Technical report No 35

Carbon removals by European forests

Technical report for the EEA report 'The environment in the European Union at the turn of the century'

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Executive summary

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. By September 1999, 180 countries had ratified the Convention. An important step towards meeting this objective of the Convention was taken in December 1997 in Kyoto. In the so-called *Kyoto Protocol*, parties included in Annex I agreed on quantified emission limitation and reduction commitments. 84 countries signed the Protocol by September 1999 including the European Community, all EU Member States and the USA. However, the Protocol has only been ratified by a few countries and has not yet entered into force. The European Union (EU) has a UNFCCC target to stabilise CO_2 emissions at the 1990 level by 2000 and a Kyoto Protocol target to reduce emissions of greenhouse gases by 8% between 2008 - 2012. This target is more demanding than the 5% overall Kyoto Protocol reduction target for the Annex I countries together. European countries outside the EU have targets to reduce their emission by 5-8 % between 2008 - 2012. Before Kyoto, however, it was estimated that greenhouse gas emissions would increase for most European countries. In particular, for the EU, CO_2 emissions were projected to increase 8% by 2010. According to the Protocol, parties can use the net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities (limited to afforestation, reforestation, and deforestation since 1990) to meet the commitments ('Kyoto Forests').

The Intergovernmental Panel on Climate Change (IPCC) has developed guidelines to be applied when countries calculate and report their national emissions and removals of greenhouse gases in so-called national communications. IPCC guidelines, for greenhouse gas inventories for land-use change and forestry (LUCF), concentrate on emissions from human activities that change the way land is used, or affect the amount of biomass in existing biomass. A new IPCC report on LUCF is being developed (see below) to be ready in 2000.

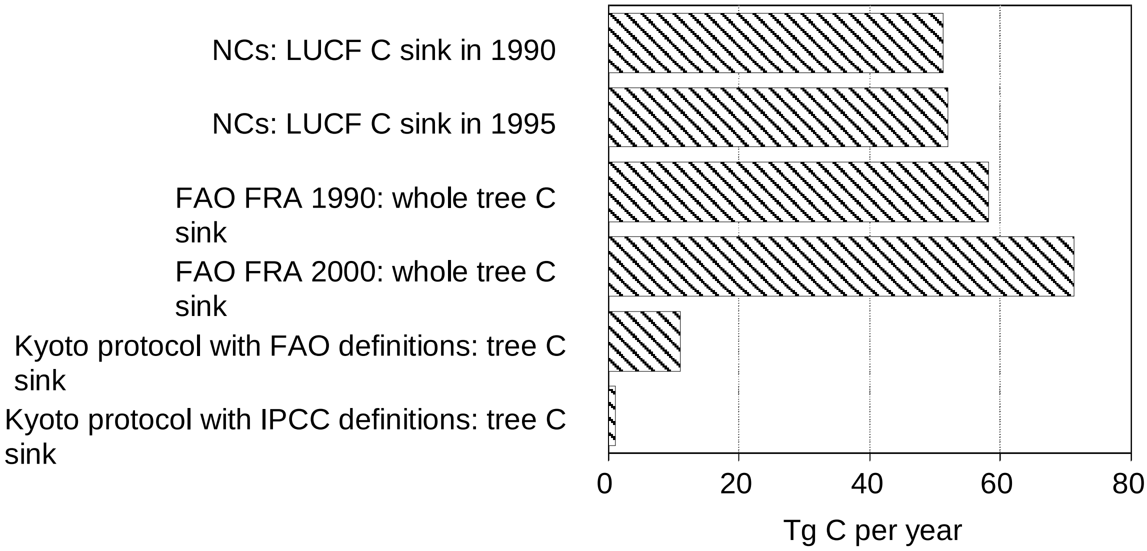
In this EEA technical report, land-use change and forestry carbon (C) balances from European countries have been compared. Comparisons are based on 1) reporting in national communications; 2) uniform calculations from FAO data/reports; and 3) two interpretations of the wording in the *Kyoto Protocol*. Note, these estimates are for different years: National Communications for 1990 and 1995, FAO FRA (Forest Resource Assessment) 1990 on average for 1986, FAO FRA 2000 on average for 1994 and *Kyoto Protocol* for 2008 - 2012.

Kyoto forests include limited land-use change and forestry activities (afforestation, reforestation and deforestation since 1990), while national communications for 1990 and 1995 cover more comprehensively all the main land-use change and forestry activities (for example commercial management, harvest of industrial round wood and fuel wood, production and use of wood commodities, establishment and operation of forest plantations). Our calculations are based on FAO FRA 1990 and 2000 forests, as included in the FAO statistics.

These comparisons show that:

- On the scale of the whole of Europe, the C balance of land-use change and forestry reported by countries in their national communications are comparable to the C balance of the whole tree biomass calculated from FAO forest statistics. However, for a number of individual countries these estimates are remarkably different.
- Differences may be explained by the fact that reporting categories may differ, calculations may cover different years, different assumptions may have been applied when converting tree volumes of forest inventories to whole tree biomass. Moreover, some countries have reported only aboveground biomass in their national communications while some countries have also included the below ground part in their reporting. There may also be discrepancies regarding forest areas included in the calculations.
- The C balance of tree biomass in EU countries accounted for in the *Kyoto Protocol*, as estimated in this study, is about 15% compared to the values (only tree biomass) of the national communications and forest statistics, when FAO definitions for afforestation, reforestation and deforestation are followed. When IPCC definitions are followed, this proportion is about 1%. These proportions are very different for different countries.
- The C sink of tree biomass in EU countries, according to the national communications and forest statistics, was about 6% compared to total EU anthropogenic CO_2 emissions. According to FAO definitions of *Kyoto Protocol*, the C sink of tree biomass was 1% compared to the CO_2 emissions and according to IPCC definitions 0.1%. For some countries, calculations according to *Kyoto Protocol* showed a C source, while national communications and forest statistics showed a C sink. Nevertheless, this analysis shows that C sequestration in forests can only form a small part of the overall EU CO_2 *Kyoto Protocol* commitments by 2008 to 2012.
- Possibilities for and effects of forest management practices for conserving and sequestering C vary considerably in different regions and countries, both in the short and long run.

Figure 1: Land-use change and forestry (LUCF) C balance of forest trees in the 15 EU-countries according to different calculation methods

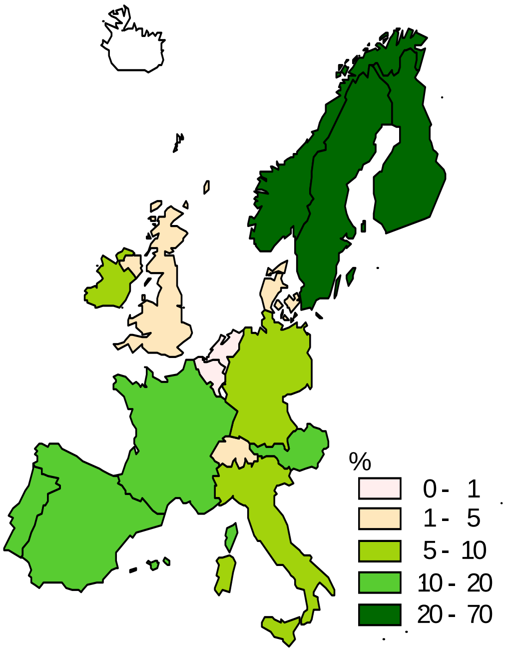


NCs = *countries' national communications under UNFCCC*;
FAO FRA 1990 = *FAO Forest Resource Assessment 1990* (UN-ECE/FAO 1992);
FAO FRA 2000 = Interim results of *the FAO Forest Resource Assessment 2000* (UN-ECE/FAO 1998).
Note that the estimates are for different years: NCs for 1990 and 1995, FAO FRA 1990 on average for 1986, FAO FRA 2000 on average for 1994 and *Kyoto Protocol* for 2008-2012 (Tg = teragram = 10^{12}g).

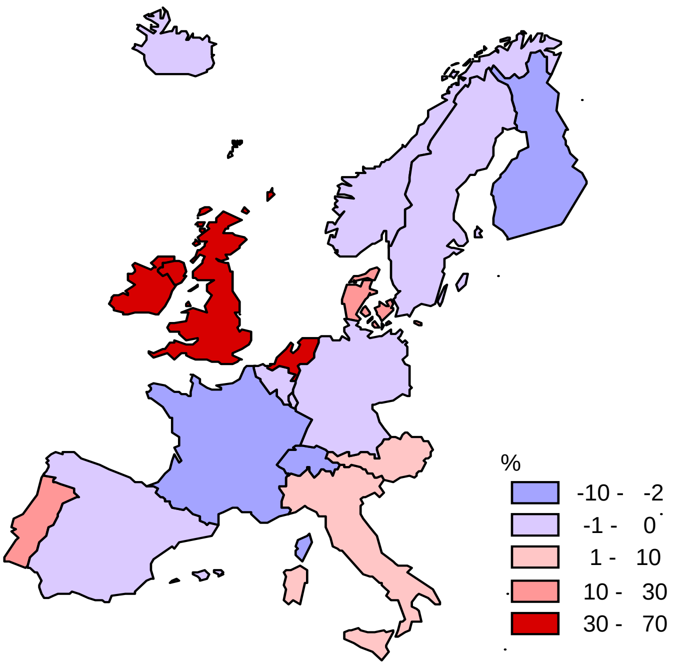
The IPCC special report on land-use, land-use change and forestry

The Subsidiary Body for Scientific and Technological Advice (SBSTA) of the Conference of the Parties (COP) to the UFCCC has asked IPCC to prepare a special report on Land-Use, Land-Use Change and Forestry to provide scientific, technical, economic and social information that can assist governments to operationalise certain articles of the *Kyoto Protocol*. This is needed because a review of the Protocol Articles dealing with Land-Use Change and Forestry (LUCF) has shown that there are several issues where guidance is needed. This Special Report, to be completed in time for consideration by COP6 in November 2000, should provide the basis for COP decisions on the issues raised in relation to Article 3.3 ('Kyoto forests'), the question of additional activities in Article 3.4 (other sinks types like, for example, soil sinks), the role of LUCF activities in Article 6 Joint Implementation projects and any role for these activities under Article 12.

Map 1: The carbon balance of trees in 1995 as percentage of CO_2 emissions; emissions in 1994 or in 1990 for some countries as noted in table 6 of the appendix to this report



Map 2: The carbon balance of trees accounted for in the *Kyoto protocol* compared with the actual balance of all trees in 1995



1. Introduction

Climate change is widely recognised as a serious potential threat to the world's environment. The problem is being addressed through the United Nations Framework Convention on Climate Change (UNFCCC) and the EU Fifth Environmental Action Programme and by following strategy documents prepared by the European Commission and adopted by the Council. The ultimate objective of the UNFCCC is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame long enough to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The EU targets are to stabilise CO_2 emissions to 1990 levels by 2000 and to reduce emissions of greenhouse gases by 8% from 1990 levels between 2008 - 2012, as agreed at third conference of parties (COP3) of UNFCCC in Kyoto in December 1997. Several other European countries agreed reductions on 0 - 8 % by 2008-2012. In contrast, the pre-Kyoto baseline greenhouse gas emissions are estimated to increase for most European countries, in particular for the EU CO_2 emissions are projected to increase by 8% by 2010.

This shows the need for substantial additional policies and measures beyond those currently agreed. Reducing emissions of greenhouse gases can have multiple benefits due to the associated emission reduction of other pollutants contributing to ozone depletion, acidification, tropospheric ozone and urban air pollution.

In addition, the *Kyoto Protocol* widens the scope of UNFCCC, reflected by the fact that net emission of greenhouse gases can also be reduced by greenhouse gas removal (uptake), in particular that of CO_2. Subject to further definition by subsequent COPs, net changes in C stocks due to specific types of greenhouse gas sinks can also be used in national inventories to meet emission reduction commitments. This should not lead, however, to the neglect of emission reductions in the energy production and consumption side, where the majority of the emissions are produced. According to Article 3(3) of the *Kyoto Protocol* such sinks must result from 'direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990'. Of these activities, afforestation and reforestation can increase the stock of C and thus act as a net sink. On the other hand, deforestation leads to additional net emissions of CO_2. The inclusion of sinks was controversial since major uncertainties remain regarding methodologies and appropriate modalities, which will be addressed at the next COPs of the UNFCCC in 1999 and 2000.

The aim of this report is to show the main results of a case study carried out by the European Forest Institute (EFI) under a contract with the European Topic Centre for Nature Conservation for the EEA report 'Environment in the European Union at the turn of the century' (EEA, 1999). The report analyses the issue of C sequestration (sinks) and its definitions in the *Kyoto Protocol*. Furthermore, the report shows for the years 1990, 1995 and for the Kyoto commitment period 2008 - 2012, the potential maximum scope for total CO_2 sinks, the much lower potential scope for CO_2 sinks according to the UNFCCC *Kyoto Protocol* definitions and the small size of these removals compared with the actual CO_2 emissions now and up to 2008 - 2012. Furthermore, the negative side-effects of increasing forests only to increase CO_2 sinks are discussed.

1.1. Research projects on climate change impacts on forests

There have been several projects funded recently by the European Union that relate to climate change and forests in Europe. The projects have had direct links and also intensive collaboration with each other:

EUROFLUX (Long Term Carbon Dioxide and Water Vapour Fluxes of European Forests and Interactions with the Climate System). The objectives of the EUROFLUX project were to investigate long term fluxes and energy exchanges of representative European forests in order to provide useful parameters to global and regional climate modellers and analyse the variables that determine energy partitioning by forests in different climatic conditions, including extreme events and stress limitations. Other important objectives were to determine the sink strength of European forests for carbon, to analyse the variables that determine the gains and the losses of carbon from forests of differing vegetation composition and in different climate regions, to analyse the response of European forests' water and carbon fluxes to climatic factors in order to aid regional scale modelling designed to predict impacts of global environmental change on forest ecosystem functions, and to provide a common database of objective data for the validation of forest models, related to growth, partitioning of primary production, water cycling and hydrology. Project duration 1996 - 1999. More information can be found at http://www.unitus.it/eflux/euro.html.

ECOCRAFT (European Collaboration on Carbon Dioxide Responses Applied to Forests and Tree). ECOCRAFT is a core project in Global Change and Terrestrial Ecosystems, a part of the International Geosphere-Biosphere Program. The project is concerned with the impacts of rising carbon dioxide and temperature on the growth processes of trees, the use of models to upscale the responses of the processes to the scale of forests over tens of years, and the use of flux measurements of carbon dioxide and water vapour to test the models and to measure directly the sequestration of carbon by European forests. Project duration 1996 - 1999. More information can be found at http://www.ed.ac.uk/~cbarton/ecocraft.

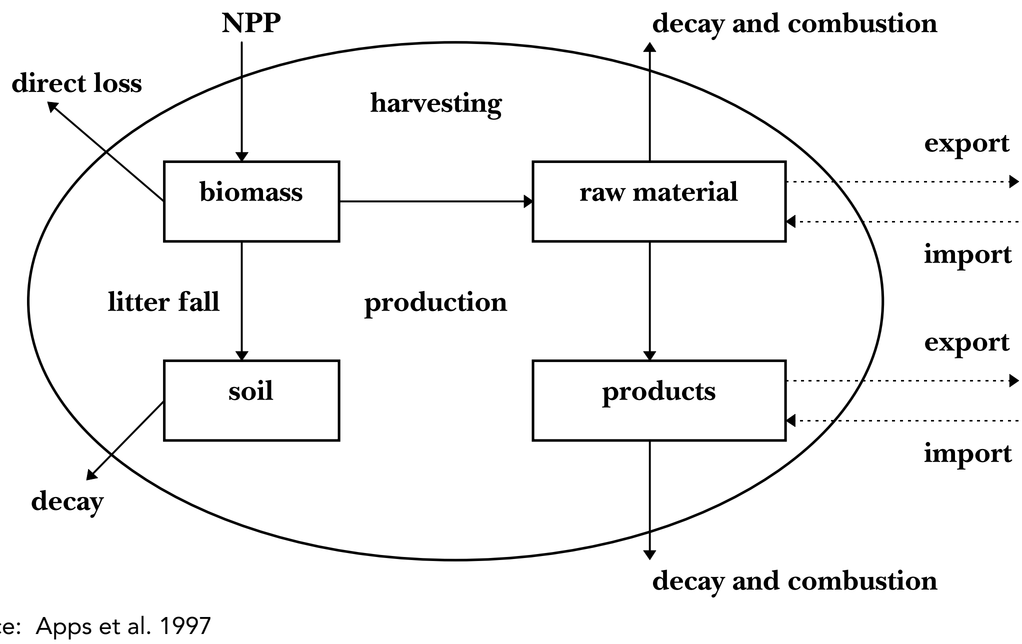
LTEEF (Long-Term-Effect on European Forests). To determine the range of uncertainty in the estimation of long-term dynamics of forest stands in a changing climate, an intercomparison of model results was undertaken within the framework of the EU project LTEEF. The main objective was to investigate the long-term growth and development of European forests under the influence of climate change, with respect to fluxes of water and carbon between the vegetation and the atmosphere, and with respect to possibilities for accommodation to changes in site conditions. Project duration 1994 - 96.

LTEEF-II (Long-term Regional Effects of Climate Change on European forests: Impact Assessment and Consequences for Carbon Budget) The central objective of the project was to assess climate change impacts on European forests with respect to water and carbon fluxes, regional differences, long-term effects, and the overall carbon budget for forests in Europe. The results of this assessment will be used to identify sustainable forest management strategies that account for these impacts, and that maximise carbon sequestration. The project directly builds upon the above-mentioned LTEEF project. Project duration 1998 - 2000. More information can be found at http://www.ibn.dlo.nl/LTEEF-II.

1.2. General principles for forestry carbon budget assessments

Carbon budget assessments are usually presented as quantification of the size of C stocks, changes in the stocks and C fluxes between stocks and the atmosphere (Figure 2). The difference between C uptake and release describes the net balance. The dynamics of C sequestration includes the investigation of the C fluxes, and the state of C sequestration includes the investigation of the C stocks. Carbon sequestration in forest ecosystems is affected by climate (temperature, precipitation), the structure of forests (tree species composition, age structure, density), forest management and natural disturbances (like fire, insect). The production processes, the use of products, and the structure of forest industry affect carbon sequestration in wood products. Since the methods and data in C budget assessments vary, it is usually difficult to compare results between different studies. The IPCC has tried to help Parties standardise national greenhouse gas inventories (IPCC 1993, 1997), but problems in the availability of data, use of given default values, and use of over-simple methods is likely to lead to inaccurate assessments. Apps et al. (1997) suggest five principles that should be recognised in an accounting strategy: accuracy, simplicity, scale independence, precedence, and incentives.

Figure 2: System definition for the estimation of CO_2 emissions from forestry, forest products, and land-use changes



Source: Apps et al. 1997

Figure 2 illustrates how the various carbon stocks are related and how carbon is transferred from one stock to another. The change in any carbon stock is the difference between inputs and outputs and each stock has its own dynamics. An estimate of emissions from any part of the system requires consideration of all transfers with other parts of the system, including the atmosphere, and with other parties. Solid arrows in the figure represent transfers to and from the atmosphere and between stocks while dashed arrows represent transfers to and from other parties. 'Direct loss' includes losses due to disturbances such as fire and insects. 'Litter fall' includes transfers due to disturbance, also annual litter production and felling residues. 'Decay and combustion' includes waste decomposition and burning of industrial waste and fuel. NPP is Net Primary Production = gross primary production - plant respiration.

Methodologies used to assess the C budget of a forest ecosystem - forest sector system can be grouped as follows:

1) IPCC guidelines (1996)
   IPCC has developed guidelines to be applied when countries report their national emissions and removals of greenhouse gases. IPCC guidelines for greenhouse gas inventories (IPCC 1996) for land-use change and forestry concentrate on emissions from human activities that change the way land is used (for example, clearing of forests for agricultural use, including open burning of cleared biomass), or affect the amount of biomass in existing biomass stocks (such as forests, village trees, woody savannas). The basic assumptions in this methodology are that the flux of CO_2 to or from the atmosphere is assumed to be equal to changes in C stocks in existing biomass and soils, and that changes in C stocks can be estimated by first establishing rates of change in land-use and the practice used to bring about the change (such as burning, clear-cutting, selective cutting). The methodology is designed to be comprehensive, that is to cover all of the main land-use change and forestry activities; and to be feasible to implement by all participating countries. It can be carries out at several different levels of complexity, depending on the needs and capabilities of national experts in different countries.

   Changes in forest and other woody biomass stocks may be either a source or a sink of CO_2 for a given year and country or region. The simplest way to determine which, is to compare the annual biomass growth versus annual harvest, including the decay of forest products and slash left during harvest. For the basic calculations, the recommended default assumption in the IPCC guidelines is that all C removed in wood and other biomass from forests is oxidised in the year of removal. This is clearly not strictly accurate in the case of some forest products, but is considered a legitimate, conservative assumption for initial calculations. Inclusion of wood products in the calculations is now under consideration (IPCC 1998). Calculations should be done by ecosystem categories, that have been established based on conventions common in the literature.

   On a global scale, the most important land-use changes that result in CO_2 emissions and removals are grouped in the guidelines as:

   - **changes in forest and other woody biomass stocks –** the most important effects of human interactions with existing forests are considered in a single broad category, which includes commercial management, harvest of industrial roundwood (logs) and fuelwood, production and use of wood commodities, and the establishment and operation of forest plantations, as well as planting of trees in urban, village and other non-forest locations;
   - **forest and grassland conversion –** the conversion of forests and grasslands to pasture, cropland, or other managed uses can significantly change C stored in vegetation and soil;
   - **abandonment of croplands, pastures, plantation forests, or other managed lands** that regrow into their prior natural grassland or forest conditions;
   - **changes in soil C** three potential sources of CO_2 emissions from agricultural soils are included in the inventory. These are 1) net changes in organic C stocks of mineral soil associated with changes in land-use and

management; 2) emissions of CO_2 from cultivated organic soils (i.e. Histosols); and 3) emissions of CO_2 from liming of agricultural soils.

2) Static stocks/fluxes
Static calculations of the present stocks and fluxes based on forest inventory data and other sources. This method is based on converting stemwood volumes into C content for the whole tree; if data are available the stocks in the soils are calculated as well. If successive inventories are available, fluxes can be calculated from differences in the standing volumes. Wood product fluxes are sometimes included based on harvested volumes. This method is often used for temperate forests, whenever a first approximation is desired (Graudal, 1991; Burschel et al., 1993; Führer et al. 1993; Karjalainen and. Kellomäki 1993; Nabuurs and Mohren 1993). In this methodology, often only the forest part of a complete C cycle is taken into account. In the tropics, where the primary forests are considered to be in a steady state, a static methodology can be used as well, but there area changes are emphasised, because the prime factor affecting the C balance is land-use change. The differences in forest area can be assessed from remote sensing images from successive years. The area change may be converted to C emission by using C density data (Hall and Uhlig, 1991; Houghton, 1995).

3) Dynamic stocks/fluxes
Dynamic calculations at the stand level with a bookkeeping model or gap-type model. The bookkeeping models represent all the stocks and fluxes in the forest ecosystem and wood product system (and sometimes the C emission reduction effect of wood products and bio-energy), and are usually driven by stem volume growth figures that are derived from yield tables. Different options in forest management and wood product use can be evaluated. The advantage is that the complete C cycle can be regarded in a dynamic way. More detailed input is required in case a gap-type model is used in which individual tree growth is driven by site characteristics and weather circumstances, but the advantage is that effects of climate change can be taken into account in a dynamic way in the latter case (Dewar,1990; Mohren and Klein-Goldewijk, 1990; Schroeder and Ladd, 1991; Karjalainen, 1996; Schlamadinger and Marland 1996).

4) Dynamic estimates forest
Dynamic calculations for the national forest sector with a book keeping model. These dynamic modelling approaches simulate the development of the forest resource, the soil compartment and the wood product compartment at a national level in terms of C (Kurz et al. 1992; Price et al. 1996; Turner et al 1995). Growth, management, disturbances, and turnover rates drive fluxes to the atmosphere and between the compartments.

5) Biome models
The biome models are based on a geographically explicit simulation of the C fluxes in different compartments of the terrestrial biosphere and between the biosphere and the atmosphere (Klein-Goldewijk et al. 1994). The distribution of the biomes is simulated explicitly from climatic parameters, thus assigning each pixel to a biome. Under changed climate circumstances, the distribution of the biomes over the continents (pixels) is assessed again and a corresponding C content can be quantified.

6) CO_2 flux
Upscaling of CO_2 flux data or Net Primary Production measurements. This method uses CO_2 flux data assessed with the eddy covariance technique above the canopy (Jarvis 1995). This provides accurate C balance data only for the investigated forest ecosystem plot and only for the period of investigation.

7) Deconvolution method
   Deconvolution methodology for assessing the terrestrial biospheric C budget uses knowledge about other fluxes in the global C cycle to estimate the net flux of the terrestrial biosphere (Tans et al. 1990).

1.3. Carbon sequestration potentials for forests and wood-based products

In the long run, the C accumulated in the growing stock will be released through respiration, death, and the decay of litter and humus, and oxidation of wood products. The delay between the accumulation and release represents the sequestration, which is a temporary stock by definition. In this respect, forests and wood products can provide only temporary C stocks compensating for the human-induced C releases. These stocks can be, however, long lasting ones and they can be affected by management.

Forest management practices for conserving and sequestering C can be grouped into four major categories (Dixon et al. 1994):

I. the maintenance of existing C pools (slow deforestation and forest degradation);
II. the expansion of existing C sinks and pools through forest management;
III. the creation of new C sinks and pools by expanding tree and forest cover:
IV. the substitution of fossil fuels and fossil fuel based product with renewable wood-based fuels and products.

Potentials and effects of these practices can vary considerably in different regions and countries. Moreover, potentials vary also in the short and long run. Some global estimates of the C sequestration potentials show that currently available options could offset about 5 to 15% of the current fossil fuel emissions (Nilsson and Schopfhauser 1995). Also short rotation woody crops could reduce global fossil fuel emissions by up to 20%, if advances in energy conservation and crop yield are implemented. These estimates demonstrate, however, that forestry can solve the mitigation problem only partly, thus changes in energy production and consumption are urgently needed in order to cut net emissions.

The C balance indicates the difference between the fluxes in and out of components, that is stock change in the forest or in wood products. Carbon stock (Mg C/ha, Gg C, Tg C) (Mg = megagram = 106g, Gg = gigagram = 109g, Tg = teragram = 1012g) indicates the amount of C in the component. The C balance of the whole system, or of one component, is a measure showing the system or component acting at a given time as a:

- *carbon sink*, if fluxes to the system or component are larger than fluxes from the system or component;
- *carbon source*, if fluxes to the system or component are smaller than fluxes from the system or component;
- a system in *balance*, neither sink nor source, if fluxes to the system or component equals fluxes from the system or component.

It should be noted that the state of a system or component varies over time, i.e. the system or component can be a sink in one year but a source the next year. So, it is necessary to also look at the C sequestration dynamics over a time sufficiently long enough to recognise the long-term performance of the system. It is possible to increase carbon stocks in the forest close to the maximum level, but then, sooner or later, stock will decrease either due to increased natural disturbances or due to harvesting. In the long run, the only sustainable solution to cut net emissions is to substitute fossil fuels and fossil fuel based products with renewable wood-based fuels and products.

1.4. Sinks in the Kyoto Protocol

The third Conference of Parties (COP3) to UNFCCC at Kyoto (December 1997) was successful in the sense that emission limitation and reduction commitments were quantified for Annex I countries. The European Community agreed to reduction commitments, by 8% from the 1990 levels in the first commitment period 2008 to 2012. Several articles in the Kyoto Protocol are related to land-use change and forestry. It has appeared, however, that the content of those articles is not necessarily clear, for example what is meant with afforestation, reforestation, deforestation, and C stocks (see for example FCCC/SBSTA/1998/INF.1., Lund 1998).

Article 3.3 limits the net changes in greenhouse gas emissions by source and removals by sinks to direct human-induced land-use change and forestry activities: afforestation, reforestation and deforestation since 1990, measured as verifiable changes in C stocks in each commitment period, but allows the net changes to be used to meet the commitments. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8. Direct human-induced activities are not defined and thus raise the question if these relate to policies and programmes, or whether only the physical activities on the land be considered. Policies and programmes could, for example, include promotion of afforestation and reforestation in various ways. Usually it takes some time to implement policies and programmes, and the actual change in the C stocks would take place later. Nitrogen deposition and climate change are human-induced, and affect C sequestration, but the impact is difficult to quantify. Should prevention or suppression of natural disturbances, for example forest fires, be included in this activity?

The term *Afforestation, reforestation and deforestation* have raised questions. For example, which definitions should be applied, those in the IPCC guidelines for greenhouse gas inventories or those of FAO? The IPCC guidelines define afforestation as planting of new forests on lands that historically have not contained forests. The FAO definition is similar: artificial establishment by planting or seeding of forest on an area of agricultural or other non-forest land, and it seems that application of both definitions would provide similar results. IPCC and FAO definitions for reforestation, however, are different. According to the IPCC guidelines reforestation is planting of forests on lands that have past contained forests but that have been converted to some other use. FAO defines reforestation as artificial or natural re-establishment of forest on previously forested or other wooded land. Artificial reforestation may be planting or seeding. The FAO definition has been interpreted so that regeneration of clearfelled areas are included in reforestation, while the IPCC definition would leave these out (the area should have been in some other use before regeneration). Obviously, these definitions would provide different results, as can be seen in Chapter 2.3. and Appendices, Table 3. If the FAO definition is applied, one could argue that timber harvesting prior to reforestation should also be taken into account. This would show substantial CO_2 emissions from LUCF categories, since it would take a long time in the reforestation areas to accumulate the amount of C harvested in the clearfelled areas. The IPCC guidelines do not define deforestation. FAO defines deforestation in the strict sense of complete clearing of tree formations (closed or open) and their replacement by non-forest land-uses.

Regarding *changes in C stocks* – the question is which C stocks? Carbon stocks are not defined in the IPCC guidelines. From a scientific point of view, all the stocks should be included: forest stocks including above and below ground biomass and soil, while wood products should distinguish products in use and products in landfills. Article 3.3 says that the net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, should be measured as verifiable changes in C stocks in each commitment period. Some of the changes in C stocks may be difficult to verify if a country does not have good statistics. It would be necessary to concentrate on stocks that change (increase or decrease). If a country is claiming credit from its activities, it should also be important to report changes in all the stocks, since activities may result in increases, for example in the biomass, but may result in decreases in the soil. Only the first commitment period has been defined it seems that the other commitment periods will be defined later by subsequent COPs of UNFCCC.

Article 3.4 of the Protocol requires each Party included in Annex B to provide, for consideration by the Subsidiary Body for Scientific and Technological Advice (SBSTA), data to establish its level of C stocks in 1990 and to enable an estimate to be made of its changes in C stocks in subsequent years. This article allows the conference of the parties to decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned amounts for Parties included in Annex B. Regarding uncertainties, transparency in reporting, and verifiability, future COPs to UNFCCC will take into account the methodological work of the IPCC and advice provided by the SBSTA. Carbon stocks in 1990 and changes in stocks in subsequent years have to be calculated. This probably means that C stocks and stock changes should be estimated in the whole land-use change and forestry category, and not necessarily only to stocks that are affected by afforestation, reforestation and deforestation.

The connection between Articles 3.3 and 3.4 should be clarified. Additional activities that could decrease emissions or increase sequestration could include, for example, the following: forest management, wood products and forest soils. Forest management includes a wide variety of activities with effects on C stocks already in the current forest area: changes in the intensity and timing of thinning, timing of final felling, selection of tree species, choice of soil preparation methods in regeneration, prevention of forest fires and insect damages. Release of C from wood products can be delayed, for example, if products are used for longer times (longer lifespans, increased recycling). Carbon stocks in forest soils are large and some activities can even increase these stocks and some activities prevent these stocks from decreasing. Future COPs to UNFCCC will have to decide upon which additional activities should be reported, since a country may want to report only those activities that help to meet emission reduction commitments and not those that would make it even more difficult to meet such commitments.

2. Three carbon balance assessments for forests and land-use change in Europe for 1990, 1995 and 2008 – 2010

The carbon balance of forests and land-use change is presented based on three different approaches. Firstly, estimates from the national communications under the UNFCCC are presented and discussed (Appendix, Table 1). In most cases, countries report that they have used IPCC guidelines and nationally available forest statistics, but usually the national communications do not contain detailed background information and statistics. The second estimate is based on unified calculations from FAO Forest Resource Assessments (FAO/UN-ECE 1992, Interim results from FAO/UN-ECE 1998, Appendix, Table 2) and the projection of forest resources to 2010 (Pajuoja 1995). The third estimate is based on two different interpretations of the wording in the Kyoto Protocol (Appendix, Table 3).

2.1. National communications under the United Nations Framework Convention on Climate Change

2.1.1. Methods

Carbon dioxide emissions and removals from land-use change and forestry can be estimated using two basic approaches: 1) by quantifying the C fluxes in plant growth, harvesting and other losses and summing them up; and 2) by measuring C stocks at two points of time and calculating the balance as the difference between these measurements.

The IPCC has developed special instructions for calculating and reporting CO_2 emissions and removals. The 1995 and 1996 revised IPCC guidelines (IPCC 1997) can be implemented at different levels of detail depending on data availability in different countries. Although the data availability determines the confidence in the results, the reporting framework enables the comparison of calculations done at different levels of detail.

In their national communications under the United Nations Framework Convention on Climate Change, 13 EU countries and two EFTA countries reported CO_2 emissions and removals from land-use change and forestry in 1990 and 1995 by the four subcategories defined in the 1995 IPCC guidelines. These subcategories were 5A 'Changes in forests and other woody biomass stocks', 5B 'Forest and grassland conversion', 5C 'Abandonment of managed lands' and 5D 'Other land-use activities'. Of Central and Eastern European Countries (CEEC), eight reported these estimates for 1990 and seven for 1995. Although several countries presented their results using IPCC standard tables they did not describe the calculation method in detail. The calculation methods may, thus, differ between countries, probably impairing the comparability of the figures.

2.1.2. Results

The 'Land-use change and forestry' category (category 5) was a sink for atmospheric CO_2 in all countries except in United Kingdom where it was a C source (Appendix, Table 1). In the EU countries this sink totalled 51.1 Tg C per year in 1990 and 51.9 Tg C per year in 1995. Estimates for Greece and Luxembourg are not included in these totals. Totals for 1995 were higher in 12 countries, equal in six countries, and lower in four countries than those in 1990. The most substantial changes were in Poland (1995 estimate was 30 times higher than 1990), United Kingdom (source decreased to half), Estonia (+57%), Finland (-53%), France (+41%), Norway (+32%).

Twelve countries also projected the future C balance of 'Land-use change and forestry' category for the year 2010 (Appendix, Table 1) (see FCCC/SBI/1997/19/Add.1.). The balance was a projected increase in net C sequestration in six countries, a projected net C sequestration to remain at the 1995 levels in three countries and a projected decrease in net C sequestration in three countries. The most substantial changes were in Slovakia (+57%), Ireland (+53%), France (+38%), Finland (+28%) and Sweden (-27%).

Within this 'Land-use change and forestry' category, most of the C sink was associated with subcategory 5A 'Changes in forests and other woody biomass stocks'. Subcategory 5B 'Forest and grassland conversion' was always a C source, subcategory 5C 'Abandonment of managed lands' a C sink and subcategory 5D 'Other land-use activities' a C sink except in the United Kingdom where it was a C source. According to the *UK second national communication*, a source is largely caused by wetland drainage and peat extraction.

2.2. Uniform calculations from FAO data/reports

2.2.1. Methods

The C balance of tree biomass was calculated from the FAO Forest Resource Assessment 1990 (UN-ECE/FAO 1992) and from interim results of the FAO Forest Resource Assessment 2000 (UN-ECE/FAO 1998) for the years 1990 and 1995 and projected for the years 2000 and 2010 from FAO projections of future forest resources in Europe (ECE/FAO, European Timber Trends and Prospects in the 21st Century, Pajuoja 1995). The C balance was calculated as a balance between the sink resulting from the gross annual increment in carbon of free biomass, minus the C emissions resulting from natural mortality and fellings. The stem wood volumes reported in the forest statistics were converted into C masses of the whole tree biomass by using country specific data if reported in the forest statistics or by using standard values. This approach is similar to that used by Kauppi et al. 1992, 1995 and Karjalainen and Kellomäki 1996. If the increment, mortality and fellings were reported for different years in the statistics, they were averaged to obtain the C balance for a single year. The C balances for years 1990 and 1995 were estimated by linearly interpolating the balances calculated for these single years from the Forest Resource *Assessments 1990* and *2000.*

2.2.2. Results

The amount of tree biomass increased in all countries studied both in 1990 and 1995 (Appendix, Table 2), the only exception was Albania where the amount of tree biomass decreased in 1990. The C sink of the increased tree biomass totalled 58.2 Tg C per year in 1990 in 15 EU countries and 22% more, 71.2 Tg C per year, in 1995. This increase was mostly due to the increase in the C sink of forests in Germany which was, in turn, largely caused by a change in the forest inventory methods (change in estimating the growth). If Germany is excluded, the C sink of tree biomass increased by 5% from 1990 to 1995.

Based on the projections of the future forest resource in Europe, the C sink of tree biomass was expected to increase in most of the studied countries until 2010. Only in France, Ireland and Switzerland was it expected to be smaller in 2000 and 2010 than in 1990 and 1995. The C sink of tree biomass in 15 EU countries was projected to total 85.4 Tg C year^{-1} in 2000 and 88.7 Tg C year^{-1} in 2010. Compared with the sink in 1990, this was a 47% increase until 2000 and 52% increase until 2010, almost entirely due to much larger sinks in Finland and Sweden in 2000 and 2010 compared to 1995. It is worth noting that these estimates are directly based on the *ECE/FAO European Timber Trends and Prospects of the 21st Century* (Pajuoja 1995). In these projections, harvesting in Switzerland and the Czech Republic are projected to decrease, and in Sweden and Finland to remain at late 1980 levels, whereas in most of the other countries harvesting is projected to increase. It should be noted that projection of harvesting rates is difficult, and that harvesting rates strongly influence the net C sequestration in Europe.

2.3. Two interpretations of the wording in the Kyoto Protocol

2.3.1. Methods

The C balance of tree biomass as accounted for in the *Kyoto Protocol* was estimated from the *FAO Forest Resource Assessment 1990* (UN-ECE/FAO 1992). The C balances of afforested and reforested areas since the 1 January 1990 were calculated for the years 2008 - 2012. For deforestation, the C balance of deforested area between 2008 - 2012 was calculated.

It was assumed that the annually afforested, reforested and deforested land areas remained the same as was reported in the *FAO Forest Resource Assessment 1990* (UN-ECE/FAO 1992). It was also assumed that net annual increment, in terms of C mass of the whole tree biomass, in these afforested areas was equal to the average net annual increment (NAI) in the given country. This most likely overestimates the growth of the young forests in the afforested areas but the overestimation is compensated for by also applying the average allocation figures for the afforested areas. In young forests a larger proportion of the growth is allocated to other biomass compartments than to stem wood.

On the basis of these assumptions, the C balance of tree biomass in the afforested areas in different countries (Tg C year^{-1}), following the FAO definition, was calculated by multiplying the annually afforested area (ha year^{-1}) by 20 years and the average NAI of the whole tree biomass (kg C ha^{-1} year^{-1}). The C balance of tree biomass in the reforested areas in different countries (Tg C year^{-1}), following the FAO definition, was calculated similarly except that the annually afforested area in the formula was replaced by the annually reforested area. The C balance of deforestation in different countries (Tg C year^{-1}) was calculated by multiplying the annually deforested area (ha year^{-1}) by the average amount of C in tree biomass (kg C ha^{-1}).

The IPCC definition for reforestation is essentially different from the FAO definition (for definitions see Chapter 1.4. Sinks in the *Kyoto Protocol*). In these calculations based on the *FAO Forest Resource Assessment*, what is reforestation according to the IPCC definition is included in the afforestation figures. The C balance of reforestation following the IPCC definition cannot therefore be distinguished from that of afforestation using the available forest statistics. The C balance of afforestation plus reforestation following the IPCC definitions thus equals the C balance of afforestation calculated according to the FAO definition as described above. For deforestation, the FAO and IPCC definitions are essentially the same.

These calculations should be considered rather crude approximations of the actual C balance as accounted for in the *Kyoto Protocol.* Still, they give the correct order of magnitude and thus make it possible to evaluate the significance of carbon removals within the framework of the Protocol.

2.3.2. Results

Following the FAO definitions for direct human-induced land-use change and forestry activities in the Article 3.3, the C sink between 2008 and 2012 in 15 EU countries due to afforestation was 4.0 Tg C year^{-1} and due to reforestation 9.1 Tg C year^{-1} (Appendix, Table 3). The C source due to deforestation was 3.1 Tg C year^{-1}. The net balance was a sink of 10 Tg C year^{-1}.

Following IPCC definitions for direct human-induced land-use change and forestry activities in Article 3.3, the C sink due to afforestation and reforestation between 2008 and 2012 in 15 EU countries was also 4.0 Tg C year^{-1} since it was not possible to distinguish afforestation in the forestry statistics (Appendix, Table 3). Since IPCC and FAO definitions for deforestation are essentially the same, the C source due to deforestation applying the IPCC definition was also 3.1 Tg C year^{-1}. The net balance was a sink of 1.0 Tg C year^{-1}.

2.4. Comparison of estimates

2.4.1. National communications and uniform calculations from FAO data/reports

The C balances of IPCC category 5 ‘Land-use change and forestry’ reported in the national communications and those calculated in a uniform way for whole tree biomass from the FAO forest statistics are not exactly comparable. The total balance of category 5 includes some activities that are excluded from the forest statistics. On the other hand, none of the sub-categories are exactly comparable to forest statistics either. For instance, forest statistics include some activities that are not included in sub-category 5A ‘Changes in forest and other biomass stocks’, such as a part of deforestation that is reported in sub-category 5B ‘Forest and grassland conversion’. Other sources of discrepancy are: calculations are for different years in some countries (due to for example different forest inventory data), different assumptions have been applied when converting tree volumes of forest inventories to whole tree biomass. In fact, some countries have reported only aboveground biomass in their national communications, while some countries have reported whole biomass including also the belowground part. Also, there may be discrepancies in the forest areas included in the calculations. National communications may be based on different datasets (not the same as FAO data) and may include adjustments that have not been made in the current calculations. Despite these differences, the C balances calculated from the forest statistics were compared to the total balance of sub-category 5.

The C balance of EU countries according to the national communications was 12% smaller in 1990 and 27% smaller in 1995 than the balance calculated from the FAO forest statistics (Appendix, Table 4). Excluding Germany from the estimates for 1995, the national communications total was 20% smaller than the balance calculated from FAO forest statistics. In the individual EU countries, the value of the national communication was at its smallest 81% smaller than the forest statistics value and at its biggest 255% bigger. The differences in the values of the United Kingdom were even bigger but the estimates are clearly not comparable, since the national communication also included emissions from wetland drainage and peat extraction. For Ireland, growth estimates on the expanding forest area may explain the differences between the two estimates. In the other countries studied, the differences between these two estimates were similar to the differences in the EU countries.

The projection of the future C balance in the national communications was different from that calculated from the projected future forest resources in Europe, particularly for Sweden, Finland and France. These differences were due to the projected decrease in fellings in Sweden and Finland and the projected increase in fellings in France in the FAO projections used for the calculations.

In conclusion, keeping the difficulties in the comparison of these two estimates in mind, the C balances reported in the national communications are reasonably comparable to the balances calculated from the FAO forest statistics at the scale of whole Europe. In individual countries, the estimates differ considerably. The lack of detailed description of the applied calculation methods in the national communications makes it difficult to analyse the reasons for this difference. It is likely that estimates in the national communications are based on statistics other than the FAO statistics (probably more precise national statistics). Moreover, conversion from volumes to C may be different in the national communications than in our calculations, and some national communications may include components that have not been included in the FAO statistics based calculations.

2.4.2. Uniform calculations from FAO data/reports and two interpretations of the wording in the Kyoto Protocol

Following the FAO definitions for afforestation, reforestation and deforestation, the C balance of the tree biomass in EU countries accounted for in the *Kyoto Protocol* was about 14% of the C balance of tree biomass calculated from forest statistics (Appendix, Table 5). Following the IPCC definitions, the *Kyoto Protocol* type C sinks accounted for 1% of the C balance calculated from forest statistics.

These proportions were different for different EU countries. Following the FAO definitions, they ranged from 0% in Belgium to very large percentages in Denmark and the Netherlands. The percentages larger than 100% were of course artificial and due to the present method used. Following the IPCC definitions, the percentages ranged from 0% to about 30-50 % in countries which afforest their land area, such as Ireland, the Netherlands, Portugal and United Kingdom. Non-EU countries showed similar characteristics.

On this basis, it can be concluded that only a small proportion of the C balance of forests are accounted for in the *Kyoto Protocol* - depending on the definitions used. For the EU, on average, it is about 1 to 14% of the actual C balance of forests in Europe. However, this proportion may be quite large in some countries but in these countries the C balance of forests in absolute terms is small and does not play a major role in the national C balance. It is also worth noting that the use of the FAO definition for reforestation when interpreting the *Kyoto Protocol* does not seem reasonable, since it only accounts for the C sink resulting from regeneration of forests and ignores the loss of C when harvesting.

2.4.3. *Comparison between anthropogenic CO_2 emissions and different estimates for the C sinks of tree biomass for the EU*

Anthropogenic CO_2 emissions, excluding the emissions of land-use change and forestry, totalled 905 Tg C year^{-1} in EU countries in 1990 (Appendix, Table 6) (FCCC/CP/1998/11/Add.2)). The C removal of tree biomass according to both the national communications and C balance of the whole tree biomass based on FAO forest statistics was about 6% of this value. This percentage varied widely between countries, from less than 2% in Belgium, Denmark, the Netherlands and United Kingdom to more than 40% in Finland and more than 60% in Sweden.

The C removal of tree biomass accounted for using definitions and specifications in the *Kyoto Protocol* was about 1% of the value for EU CO_2 emissions (Appendix, Table 6) following FAO definitions (14% of the 72.2 Tg C reduction commitment) and 0.1% following IPCC definitions (1% of the reduction commitment). Following FAO definitions, this proportion ranged from 0% in Belgium and Germany to about 7% in Portugal and 18% in Finland. Following IPCC definitions, it ranged from –1% in Finland and France to about 4% in Ireland and Portugal.

2.5. Some related reports

IPCC Special Report on Land-Use, Land-Use Change and Forestry
The Subsidiary Body for Scientific and Technological Advice (SBSTA) of the Conference of the Parties (COP) to the UFCCC has asked IPCC to prepare a special report on Land-Use, Land-Use Change and Forestry to provide scientific, technical, economic and social information that can assist governments to operationalise certain articles of the Kyoto Protocol. This is needed because a review of the Protocol Articles (FCCC/SBSTA/1998/INF.1) dealing with Land-Use Change and Forestry (LUCF) has shown that there are several issues where guidance is needed. This Special Report, to be completed in time for consideration by COP6 in the year 2000, would provide the basis for COP decisions on the issues raised in relation to Article 3.3, the question of additional activities in Article 3.4, the role of LUCF activities in Article 6 Joint Implementation projects and any role for these activities under Article 12. The IPCC chairman has said that this report will be policy relevant, but not policy prescriptive. The outline of the IPCC special report was approved at the fourteenth session of IPCC (Vienna, 1-3 October 1998), and will go through expert and government review before it will go through the IPCC approval and acceptance procedures. This report is expected to be ready by May 2000.

WBGU special report 1998
The German Advisory Council on Global Change (WBGU) released a special report in 1998 that assessed the Kyoto Protocol with respect to accounting for biological sources and sinks. The WBGU report stresses for example the importance of soil protection, and careful consideration of possible risks and problems associated with accounting for biological sinks. The report criticises the form in which land-use change and forestry activities are accounted for under the Kyoto Protocol for being inadequate and in need of improvement if the objectives of climate protection and biodiversity conservation are both to be served. It is considered possible that Parties may respond to the requirements and specifications of the Kyoto Protocol with actions which produce negative impacts upon climate protection, biodiversity and soil protection. Because of uncertainties attached to the estimation of carbon stocks, accounting of sinks may reduce the transparency of reduction commitments, and thus hamper verification. The

Council recommends requesting IPCC to examine all issues relating to uncertainty in the recording of, and verifiability, of sink conservation measures, including the long-term impacts upon the stabilisation of greenhouse gases, and to publish its results in a Special Report.

The WBGU's report has been proposed from a more global and general point of view than this technical report, which only concentrates on European forests. The WBGU also includes wetlands, cultivated lands, and grasslands besides forest when assessing global distribution of carbon fluxes and C stock. Some comparisons are made such as between different vegetation zones or/and between specific lands, for example in Australia, Russia and China. The report also presents figures for C stock after conversion of primary forest to pasture or grassland. The report concludes that, per unit area, the temperate forests are at present probably the largest terrestrial sink (NEP ranging from -1.4 to -15.5 t C ha^{-1} $year^{-1}$). The NEP of boreal and tropical forests was also negative, though to a far smaller degree. According to the report, although the Annex I countries together account for only around a third of the global terrestrial land surface, this area contains about 50% of terrestrial carbon, mainly in soils. European forest soils have a small carbon stock which may be due to intense forest management. The total carbon stock in Europe was estimated to be 34 Gt C, of which 25 is in soils and 9 in vegetation. Direct comparison of WBGU calculations and our calculations is not possible because of differences in assumptions, included areas and points of views.

Euroflux
An EU funded project, EUROFLUX, has recently estimated the carbon sink of forests in the EU to be between 170 and 350 Pg $year^{-1}$ (Martin *et al.* 1998). The estimate is based on measurements of CO_2 flux between forest and atmosphere during one year at 15 forest sites in the EU. These flux measurements were generalised for all forests in the EU with the help of some georeferenced forest data.

The EUROFLUX estimate is significantly larger than any of the estimates in the present report. It is 120 to 300 Tg larger than what the EU countries have reported in their national communications under the UNFCCC and 100 to 280 Tg larger than the estimate calculated from *FAO Forest Resource Assessments*. There are several reasons for this difference in the results. First, removing C from forests in the harvested wood is not accounted for in the EUROFLUX estimate. Thus, it is not a complete C balance of forests, since it does not take into account this C flux from managed forests. In both the national communications and the estimates calculated from forest statistics, the C flux out of forests in harvested wood has been accounted for. According to the forest statistics, this C flux in the wood harvested and removed from forests in EU equals about 60 Tg C $year^{-1}$.

Subtracting this C flux from the EUROFLUX estimate brings it much closer to the other estimates. Secondly, the EUROFLUX estimate takes into account the C balance of soil whereas the estimate calculated from forest statistics does not. Assuming that the amount of C in soil increases as the amount of C in trees does, this increase in soil C should be added to the estimate calculated from forest statistics to make these two estimates comparable. This may explain a part of the remaining difference between the EUROFLUX estimate and the estimate calculated from forest statistics. Thirdly, extrapolating measurements from 15 individual EUROFLUX sites to all forests in EU involves many assumptions and associated for possibilities error. The EUROFLUX sites were not selected in an objective and statistically sound way to represent all forests in EU. Many of them are rather young fast growing forest sites quickly binding C from the atmosphere in their biomass quickly.

2.6. Summary

On a European scale, the C balance of land-use change and forestry reported by countries in their national communications was comparable to the C balance of the whole tree biomass calculated from FAO forest statistics (Appendix, Table 4). However, for a number of individual countries these estimates were quite different (biggest differences in 1990, United Kingdom and Spain; in 1995, United Kingdom, Germany and Finland; and in 2010, Sweden, France and Finland). Differences may be explained by different reporting categories, calculations may cover different years, different assumptions may have been applied when converting tree volumes of forest inventories to whole tree biomass, and some countries have reported only aboveground biomass in their national communications while some countries have reported whole biomass including the below ground part. There may also be discrepancies over which forest areas have been included in the calculations.

The C balance of tree biomass in EU15 to be accounted for in the *Kyoto Protocol* as estimated in this study was about 15% compared to the value of the national communications and forest statistics, when FAO definitions for afforestation, reforestation and deforestation were followed. When IPCC definitions were followed, this proportion was about 1%. These proportions were very different for individual EU countries.

Summary Table. The C balance of forests in the 15 EU countries according to different calculation methods. Note that all the estimates are for different years and the estimate for the *Kyoto Protocol* is for years 2008 - 2012 (Mg = megagram = 10^6g, Gg = gigagram = 10^9g, Tg = teragram = 10^{12}g).

Estimate	Tg C yr-1
National Communications under the UNFCCC	51.1 in 1990 51.9 in 1995
Whole tree biomass	58.2 calculated from FAO FRA 1990 71.2 calculated from FAO FRA 2000
Kyoto Protocol, FAO definitions for afforestation, re-afforestation and deforestation	10.1
Kyoto Protocol, IPCC definitions for afforestation, re-afforestation and deforestation	1.0

For EU countries the C sink of tree biomass according to national communications and forest statistics was about 6% of the value for anthropogenic CO_2 emissions in these countries. According to FAO definitions applied to the *Kyoto Protocol* the C sink of tree biomass was 1% of the value for the CO_2 emissions and according to IPCC definitions 0.1%, and equals respectively 15 and 1% of the emission reduction target.

Possibilities for and effects of forest management practices for conserving and sequestering C vary considerably in different regions and countries, also in the short and long run.

Appendix

Table 1: The C balance of land-use change and forestry (Tg C year^{-1}) as reported by the countries in their National communications under the United Nations Framework Convention on Climate Change for IPCC category 5 'Land-use change and forestry' and subcategories 5A 'Changes in forests and other woody biomass stocks', 5B 'Forest and grassland conversion', 5C 'Abandonment of managed lands' and 5D 'Other land-use activities'. + = C sink/removal and - = C source (Mg = megagram = 10^6g, Gg = gigagram = 10^9g, Tg = teragram = 10^{12}g).

Country	Year 1990					Year 1995					Year 2010
	5A	5B	5C	5D	total	5A	5B	5C	5D	total	total
EU											
Austria	3.6	-	0.1	-	3.6	3.7	-	0.1	-	3.7	-
Belgium	-	-	-	0.6	0.6	-	-	-	0.6	0.6	0.6
Denmark	0.3	-	-	-	0.3	0.3	-	-	-	0.3	-
Finland	8.3	-	-	-	8.3	3.9	-	-	-	3.9	5.0
France	10.3	-3.7	2.5	-	9.1	14.0	-3.6	2.4	-	12.8	17.7
Germany	8.2	-	-	-	8.2	8.2	-	-	-	8.2	-
Greece	-	-	-	-	-	-	-	-	-	-	-
Ireland	1.4	-	-	-	1.4	1.7	-	-	-	1.7	2.6
Italy	7.4	-0.6	0.0	0.0	6.8	7.0	-0.4	0.0	0.0	6.7	-
Luxembourg	-	-	-	-	-	-	-	-	-	-	-
Netherlands	0.4	-	-	-	0.4	0.5	-	-	-	0.5	0.5
Portugal	-	-	-	0.3	0.3	-	-	-	0.3	0.3	-
Spain	-	-	-	7.9	7.9	-	-	-	7.9	7.9	-
Sweden	9.4	-	-	-	9.4	8.2	-	-	-	8.2	6.0
United Kingdom	2.6	-7.2	0.4	-0.9	-5.1	2.9	-6.8	2.1	-0.9	-2.7	-2.4
Total	51.9	-11.6	2.9	7.9	51.1	50.2	-10.8	4.7	7.9	51.9	30.0
EFTA											
Iceland	-	-	-	-	-	-	-	-	-	-	-
Liechtenstein	-	-	-	-	-	-	-	-	-	-	-
Norway	2.8	-	-	-	2.8	3.7	-	-	-	3.7	4.0
Switzerland	1.2	-	-	-	1.2	1.4	-	-	-	1.4	1.4
Total	4.0	0.0	0.0	0.0	4.0	5.1	0.0	0.0	0.0	5.1	5.4
PHARE											
Albania	-	-	-	-	-	-	-	-	-	-	-
Bosnia	-	-	-	-	-	-	-	-	-	-	-
Bulgaria	1.3	-	-	-	1.3	1.9	-	-	-	1.9	-
Czech Republic	0.6	-	-	-	0.6	1.5	-	-	-	1.5	1.4
Estonia	1.4	-0.2	1.1	-	2.3	-	-	-	-	3.6	3.1
FYROM	-	-	-	-	-	-	-	-	-	-	-
Hungary	0.8	-	-	-	0.8	1.3	-	-	-	1.3	-
Latvia	3.9	-	-	-	3.9	4.3	-	-	-	4.3	-
Lithuania	-	-	-	-	-	-	-	-	-	-	-
Poland	0.4	-	-	-	0.4	12.0	-	-	-	12.0	-
Romania	0.8	-	-	-	0.8	-	-	-	-	-	-
Slovakia	1.6	-0.1	-	-	1.4	1.4	-	-	-	1.4	2.2
Slovenia	-	-	-	-	-	-	-	-	-	-	-
Total	10.8	-0.3	1.1	0.0	11.6	22.4	0.0	0.0	0.0	26.0	6.7

- no data or data not available

Table 2: The C balance of tree biomass (Tg C $year^{-1}$) calculated from FAO *Forest Resource Assessments* 1990 and 2000 (UN-ECE/FAO 1992: FRA 1990; UN-ECE/FAO 1992: Interim results of the FRA 2000) for the years 1990 and 1995 and from FAO projections of future forest resources in Europe for the years 2000 and 2010 (Pajuoja 1995, ECE/FAO, *European Timber trends and prospects in the 21st century*) (Mg = megagram = 10^6g, Gg = gigagram = 10^9g, Tg = teragram = 10^{12}g).

Country	FRA 1990		FRA 2000					
	Base year	Balance	Base year	Balance	Year 1990	Year 1995	Year 2000	Year 2010
EU								
Austria	1987	2.1	1994	2.6	2.3	2.7	5.5	5.6
Belgium	1980	0.5	1990	0.3	0.3	0.2	0.4	0.4
Denmark	1979	0.6	1993	0.4	0.5	0.4	0.5	0.6
Finland	1987	5.2	1994	7.0	6.0	7.4	17.5	21.3
France	1986	8.8	1997	10.8	9.6	10.5	6.0	6.5
Germany	-	5.9	1996	17.6	5.9	16.5	6.0	5.1
Greece	1984	0.1	-	-	-	-	2.4	2.4
Ireland	1989	0.7	1996	0.4	0.7	0.5	0.7	0.3
Italy	1987	3.9	1995	8.7	5.9	8.7	5.4	5.5
Luxembourg	1988	0.1	1989	0.0	0.1	-	0.1	0.1
Netherlands	1990	0.6	1993	0.3	0.6	0.2	0.3	0.3
Portugal	1983	0.3	1995	1.6	1.1	1.6	2.2	2.4
Spain	1989	11.3	1992	10.7	11.0	10.3	11.8	12.8
Sweden	1987	13.6	1994	10.5	12.2	10.1	24.0	24.5
United Kingdom	1985	2.0	1995	2.1	2.0	2.1	2.6	0.8
Total		55.6		73.1	58.2	71.2	85.4	88.7
EFTA								
Iceland	-	-	-	-	-	-	-	-
Liechtenstein	-	-	1995	0.0	-	-	-	-
Norway	1986	1.9	1995	4.5	3.0	4.5	5.7	6.5
Switzerland	1986	0.3	1994	0.5	0.4	0.5	0.2	0.1
Total		2.2		4.9	3.4	5.0	5.8	6.6
PHARE								
Albania	1990	-0.3	1997	0.3	-0.3	0.1	-0.1	-0.1
Bosnia	-	-	-	-	-	-	-	-
Bulgaria	1990	2.3	1995	4.7	2.3	4.7	3.0	3.0
Czech Republic	-	-	1995	1.4	-	1.4	1.9	1.8
Estonia	-	-	-	-	-	-	-	-
FYROM	-	-	-	-	-	-	-	-
Hungary	1989.5	1.4	1996	2.3	1.5	2.2	1.9	2.2
Latvia	-	-	1996	2.5	-	-	1.1	1.1
Lithuania	-	-	1993	1.8	-	-	1.5	1.0
Poland	1989	1.3	1994	4.8	2.0	5.5	2.3	1.3
Romania	1990	5.2	-	0.0	5.2	-	6.8	6.8
Slovakia	-	-	1996	2.6	-	2.6	2.2	2.1
Slovenia	-	-	1996	1.6	-	1.6	-	-
Total		10.0		21.9	10.7	18.0	20.5	19.2

- no data or data not available

Table 3: The C balance of tree biomass (Tg C year^{-1}) between 2008-2012, as accounted for in the *Kyoto Protocol*, as calculated from FAO statistics following FAO and IPCC definitions for afforestation, reforestation and deforestation (Mg = megagram = 10^6g, Gg = gigagram = 10^9g, Tg = teragram = 10^{12}g).

Country	FAO afforestation IPCC aff- and reforestation	FAO reforestation	FAO deforestation IPCC deforestation	FAO net	IPCC net
EU					
Austria	0.10	1.17	-0.08	1.20	0.02
Belgium	0.00	-	0.00	0.00	0.00
Denmark	0.07	0.41	0.00	0.48	0.07
Finland	0.08	2.80	-0.23	2.64	-0.16
France	1.62	-	-2.66	-1.04	-1.04
Germany	0.00	-	0.00	0.00	0.00
Greece	0.01	0.03	-0.01	0.02	0.00
Ireland	0.30	0.12	0.00	0.42	0.30
Italy	0.15	-	0.00	0.15	0.15
Luxembourg	0.00	-	0.00	0.00	0.00
Netherlands	0.09	0.11	-0.01	0.18	0.07
Portugal	0.47	0.31	0.00	0.78	0.47
Spain	0.09	3.15	-0.06	3.18	0.03
Sweden	0.00	0.57	0.00	0.57	0.00
United Kingdom	1.07	0.47	-0.01	1.53	1.06
Total	4.03	9.14	-3.06	10.11	0.97
EFTA					
Iceland	-	-	-	-	-
Liechtenstein	-	-	-	-	-
Norway	0.00	-	0.00		0.00
Switzerland	0.01	0.11	-0.02	0.10	-0.01
Total	0.01	0.11	-0.02	0.10	-0.01
PHARE					
Albania	0.02	0.02	-0.05	-0.01	-0.03
Bosnia	-	-	-	-	-
Bulgaria	0.20	0.91	-0.04	1.07	0.16
Czech Republic	-	-	-	-	-
Estonia	-	-	-	-	-
FYROM	-	-	-	-	-
Hungary	0.59	1.39	-0.08	1.91	0.51
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Poland	0.23	1.78	-0.20	1.81	0.04
Romania	0.01	0.10	0.00	0.11	0.01
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Total	1.05	4.20	-0.37	4.88	0.68

- no data or data not available

Table 4: Comparison of the C balance of IPCC category 5 'Land-use change and forestry', as reported in the national communications (Nc, Tg C $year^{-1}$) with the C balances of tree biomass calculated from the forest statistics (Fs, Tg C $year^{-1}$) (Mg = megagram = 10^6g, Gg = gigagram = 10^9g, Tg = teragram = 10^{12}g).

Country	Year 1990			Year 1995			Year 2010		
	Nc	Fs	Nc-Fs	Nc	Fs	Nc-Fs	Nc	Fs	Nc-Fs
EU									
Austria	3.6	2.3	1.3	3.7	2.7	1.0	-	-	-
Belgium	0.6	0.3	0.3	0.6	0.2	0.4	0.6	0.4	0.2
Denmark	0.3	0.5	-0.2	0.3	0.4	-0.1	-	-	-
Finland	8.3	6.0	2.3	3.9	7.4	-3.5	5.0	21.3	-16.3
France	9.1	9.6	-0.5	12.8	10.5	2.3	17.7	6.5	11.2
Germany	8.2	5.9	2.3	8.2	16.5	-8.3	-	-	-
Greece	-	-	-	-	-	-	-	-	-
Ireland	1.4	0.7	0.7	1.7	0.5	1.2	2.6	0.3	2.3
Italy	6.8	5.9	0.9	6.7	8.7	-2.0	-	-	-
Luxembourg	-	0.1	-	-	-	-	-	-	-
Netherlands	0.4	0.6	-0.2	0.5	0.2	0.3	0.5	0.3	0.2
Portugal	0.3	1.1	-0.8	0.3	1.6	-1.3	-	-	-
Spain	7.9	11.0	-3.1	7.9	10.3	-2.4	-	-	-
Sweden	9.4	12.2	-2.8	8.2	10.1	-1.9	6.0	24.5	-18.5
United Kingdom	-5.1	2.0	-7.1	-2.7	2.1	-4.8	-2.4	0.8	-3.2
Total	51.1	58.2	-7.1	51.9	71.2	-19.3	30	54.2	-24.2
EFTA									
Iceland	-	-	-	-	-	-	-	-	-
Liechtenstein	-	-	-	-	-	-	-	-	-
Norway	2.8	3.0	-0.2	3.7	4.5	-0.8	4.0	6.5	-2.5
Switzerland	1.2	0.4	0.8	1.4	0.5	0.9	1.4	0.1	1.3
Total	4.0	3.4	0.6	5.1	5.0	0.1	5.4	6.6	-1.2
PHARE									
Albania	-	-	-	-	-	-	-	-	-
Bosnia	-	-	-	-	-	-	-	-	-
Bulgaria	1.3	2.3	-1.0	1.9	4.7	-2.8	-	-	-
Czech Republic	-	-	-	1.5	1.4	0.1	1.4	1.8	-0.4
Estonia	-	-	-	-	-	-	-	-	-
FYROM	-	-	-	-	-	-	-	-	-
Hungary	0.8	1.5	-0.7	1.3	2.2	-0.9	-	-	-
Latvia	-	-	-	-	-	-	-	-	-
Lithuania	-	-	-	-	-	-	-	-	-
Poland	0.4	2.0	-1.6	12.0	5.5	6.5	-	-	-
Romania	0.8	5.2	-4.4	-	-	-	-	-	-
Slovakia	-	-	-	1.4	2.6	-1.2	2.2	2.1	0.1
Slovenia	-	-	-	-	-	-	-	-	-
Total	3.3	11.0	-7.7	18.1	16.3	1.8	3.5	3.9	-0.4

- no data or data not available

Table 5: Comparison of the C balance of tree biomass accounted for by using the *Kyoto Protocol* (Tg C year^{-1}) with the C balance of tree biomass calculated from the FAO forest statistics (Fs, Tg C year^{-1}). FAO net stands for the net balance of *Kyoto Protocol* following FAO definitions and IPCC net the net balance following IPCC definitions (Mg = megagram = 10^6g, Gg = gigagram = 10^9g, Tg = teragram = 10^{12}g).

Country	Fs 1995	FAO net	IPCC net	FAO vs Fs	IPCC vs Fs
EU					
Austria	2.69	1.20	0.02	44%	1%
Belgium	0.20	0.00	0.00	0%	0%
Denmark	0.41	0.48	0.07	117%	17%
Finland	7.43	2.64	-0.16	36%	-2%
France	10.51	-1.04	-1.04	-10%	-10%
Germany	16.50	0.00	0.00	0%	0%
Greece	-	0.02	0.00	-	-
Ireland	0.48	0.42	0.30	88%	62%
Italy	8.72	0.15	0.15	2%	2%
Luxembourg	-	0.00	0.00	-	-
Netherlands	0.16	0.18	0.07	115%	46%
Portugal	1.63	0.78	0.47	48%	29%
Spain	10.29	3.18	0.03	31%	0%
Sweden	10.06	0.57	0.00	6%	0%
United Kingdom	2.10	1.53	1.06	73%	50%
Total	71.19	10.11	0.97	14%	1%
EFTA					
Iceland	-	-	-	-	-
Liechtenstein	-	-	-	-	-
Norway	4.45	-	0.00	0%	0%
Switzerland	0.50	0.10	-0.01	19%	-2%
Total	4.95	0.10	-0.01	2%	0%
PHARE					
Albania	0.11	-0.01	-0.03	-11%	-27%
Bosnia	-	-	-	-	-
Bulgaria	4.72	1.07	0.16	23%	3%
Czech Republic	1.37	-	-	0%	0%
Estonia	-	-	-	-	-
FYROM	-	-	-	-	-
Hungary	2.17	1.91	0.51	88%	24%
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Poland	5.48	1.81	0.04	33%	1%
Romania	-	0.11	0.01	-	-
Slovakia	2.55	-	-	0%	0%
Slovenia	1.62	-	-	0%	0%
Total	18.03	4.88	0.68	27%	4%

- no data or data not available

Table 6: Comparison of anthropogenic CO_2 emissions (Tg C $year^{-1}$) in 1990 (FCCC/CP/1998/11/Add.2) with the C balance of tree biomass calculated in different ways: national communications, FAO forest statistics and *Kyoto Protocol* following the definitions of FAO and IPCC. The percentages represent the proportion of the tree C sink of the emissions (negative value indicates how much smaller net emissions would be if C balance of tree biomass included, negative value indicates how much higher emissions would be, respectively) (Mg = megagram = 10^6g, Gg = gigagram = 10^9g, Tg = teragram = 10^{12}g).

Country		C balance of the tree biomass			
	1990 CO_2 emissions	National communi-cations	Forest statistics	Kyoto FAO	Kyoto IPCC
EU					
Austria	16.9	21.5%	13.8 %	7.1%	0.1%
Belgium	31.7	1.8%	0.9%	0.0%	0.0%
Denmark	14.2	1.8%	3.2%	3.4%	0.5%
Finland	14.7	56.9%	41.1%	18.0%	-1.1%
France	103.2	8.8%	9.3%	-1.0%	-1.0%
Germany	276.6	3.0%	2.1%	0.0%	0.0%
Greece	23.1	-	-	0.1%	0.0%
Ireland	8.4	16.8%	8.0%	5.0%	3.6%
Italy	117.9	5.8%	5.0%	0.1%	0.1%
Luxembourg	3.5	-	2.9%	0.0%	0.0%
Netherlands	45.7	0.9%	1.3%	0.4%	0.2%
Portugal	12.9	2.3%	8.6%	6.1%	3.7%
Spain	61.8	12.8%	17.8%	5.1%	0.0%
Sweden	15.1	62.0%	80.4%	3.8%	0.0%
United Kingdom	159.2	3.2%	1.3%	1.0%	0.7%
Total	904.9	5.6%	6.4%	1.1%	0.1%
EFTA					
Iceland	0.6	-	-	-	-
Liechtenstein	-	-	-	-	-
Norway	9.7	28.7%	31.3%	0.0%	0.0%
Switzerland	12.3	9.7%	3.2%	0.8%	-0.1%
Total	22.6	17.6%	15.2%	0.4%	0.0%
PHARE					
Albania	-	-	-	-	-
Bosnia	-	-	-	-	-
Bulgaria	26.4	4.8%	8.7%	4.0%	0.6%
Czech Republic	45.1	1.4%	0.0%	0.0%	0.0%
Estonia	10.3	22.6%	0.0%	0.0%	0.0%
FYROM	-	-	-	-	-
Hungary	22.8	3.7%	6.5%	8.4%	2.2%
Latvia	6.8	62.2%	0.0%	0.0%	0.0%
Lithuania	10.8	-	-	-	-
Poland	130.0	0.3%	1.5%	1.4%	0.0%
Romania	54.1	1.5%	9.6%	0.2%	0.0%
Slovakia	16.4	8.8%	0.0%	0.0%	0.0%
Slovenia	3.8	-	-	-	-
Total	326.5	1.1%	3.4%	1.5%	0.2%

- no data or data not available

Table 7: Areas (Forest and Other Wooded Land) used in calculations of C balance of tree biomass (Tg C year-1) from *FAO Forest Resources assessments* for 1990 and 2000 (UN-ECE/FAO 1992:FRA 1990;UN-ECE/FAO 1992:Interin results of the FRA 2000) and afforestation, reforestation and deforestation areas used in calculations of C balance of tree biomass (Tg C year-1) between 2008-12, as accounted for in the *Kyoto Protocol*, as calculated from FAO statistics following FAO and IPCC definitions.

Country	FOWL, 1000 ha		ARD activities, 1000 ha yr-1		
	FAO, FRA 1990	FAO, FRA 2000	Afforestation FAO, IPCC	Reforestation FAO	Deforestation FAO
EU					
Austria	3877	3924	2.5	29.4	1
Belgium	619.5	672	0	-	0
Denmark	466	538	1	5.8	0
Finland	23373	22605	3.5	130.1	9.5
France	16242	16989	45.5	-	60
Germany	10735	10740	0	-	0
Greece	6031.9	6513	1.3	4.85	0.7
Ireland	429	591	4.8	2	0
Italy	8550	10842	9.1	-	0
Luxembourg	87.3	89	0.05	-	0
Netherlands	334	339	1.2	1.5	0.2
Portugal	3102.2	3467	13.8	9.18	0
Spain	25622	25984	4.4	160	4
Sweden	28015	30259	0	22	0
United Kingdom	2380	2489	24.6	10.8	0.4
Total	129863.9	136041	111.75	375.63	75.8
EFTA					
Iceland	134	130	0	-	0
Liechtenstein	-	7	-	-	-
Norway	9565	12000	0	-	0
Switzerland	1186	1234	0.3	2.8	0.2
Total	10885	13371	0.3	2.8	0.2
PHARE					
Albania	1449	1048	2.5	2.4	2.4
Bosnia	-	-	-	-	-
Bulgaria	3683.383	3903	8.8	40.1752	1.1
Czech Republic	-	2630	-	-	-
Estonia	-	-	-	-	-
FYROM	-	-	-	-	-
Hungary	1675	1811	9.1	21.4	0.9
Latvia	-	2995	-	-	-
Lithuania	-	2050	-	-	-
Poland	8672	8942	8.4	63.9	3.4
Romania	6265.1	6660	0.2	2.97	0
Slovakia	-	2031	--	-	-
Slovenia	-	1166	-	-	-
Total	21744.483	33236	29	130.8452	7.8

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