whether it is possible to find the desired total national felling levels as foreseen in ETTS. In addition, we present the age class distribution development for each country to explain the development of net annual increment.

Comparisons of ETTS V results with EFISCEN model outcome were made for Austria, Bulgaria, Finland, Germany, Hungary, Ireland and Turkey.

### Austria

For Austria, the EFISCEN initial forest area was slightly smaller than in ETTS V scenario. The 2.93 million ha which were included in EFISCEN cover only ‘Hochwald Wirtschaftswald’. Thus ‘Hochwald Schutzwald im Ertrag’ which was included in ETTS is excluded. However, a comparable afforestation scheme as in ETTS was simulated (Table 7). EFISCEN is able to find the required harvesting volumes as in ETTS but these harvesting volumes result in slightly different development of the growing stock and in quite strong difference in the net annual increment. The gradual decrease in net annual increment (NAI) which EFISCEN shows is caused by the developing very high average growing stock levels. EFISCEN and ETTS V results are rather comparable except for NAI. The discontinuity between recorded (up to 1980) and scenario values is partly due to fact that a new forest inventory was done in Austria in 1986-1990 and volume and increment estimates changed quit remarkably (see jump in e.g. growing stock in Figure 1 between 1985 and 1990).

**Table 7.** The development of forest area, growing stock, net annual increment and fellings in Austria according to EFISCEN and ETTS V scenarios.

| | Area 1000 ha | | Growing stock $m^3/ha$ | | Net annual increment $m^3/ha$ | | Fellings mill.$m^3$ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| EFISCEN | 2933.7 | 3013.7 | 309 | 447 | 10.1 | 8.77 | 16.76 | 21.02 |
| ETTS V | 3330 | 3414 | 290 | 453 | 9.13 | 10.54 | 18.78 | 24.97 |

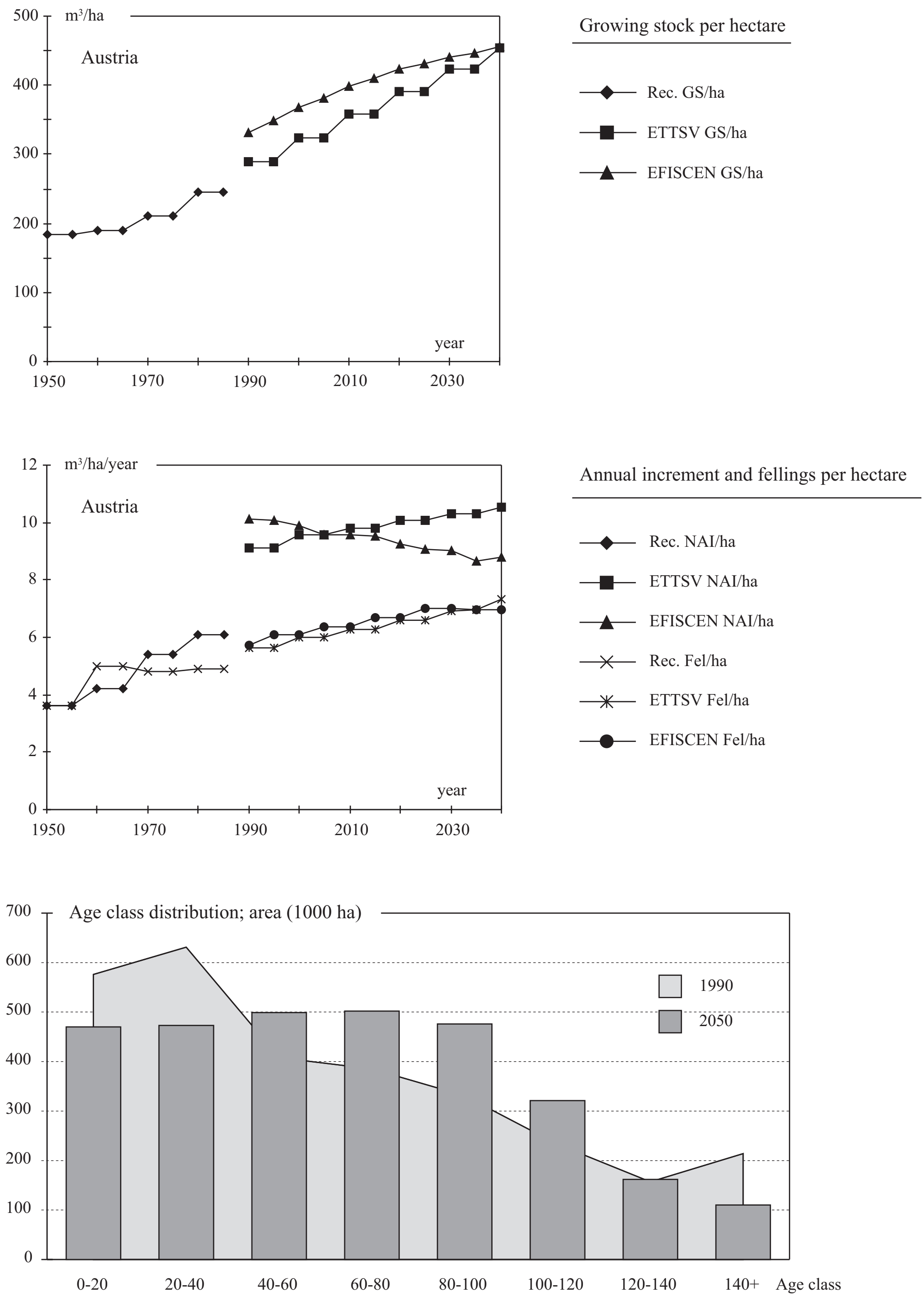



**Figure 1.** Austria: a) recorded growing stock (1950-1980, Kuusela 1994) and EFISCEN and ETTS V projections for 1990-2040 b) recorded increment and fellings 1950-1980 and EFISCEN and ETTS V projections for 1990-2040 c) EFISCEN age class distribution.

## Bulgaria

The EFISCEN development of growing stock starts to level off at 2040. This is because the area with older forests (and thus lower increments) increases. In the EFISCEN scenario, new afforestations in 1995 lead to some reduction of the increment. These afforestations add slow growing areas in the beginning. Increment then stabilizes from 2020 onwards.

**Table 8.** The development of forest area, growing stock, net annual increment and fellings in Bulgaria according to EFISCEN and ETTS V scenarios.

| | Area 1000 ha | | Growing stock m³/ha | | Net annual increment m³/ha | | Fellings mill. m³ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| EFISCEN | 3198 | 3455 | 118 | 194 | 3.88 | 3.33 | 4.74 | 7.36 |
| ETTS V | 3222 | 3480 | 126 | 199 | 3.28 | 3.76 | 4.76 | 8.00 |

## Finland

In the case of Finland the two scenarios differ quite much. ETTS V uses very high net annual increment figures for coming years. As a consequence, the development of growing stock per hectare seems to be very different depending on the made assumptions. The level of fellings used in ETTS V scenario may seem pessimistic regarding the net annual increment (Table 9). Net annual increment decreases gradually in EFISCEN scenario because higher average volumes are reached. Significant differences in increment in the input data and on increment development during the simulation have caused the deviation in the development of growing stock (Figure 3). In case we had assumed a comparable increment as done in ETTS, the scenario output would have been more comparable.

**Table 9.** The development of forest area, growing stock, net annual increment and fellings in Finland according to EFISCEN and ETTS V scenarios.

| | Area 1000 ha | | Growing stock m³/ha | | Net annual increment m³/ha | | Fellings mill. m³ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| EFISCEN | 19621 | 19621 | 93 | 128 | 3.63 | 3.27 | 54.98 | 52.09 |
| ETTS V | 19511 | 19511 | 92 | 209 | 4.18 | 6.26 | 54.98 | 52.03 |

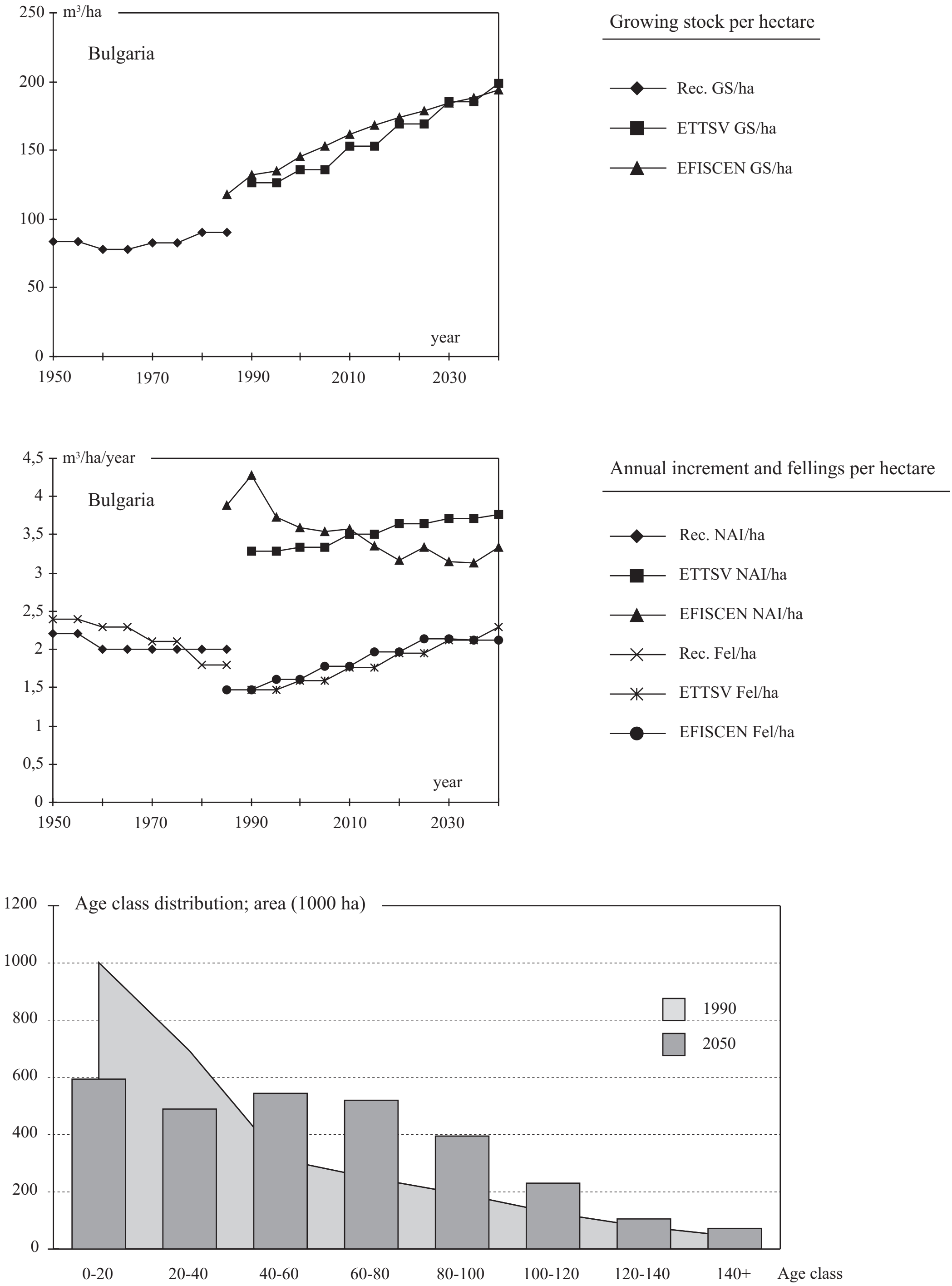



**Figure 2.** Bulgaria: a) recorded growing stock (1950-1980, Kuusela 1994) and EFISCEN and ETTS V projections for 1990-2040 b) recorded increment and fellings 1950-1980 and EFISCEN and ETTS V projections for 1990-2040 c) EFISCEN age class distribution.

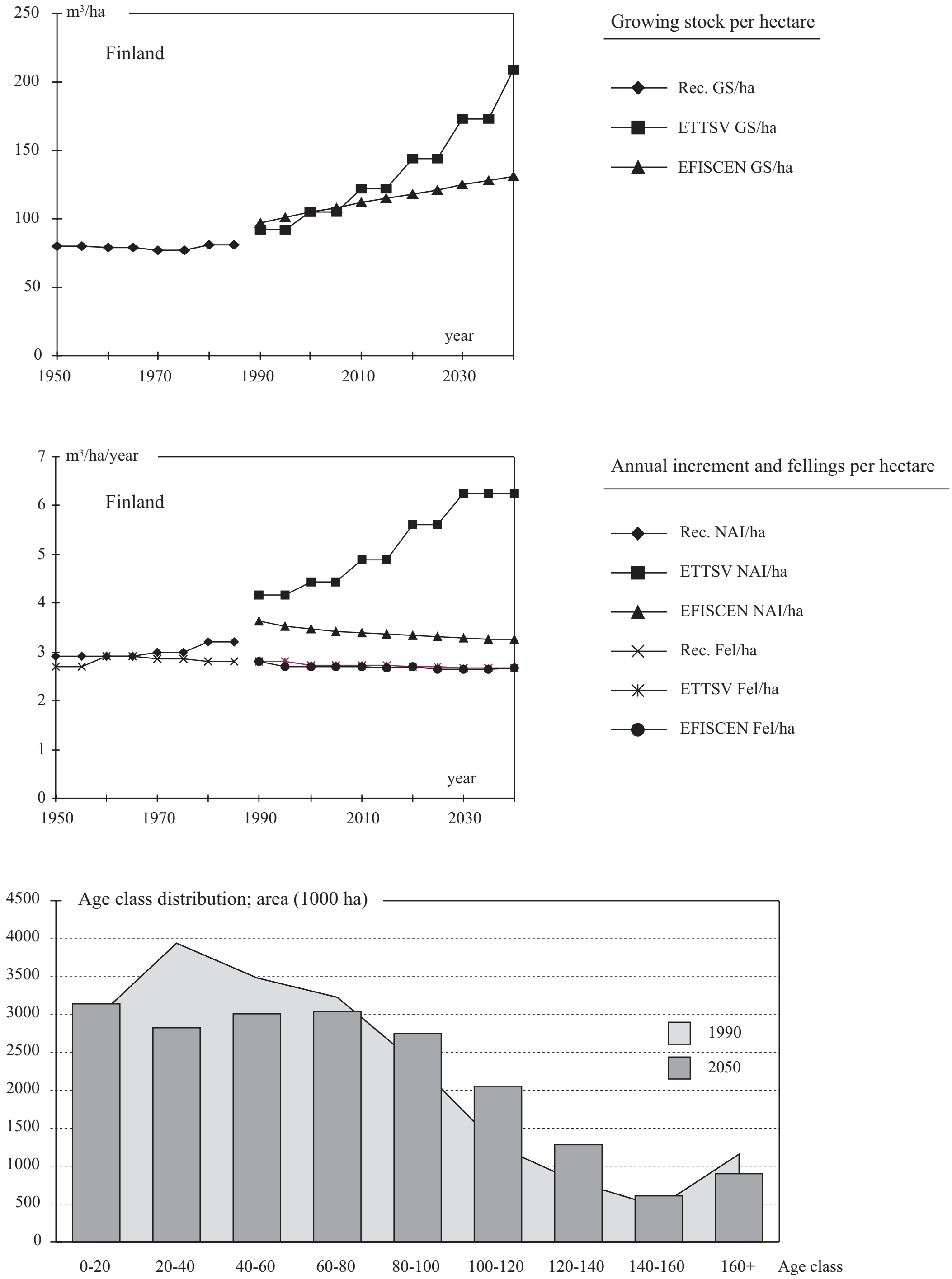



**Figure 3.** Finland: a) recorded growing stock (1950-1980, Kuusela 1994) and EFISCEN and ETTS V projections for 1990-2040 b) recorded increment and fellings 1950-1980 and EFISCEN and ETTS V projections for 1990-2040 c) EFISCEN age class distribution.

## Germany

For Germany EFISCEN was run for a slightly smaller area than in ETTS V (Table 10). ETTS V had all forest land included in forest land and EFISCEN only exploitable forest area. The required harvesting levels were set according to the ETTS V scenario. The growing stock development is very comparable as the ETTS results suggest. However, the increment declines more in EFISCEN than in the ETTS result (Figure 4). Also remarkable is that EFISCEN suggests that the required harvesting level cannot be found around 2005-2010 given the constraints on final felling and thinning regimes as set up in EFISCEN. The forest therefore hardly gains in average age. Earlier estimates of growing stock were rather low and that explains why there is a very high jump in initial growing stock visible in Figure 4. However, FRA 1990 gives a growing stock of 271 $m^3$/ha which supports the model initial value.

**Table 10.** The development of forest area, growing stock, net annual increment and fellings in Germany according to EFISCEN and ETTS V scenarios.

| | Area 1000 ha | | Growing stock $m^3$/ha | | Net annual increment $m^3$/ha | | Fellings mill. $m^3$ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| EFISCEN | 9874 | 9874 | 265 | 315 | 8.69 | 7.02 | 64.60 | 69.80 |
| ETTS V | 10225 | 10225 | 275 | 330 | 8.19 | 7.72 | 68.77 | 75.54 |

## Hungary

The EFISCEN model predicts small fluctuations in the net annual increment in Hungary. Thsi is caused by new afforestations (Table 11) which affect NAI per hectare. Because EFISCEN works at a five-year time step, sudden additions of area occur for afforestations, while in reality they will be added gradually. The annual fellings were below net annual increment in the past, but the gradual decrease in increment in EFISCEN results in predicted fellings that are higher than increment after 2020. Therefore the average growing stock is somewhat reduced.

**Table 11.** The development of forest area, growing stock, net annual increment and fellings in Hungary according to EFISCEN and ETTS V scenarios.

| | Area 1000 ha | | Growing stock $m^3$/ha | | Net annual increment $m^3$/ha | | Fellings mill.$m^3$ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| EFISCEN | 1604 | 1964 | 191 | 175 | 6.35 | 5.78 | 8.56 | 11.36 |
| ETTS V | 1626 | 2085 | 172 | 176 | 5.95 | 6.63 | 7.03 | 12.05 |

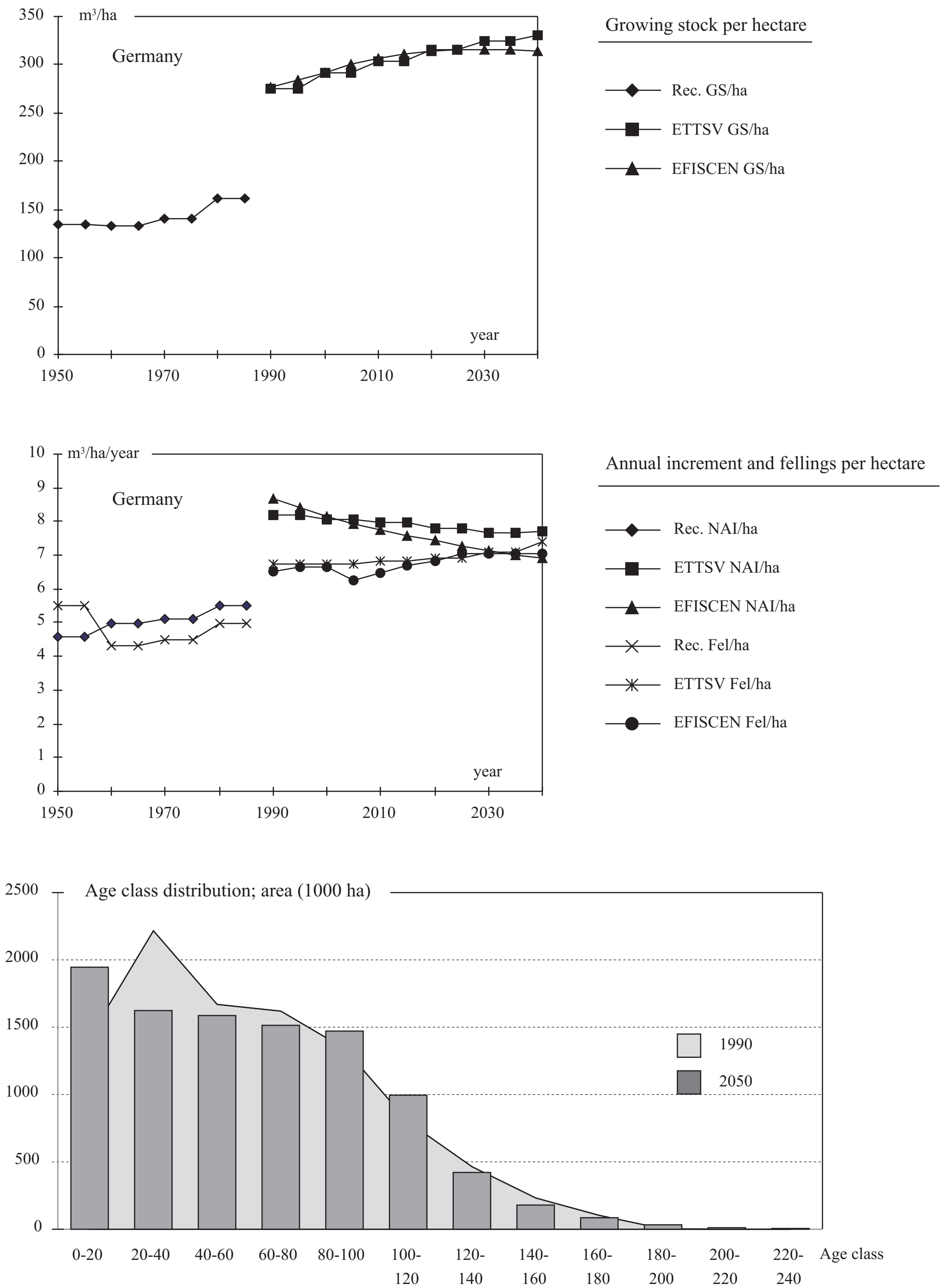
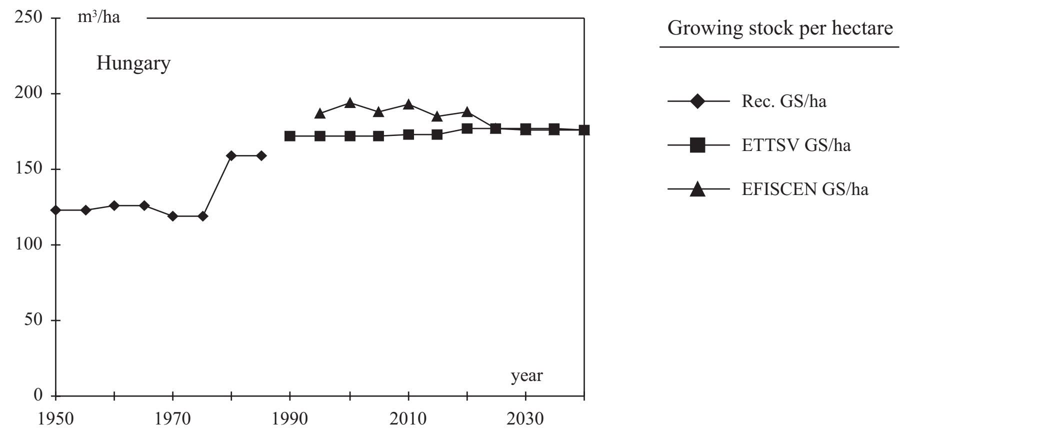
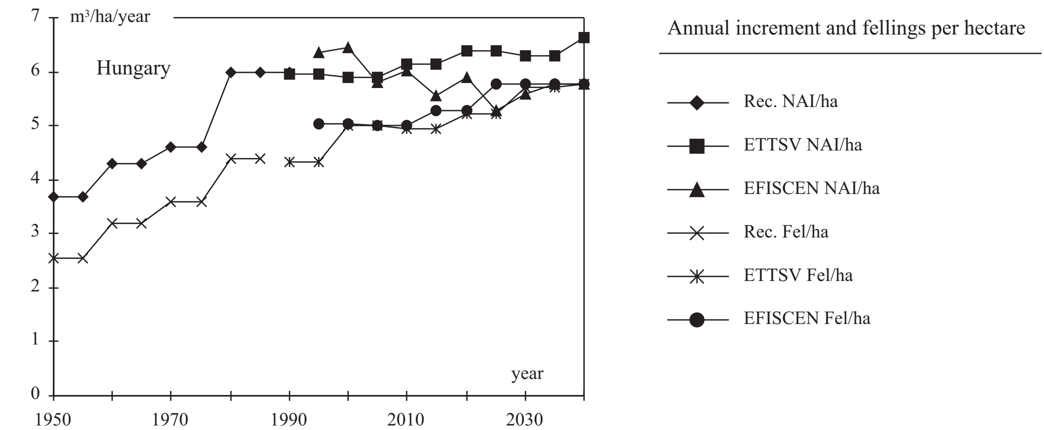



**Figure 4.** Germany: a) recorded growing stock (1950-1980, Kuusela 1994) and EFISCEN and ETTS V projections for 1990-2040 b) recorded increment and fellings 1950-1980 and EFISCEN and ETTS V projections for 1990-2040 c) EFISCEN age class distribution.



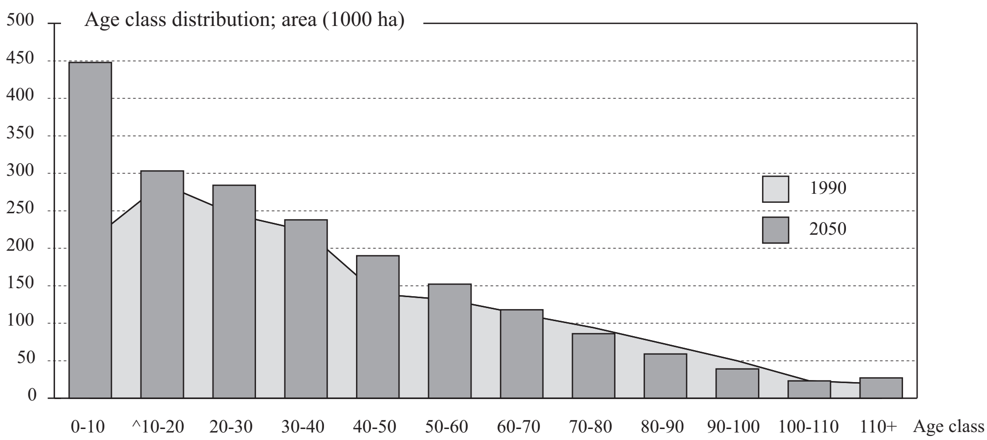




**Figure 5.** Hungary: a) recorded growing stock (1950-1980, Kuusela 1994) and EFISCEN and ETTS V projections for 1990-2040 b) recorded increment and fellings 1950-1980 and EFISCEN and ETTS V projections for 1990-2040 c) EFISCEN age class distribution.

## Ireland

Both scenarios include a large increase in forest area. The ways how the effects of that change are taken into account in the model approach differ. In EFISCEN, model results of NAI are quite low because of new afforestation (Table 12) which adds large areas of initially slow growing forest. A combination of a very high level of desired fellings and new afforested areas (with initially a small growing stock) are resulting in a declining average growing stock in EFISCEN (Figure 6). In ETTS V scenario the effect of new afforestation is causing an opposite effect: it predicts that NAI will stay at a comparably high level in the future. In the ETTS scenario, the levels of both increment and fellings seem rather optimistic. The EFISCEN model suggests that not all desired fellings can be found from 2010 onwards.

**Table 12.** The development of forest area, growing stock, net annual increment and fellings in Ireland according to EFISCEN and ETTS V scenarios.

| | Area 1000 ha | | Growing stock $m^3/ha$ | | Net annual increment $m^3/ha$ | | Fellings mill.$m^3$ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| EFISCEN | 322 | 633 | 108 | 91 | 9.55 | 6.61 | 1.40 | 3.83 |
| ETTS V | 320 | 630 | 98 | 111 | 10.78 | 11.10 | 1.44 | 6.06 |

## Turkey

The area of exploitable forest used in EFISCEN and ETTS for Turkey are rather different. The 5.4. million ha included in EFISCEN covers the most productive part of the exploitable forest (Table 13). Therefore the initial average growing stock in EFISCEN is higher than in ETTS. Net annual increment is also higher and indicates that EFISCEN data cover the more productive part of forests. Both scenarios indicate that the growing stock will gradually increase. Due to the development of more older forests, the net annual increment declines in EFISCEN.

**Table 13.** The development of forest area, growing stock, net annual increment and fellings in Turkey according to EFISCEN and ETTS V scenarios.

| | Area 1000 ha | | Growing stock $m^3/ha$ | | Net annual increment $m^3/ha$ | | Fellings mill.$m^3$ | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 | 1990 | 2040 |
| EFISCEN | 5405 | 5405 | 157 | 200 | 3.74 | 3.28 | 14.22 | 14.22 |
| ETTS V | 6642 | 6642 | 114 | 134 | 2.97 | 2.97 | 17.15 | 17.15 |

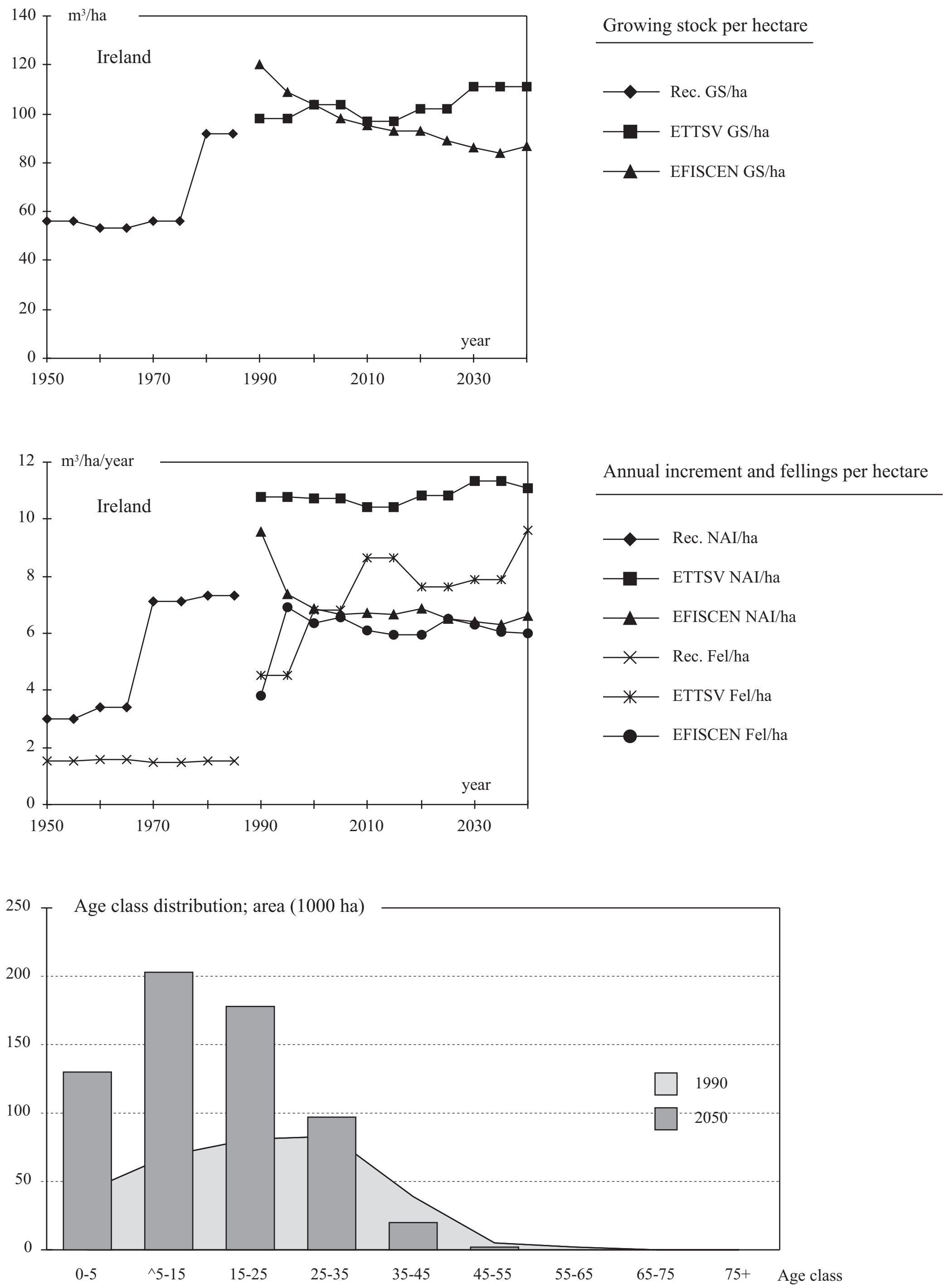



**Figure 6.** Ireland: a) recorded growing stock (1950-1980, Kuusela 1994) and EFISCEN and ETTS V projections for 1990-2040 b) recorded increment and fellings 1950-1980 and EFISCEN and ETTS V projections for 1990-2040 c) EFISCEN age class distribution.

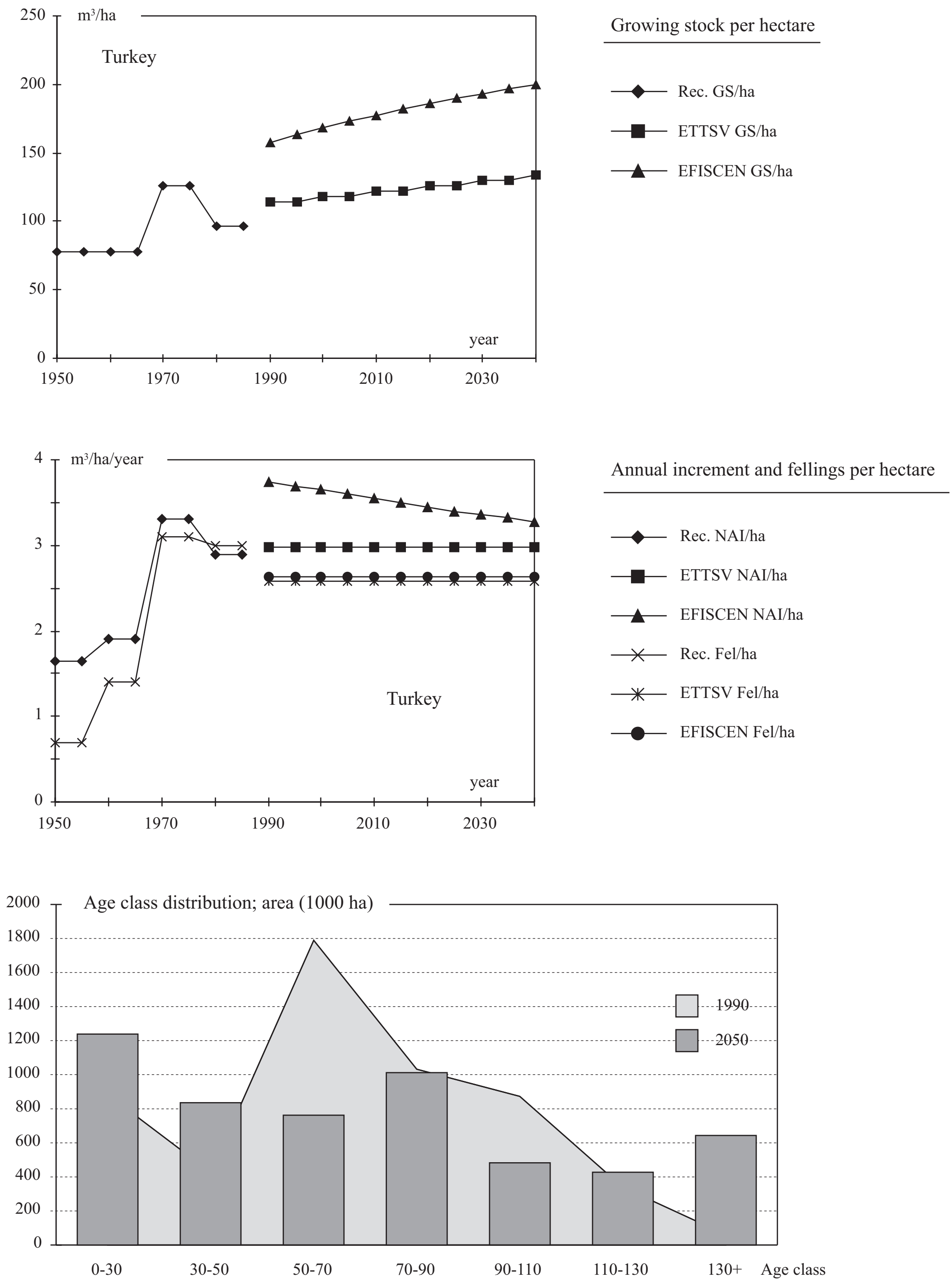



**Figure 7.** Turkey: a) recorded growing stock (1950-1980, Kuusela 1994) and EFISCEN and ETTS V projections for 1990-2040 b) recorded increment and fellings 1950-1980 and EFISCEN and ETTS V projections for 1990-2040 c) EFISCEN age class distribution.

# DISCUSSION

The work outlined in this report consisted of two parts: 1) a general review of consistency in the ETTS V scenarios, and 2) an assessment of running ETTS scenarios with the EFISCEN model.

General ways to review consistency in ETTS included checking the basic input data, the balance method and climate potential. Sometimes basic data (mainly increment and removals) of FRA 1990 and ETTS differ. We pointed out the possible causes of those differences. The balance method and climate potential method have shown that some of the country ETTS scenarios are questionable. We therefore support the view of the Timber Committee that continuous improvement of the ETTS studies both on data and methods is required.

We assessed the output of EFISCEN when running it for ETTS V scenarios. We have compared our output with the country correspondents scenarios as given in Pajuoja (1995). It should be kept in mind that those correspondents' scenarios were sometimes adapted for ETTS' final report based on demand models which were also developed in ETTS V.

EFISCEN is able to reproduce the ETTS scenarios in a satisfactory way. When differences in output occur they can be explained either by the differences in input data, growth models, or by the fact that a more dynamic approach was incorporated in EFISCEN. This more dynamic approach takes into account the development of growing stock volumes and the age of the forest and thus the increment of the forest. EFISCEN provides output on more variables and at a more detailed level.

EFISCEN could be a more dynamic and especially harmonised tool for ETTS VI. It could be a part of a combination of methods, where the combination may vary by country. In those cases where good dynamic models exist at a national level, EFISCEN could be a tool for validation of the national models. Also, EFISCEN can be improved based on those national models. Where dynamic national models do not exist, the ETTS country correspondents can use EFISCEN as an additional tool to their expertise. Thus, we combine the required country expertise and a dynamic modelling approach.

EFISCEN provides country scenarios at a rather detailed and harmonised way. This avoids uncertainty over the data and methods which country correspondents have used. However, EFISCEN can also be improved. The gradual decline of increment in the long term cannot always be explained from age and volume distributions. The growth dynamics (e.g. the growth after thinnings) can be improved. Because of the decline in increment, EFISCEN may be underestimating felling potential in the long term. Also, improvements can be made on changes in species distribution after regeneration, natural mortality, and changes in forest management towards unevenaged forest management.

## References

**Baudin, A. and Brooks, D. 1994.** Projections of forest products demand, supply and trade in ETTS V. Geneva Timber and Forest Discussion Papers. ETTS V Working Paper. UN-ECE/FAO ECE/TIM/DP/6. Geneva. 41 p.

**Camenson, D.M., Sleavin, K.E. and Greer, K.D. 1996.** SPECTRUM: an analytical tool for building natural resource management models. In: Päivinen, R., Roihuvuo, L. and Siitonen, M. (eds.), Large scale forestry scenario models: experiences and requirements. EFI Proceedings No 5. European Forest Institute. pp. 133-142.

**Englert, H. and Sasse, V. 1994.** Entwicklung des Schwachholzaufkommens in den neuen deutschen Bundesländern. Bundesforschungsanstalt für Forst- und Holzwirtschaft. Arbeitsbericht aus den Institut für Öconomie. Aussenstelle Eberswalde. 94/2. 31 p.

**FAO 1993.** Yearbook of Forest Products 1982-1993. FAO, Rome.

**FAO/UN-ECE 1996.** European timber trends and prospects: into the 21st century. Geneva Timber and Forest Study papers, No 11. United Nations New York, Geneva. ECE/TIM/SP/11. 103 p.

**Hinssen, P.J.W. 1994.** HOPSY, a model to support strategic decision making in forest resource management. Forest Ecology and Management 69: 321-330.

**Kuusela. K. 1994.** Forest Resources In Europe. Research report 1. European Forest Institute. Joensuu, Finland. 154 p.

**Lundström, A. and Söderberg, U. 1996.** Outline of the HUGIN system for long-term forecasts of timber yields and possible cuts. In: Päivinen, R., Roihuvuo, L. and Siitonen, M.(eds.), Large scale forestry scenario models: experiences and requirements. EFI Proceedings No 5. European Forest Institute. pp. 63-78.

**Manley, B., Papps, S., Threadgill, J. and Wakelin, S. 1991.** Application of FOLPI, A linear programming estate modelling system for forest management planning. Bulletin no 164. Forest Research Institute, Rotorua New Zealand. 14 p.

**Nabuurs G.J. and Päivinen, R. 1996.** Large scale forestry scenario models: a compilation and review. Working paper 10. European Forest Institute. 174 p.

**Nabuurs, G.J. 1996.** EFI New European Forest Resource Database. Internal Document no 1. European Forest Institute Joensuu, Finland 756 pp.

**Nilsson, S., Sallnäs, O. and Duinker, P. 1992.** Future forest resources of Western and Eastern Europe. International Institute for Applied Systems Analysis. A report on the IIASA forest study. The Parthenon Publishing Group. England. 496 p.

**Päivinen, R., Nabuurs, G.J., Lioubimov, A.V. and Kuusela, K.** The state, utilisation and possible future developments of Leningrad region forests. European Forest Institute. Joensuu, Finland. In preparation.

**Pajuoja, H. 1995.** The outlook for the European Forest Resources and roundwood supply. Geneva Timber and Forest Discussion Papers. ETTS V Working Paper. UN-ECE/FAO ECE/TIM/DP/4. Geneva. 59 p.

**Paterson, S.S. 1956.** The forest area f the world and its potential productivity. Meddelande från Göteborgs Universitets Geografiska Institutionen 51. Göteborg, Sweden.

**Sallnäs, O. 1989.** A matrix growth model of the Swedish forest. Studia Forestalia Suecica. No 183. Swedish Univ Agr. sci. Faculty of Forestry. Uppsala. 23 p.

**Siitonen, M. and Nuutinen, T. 1996.** Timber production analyses in Finland and the MELA system. In: Päivinen, R., Roihuvuo, L. and Siitonen, M. (eds.) Large scale forestry scenario models: experiences and requirements. EFI Proceedings No 5. European Forest Institute. pp. 89-98.

**UN-ECE/FAO 1992.** The forest Resources of the Temperate Zones, The UN-ECE/FAO 1990 Forest Resource Assessment. Vol 1. General Forest Resource Information. United Nations Economic Commission for Europe. Food and Agriculture Organization. ECE/TIM/62. Un Publ. No E.92.II.E.27.