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Harmonized Methods for Assessing Carbon Sequestration in European Forests

Results of the Project "Study under EEC 2152/2003 Forest Focus regulation on developing harmonized methods for assessing carbon sequestration in European forests"

Eds. E. Cienciala, G. Seufert, V. Blujdea, G. Grassi, Z. Exnerová

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Contact information

Address: Climate Change Unit, Joint Research Centre, Via Fermi, 2749 - 21027 - Ispra (VA), Italy -
E-mail: guenther.seufert@jrc.ec.europa.eu
Tel.: + 39 0332 78 5784
Fax: + 39 0332 78 5022
http://ies.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

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Cover photographs (clock wise starting from up left corner):
Inventories of biomass and carbon stocks at JRC test sites San Rossore Pine forest(PI), Poplar High Stand Zerbolo (PV), Pristine Forest San Siro Negri (PV), Poplar short rotation Vigevano (all fotos by G. Seufert)

FOREWORD

The present study was developed in the context of Regulation (EC) 2152/2003 on the monitoring of forest and environmental interactions, the so-called "Forest Focus" Regulation.

The Forest Focus regulation centered specifically on the monitoring of the effects of atmospheric pollution and fires on European forests, previously addressed by Council Regulation (EEC) No 3528/86 of 17 November 1986 on the protection of the Community's forests against atmospheric pollution and Council Regulation (EEC) No 2158/92 of 23 July 1992 on protection of the Community's forests against fire. Furthermore, "Forest Focus" aimed at encouraging the exchange of information on the condition of and harmful influences on forests in the Community and enabling the evaluation of ongoing measures to promote conservation and protection of forests, with particular emphasis on actions taken to reduce impacts negatively affecting forests.

In order to promote a comprehensive understanding of the relationship between forests and the environment, the scheme also included the financing of studies and pilot projects aiming at the development of monitoring schemes for other important factors such as biodiversity, carbon sequestration, climate change, soils and the protective function of forests. The EC launched and financed a series of seven studies dealing with the following topics:

1. *Climate change impact and carbon sequestration in European forests*
2. *Development of a simple and efficient method field assessment of forest fire severity*
3. *Use of National Forest Inventories to downscale European forest diversity spatial information in five test areas, covering different geo-physical and geo-botanical conditions*
4. *Harmonizing National Forest Inventories in Europe*
5. *Development of harmonised Indicators and estimation procedures for forests with protective functions against natural hazards in the alpine space*
6. *Linking and harmonizing the forests spatial pattern analyses at European, National and Regional scales for a better characterization of the forests vulnerability and resilience*
7. *Evaluation of the set-up of the Level I and LevelI forest monitoring under Forest Focus.*

The specific objectives of the study on "*Climate change impact and carbon sequestration in European forests"* were:

- Strengthening and harmonizing the existing national systems in such a way that they meet the requirements of international monitoring and reporting of Green House Gas (GHG) emissions and sinks in the forestry sector.
- Improving the comparability, transparency and accuracy of the annual greenhouse gas inventory reports of the Land Use and Land Use Change in Forestry (LULUCF) sector of Member States, as implemented under the EU Monitoring Mechanism.

The results of this study set the basis for future reporting GHG and looked into the comparability of data in several European countries in which information was not readily available. It represents a step towards addressing the challenges of GHG inventories and the reporting under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto protocol related to forest land and forest activities.

Ernst Schulte	Jesús San-Miguel-Ayanz
Directorate General Environment	Joint Research Centre

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Executive Summary

The MASCAREF (Study under EEC 2152/2003 Forest Focus regulation on developing harmonized methods for assessing carbon sequestration in European forests) project was conducted by a consortium of 10 European institutions coordinated by IFER – Institute of Forest Ecosystem Research, Czech Republic. The overall objective of the project was to contribute to the development of a monitoring scheme for carbon sequestration in forests of the European Union (EU). Specifically, the project aimed at i) strengthening and harmonizing the existing national systems to better meet the requirements of international monitoring and reporting of greenhouse-gas (GHG) emissions and sinks and ii) improving the comparability, transparency and accuracy of the GHG inventory reports of the Land use, land-use change and forestry (LULUCF) sector of the EU Member States, as implemented in the EC Monitoring Mechanism.

This project represents a step towards addressing the challenges of GHG inventories and the reporting under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol related to forest land and forest activities. Reflecting the heterogeneity in land use, natural conditions and monitoring data availability, there is a wide variety in greenhouse gas reporting practices within the European Union, which becomes clearly apparent from an overview of the current GHG reporting practices prepared by MASCAREF. The particular tasks of the MASCAREF project were based on available data from regional, national and EU-wide projects and relevant activities that took place over the last decade.

The project elaboration was conducted within six tasks, followed by selected regional case-studies. Firstly, the currently available data and methodological approaches to estimate carbon stock and carbon stock change for emission inventories were analyzed. Secondly, the project conducted an analysis of ICP Forests health monitoring and Forest Focus programs. Similarly, it assessed the potential of utilizing data from the European National Forest Inventories for the purpose of emission inventory under UNFCCC and the Kyoto protocol. Related to this, the JRC AFOLUDATA website on biomass functions and conversion/expansion factors was complemented by adding new factors from the European Union Member States. Also, the methodologies to aggregate the forest carbon stock data based on the National Forest Inventory plots to a 10x10 km grid were explored. Finally, several of the above tasks were elaborated and/or applied in case studies in the selected regions of Europe.

Task 1 reviewed the reporting requirements under UNFCCC and Kyoto Protocol. It highlighted that the Kyoto Protocol emissions/removals for the LULUCF sector represent an activity-based subset of emissions/removals from all land uses and land-use changes reported under UNFCCC. The countries can elect to report for activities of Art.3.4 of the Protocol, meaning that these activities would only be elected once it is favourable to the Party. For these reasons, the Kyoto Protocol inventory will most likely underestimate the removals and particularly the emissions from LULUCF.

The analysis of the GHG inventories - annually submitted by EU Annex I countries to the UNFCCC - identified a progressive improvement of completeness and of the methods adopted for LULUCF; consequently, the estimates of emissions/removals from LULUCF also improved. It is likely that the decrease of the total net GHG sequestration in LULUCF which has been observed between 2007 to 2009, may also be influenced by the higher accuracy of the inventories. Definitely, the additional inclusion of other land-use categories in recent GHG inventories of many countries, such as Cropland, Grasslands, Wetlands and Settlements (which are net GHG sources), has mainly affected that overall decrease. In addition, the UNFCCC inventories show that most of EU Member States lack information on deforestation, a mandatory activity under the Kyoto Protocol.

Key recommendations:

1. The CRF tables should be slightly modified to clearly identify the overlap between KP and UNFCCC reporting and therefore reduce the amount of rework and the potential sources of error.

2. The increase of completeness in the GHG inventories is a key issue for increasing the accuracy of the estimate of the GHG balance at the national and EU level. Member States and the EU should constantly improve the knowledge on missing land use categories and missing pools especially when they are a GHG source. In addition they should clearly distinguish between changes of emission/removal trends due to improved methods and higher completeness from real changes in trends in LULUCF.
3. The consistency of reporting for land areas under conversion should be improved. An agreement should be reached on whether to report land-use changes in the conversion categories for a period (e.g. 20 years; cumulative approach) or to report the area that is converted annually (annual approach). For a better consistency with the KP reporting it is recommended to adopt a cumulative approach.

Task 2 chapters have focused on inventories related to forest ecosystem research and forest condition monitoring. Various activities exist in the EU Member States and continent-wide Europe. Reporting on KP 3.4 is expected to be based on the EU/ICP Forests Level I and BioSoil inventories. The BioSoil demonstration project (2006-2008), namely Soil Module, repeats the Level I (1990-1995) at about ¾ of the plots, and – with regard to the GHG reporting needs - concentrates on the soil and litter pools.

While methodological improvements under BioSoil will improve (1) the reliability of the soil carbon estimates and (2) comparability between countries, differences between the initial samplings and those under Biosoil need careful consideration. Without links to long-term measurements, and intensive monitoring sites, the plausibility and validation of such results is difficult. It is hypothesized that the main challenge to utilize the wealth of soil monitoring data in Europe is the analysis and extraction of systematic errors and the plausibility of trends, and the identification of hot spots and outliers. Certainly, the uncertainty of the European sink/source estimate is enlarged compared to national level approaches.

Very few approaches have considered the aspect of verification, for example by integrating large scale inventories with measurement-intensive monitoring, or by comparing inventory-based changes with flux measurements such as those developed by the CarboEurope project.

Key findings:

1. The definition of litter needs to be specified: it is proposed to count the OF and OH horizons of the forest floor into the litter pool; fresh residues (OL) and fine woody debris (FWD) need to be excluded from the litter assessment due to the extremely high variability and lack of data.
2. Changes of SOC and carbon in litter need to be reliable. It requires that methodological improvements do not introduce systematic error. This needs to be carefully addressed when evaluating the BioSoil data, especially at the European level.
3. Changes of SOC and carbon in litter between 1990/1995 and 2006/2007 need to be extrapolated to 2008-2012. A validation at the end of the commitment period may be needed by sampling a set of representative Level I pots.
4. Changes of SOC and carbon in litter need to be verified on the basis of integrated modeling exercises (soil + climate + management/disturbance) and comparisons with flux data and with long-term measurements (forest ecosystem research).
5. A network of forest ecosystem research sites (such as ENFORS) needs to be continued; comparability of data needs to be considered.
6. BioSoil data need to be available as geo-referenced data and applied in integrated modeling; regional strata such as climate groups need to be considered.
7. Inventory-based changes of SOC and carbon in litter need to be integrated with carbon changes in above-ground and below-ground biomass, and compared with flux measurements, at the continental scale.

Task 3 assessed the potential of using data from European National Forest Inventories (NFIs) for the purpose of compiling annual reports to the UNFCCC and the KP. NFIs are conducted in most European countries today, and typically they are conducted based on statistical sampling principles. Thus, only a small fraction of the land is inventoried, normally using sample plots on which many different measurements and assessments are made. While the NFIs largely are installed for other purposes than greenhouse gas reporting, they can rather easily be modified to serve the purpose of providing data for emissions reporting as well. The objectives of this study were twofold. Firstly, an up-to-date assessment on the role of European NFIs was conducted based on a questionnaire. Secondly, critical factors for improving the utilisation of European NFIs were identified and further measures proposed.

Key observations and recommendations:

1. National forest inventories (NFIs) currently provide a substantial portion of the data needed for LULUCF sector reporting and accounting. They are carried out in most EU countries, and in many cases they have recently been modified in order to provide better information on greenhouse gas emissions.
2. In some countries NFIs have been established only recently (or are currently being developed) and it is important that appropriate support is provided (e.g. from the JRC and the European National Forest Inventory Network) to help these countries make full use of the potentials of their NFI data. Several of the newly established NFIs are found in Eastern European countries.
3. All EU Member States probably will not conduct NFIs, and thus for the completeness of the reporting and accounting at the EU level it is important to continue the ongoing work within the EU/Life+ FutMon project that aims at finding synergies between the ICP Forests level I sample plots and the NFIs. In those countries where NFIs are not carried out the level I plots could be used to fill the gaps.
4. NFIs cannot provide all the data needed for the LULUCF/AFOLU sector reporting. In many cases it is thus important to find linkages between NFIs and the other inventories used, so that, e.g., data on land use changes is correctly combined with the corresponding changes in carbon pools.
5. Continued harmonisation of the information from NFIs is important. This includes agreements on reference definitions and bridging techniques to produce estimates according to the references, based on the data available at national level. The collaboration could also include methods for interpolation/extrapolation, uncertainty assessment, etc.

Task 4 analyzed the procedures currently used by MS for translating NFI data of timber volume into carbon stock and annual carbon increment. Secondly, it analyzed the currently recommended biomass conversion and expansion factors as recommended by GPG for LULUCF (IPCC 2003) and by the 2006 IPCC Guidelines for the National Greenhouse Gas Inventories (AFOLU; IPCC 2006). It identified significant discrepancies for some of the proposed factors of the above methodological guidelines that are applicable to Tier 1 default estimation for carbon stock held in biomass. This applies for the major tree species of the temperate region. Thirdly, this task contributed to the JRC database on biomass expansion and conversion factors, which now is a part of the Information System of the JRC Project GHG AFOLU. Finally, an approach of creating robust age-dependent biomass conversion and expansion factors using the available biomass functions and NFI data was demonstrated on one of the case study of Slovakia.

Key observations and recommendations:

1. The biomass factors recommended for biomass carbon stock assessment by the adopted guidance of IPCC (2003) and the recommended guidelines of IPCC (2006) substantially differ for some regions and tree species, indicating a need for their further consolidation.
2. Higher-tier methods and approaches should be applied for carbon stock change in biomass whenever feasible. The suitable biomass factors can be derived by utilizing the available

data from NFI, tree volume functions and locally derived biomass functions or those available from the European databases.

3. A specifically useful resource aiding emission inventory represents the Information System (http://afoludata.jrc.ec.europa.eu/index.php/public_area/home) of the JRC Project GHG AFOLU.

Task 5 introduced a set of methodologies to aggregate the forest carbon source/sink functioning based on National Forest Inventory plot data to 10 km x 10 km European Reference Grid. They were applied for the carbon sink from biomass increase in two countries (Lithuania, The Netherlands) and one region (Umbria in Italy). Following GPG LULUCF Tier 1 equations, plot level C sinks and associated uncertainty were calculated. Uncertainty caused by calculation of the carbon sink and by aggregation was propagated to one grid scale estimate using double Monte Carlo simulations.

Most of the grid cell uncertainty was caused by spatial heterogeneity. Using auxiliary information decreased this to some extent. Thus, the relative uncertainty of the grid cell estimate depended strongly on the number of NFI plots present in the cell, and decreased rapidly as multiple cells were aggregated to a regional value. There was limited spatial correlation for the carbon sink, most likely due to the large effects of management. Uncertainty in model parameters explained only a small part of total uncertainty.

The following recommendations are given to decrease the uncertainty in the estimate of a gridded European carbon sink:

1. The most important source of uncertainty at grid scale was spatial heterogeneity, even for relatively dense NFI networks (The Netherlands, Umbria). It is recommended that existing and projected 1 km x 1 km maps with spatial distribution of forest cover and primary/supporting variables are developed/improved/updated/ maintained.
2. Aggregating grids to larger units quickly decreased uncertainty to a “base” level. It is recommended to use grid cells as the basis for aggregation to (larger) administrative units. An appropriate grid cell size could be derived from the balance between the following two:
    a. grid cells can contain a low number of plots, as the uncertainties average out rapidly when aggregating (i.e. relatively small grid cells).
    b. grid cell size leading to many grid cells without plots makes it impossible to use design based methods. The use of geostatistical methods increases the calculation burden for uncertainty and error budget analysis to a very large extent (i.e. not to small grid cells). For The Netherlands and Umbria, the 10 km x 10 km grid cells seemed appropriate.
3. The current analysis focused on the aggregation of NFI data, and especially growth. An analysis with all pools represented is recommended.

Task 6 of the MASCAREF project focused on five selected test areas, including four countries (Greece, Lithuania, Romania, Slovakia) and one region (Umbria in Italy). The report introduces the forestry sector in these test areas and summarizes the main issues related to the current LULUCF reporting practices. The current National Forest Inventories in place are described, as well as the availability of data from other (European) projects.

The case study in Greece addressed the issue of reporting soil and litter carbon pool changes for the national GHG inventory. Lithuania and Italy served as the case regions for exploring the aggregation methods for a 10x10 km grid estimates. Romania was selected to analyse the possibilities of the newly implemented NFI in addressing the remaining GHG inventory and reporting gaps. Finally, the case study of Slovakia demonstrated a practical approach of deriving robust expansion and conversion factors from available NFI data, tree volume and biomass functions.

The MASCAREF project fulfilled its main objectives and its results should facilitate a further development of monitoring schemes for carbon stock change assessment in forests of the European member states, hopefully leading to an improved GHG reporting both to Member States and European Union level.

List of Abbreviations

1996 IPCC Guidelines	Revised 1996 IPCC Guidelines for National Greenhouse Inventories (IPCC, 1997)
2006 IPCC Guidelines	2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2007)
AFOLU	Agriculture, Forestry and Other Land Use
Annex A source	An source of emissions reported under the Kyoto Protocol
Annex I Party/ Country	A signatory to the Kyoto Protocol which as a specified greenhouse gas emissions limit during the period 2008-2012
BEF	Biomass Expansion/conversion Factor
BEF-1	Biomass Expansion factor type 1: conversion from increment volume to increment biomass
BEF-2	Biomass Expansion factor type 2: conversion from stock volume to stock biomass
BF	Biomass Functions
C	Carbon
CH4	Methane
CLC	Corine Land Cover
CM	Cropland management
CO2	Carbon dioxide
CRF	Common reporting format
DBEF	Biomass Expansion/conversion Factor (incl. wood density)
DBH	Diameter Breast Height
DM	Dry matter
DOM	Dead organic matter
EF	Emission Factor
EFDB	Emission Factor Database
EU	European Union
FAO	Food and Agriculture Organisation
FM	Forest management
Gg	Gigagram = 109 grams
GHG	Greenhouse Gas
GM	Grazing land management
GPG for LULUCF /	Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003)
GPG2000	Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000)
GWP	Global warming potential
HWP	Harvested wood products
IPCC	Intergovernmental Panel on Climate Change
IRR	Initial Review Report
JRC	Joint Research Centre (of the European Commission)
KP	Kyoto Protocol
LULUCF	Land Use, Land Use Change and Forestry
MS	Member States (of European Union)
N2O	Nitrous oxide
NFI	National Forest Inventory
NIR	National Inventory Report
Non-CO2	Greenhouse gases other that CO2 (i.e. CH4, N2O)
OWL	Other wooded land
SOM	Soil organic matter
T1, T2, T3	Tier 1, 2, 3 methods: level of detail at which the calculations are carried out
Tg	Terragrams = 1012 grams
UNFCCC	United Nations Framework Convention on Climate Change

MASCAREF: project management, organization and participants

"*Study under EEC 2152/2003 Forest Focus regulation on developing harmonized methods for assessing carbon sequestration in European forests*" (hereby abbreviated as MASCAREF) was launched as a tender by the Joint Research Centre of the European Commission, Institute for Environment and Sustainability located in Ispra (Italy) and entered into force on June 1st, 2007.

The overall objective of this project was to facilitate development of a monitoring scheme for carbon sequestration in forests of the EU. Specifically, the project aimed at aiding:

- strengthening and harmonizing the existing national systems to better meet the requirements of international monitoring and reporting of GHG emissions and sinks, and
- improving the comparability, transparency and accuracy of the GHG inventory reports of the LULUCF sector of Member States, as implemented in the EC Monitoring Mechanism.

The project was executed in coordination and collaboration with the JRC team led by Guenther Seufert. The project team (see picture below) was composed by 10 research institutes across Europe (Figure 1) and led by IFER – Institute of Forest Ecosystem Research.

The *partners* of the consortium were:

1. IFER - Institute of Forest Ecosystem Research, Jílové u Prahy, Czech Republic;
2. JR - Joanneum Research, Graz, Austria
3. BGR - Federal Institute for Geosciences and Natural Resources, Hannover, Germany;
4. SLU - Swedish University of Agricultural Sciences, Umeå, Sweden, and
5. ALTERRA - Wageningen, the Netherlands.

Meanwhile, the *subcontracted partners* of the consortium were:

6. LFRI - Lithuanian Forest Research Institute, Lithuania;
7. FRMI - Forest Research and Management Institute, Romania;
8. IBAF-CNR - National Research Council, Institute of Agro-Environmental and Forest Biology, Italy;
9. NAGREF, FRI - National Agricultural Research Foundation- Forest Research Institute, Greece
10. NFC - National Forest Centre, Slovakia.

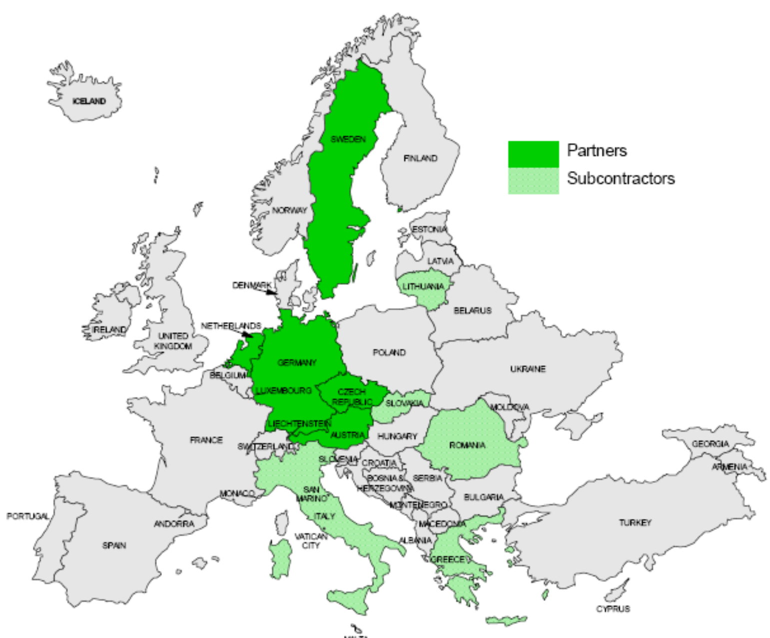

Figure 1. Participants team in the MASCAREF project

The project was based on individual Tasks (1 to 6) with duration of two years. Each of the Tasks 1 to 5 was under the dedicated responsibility of one major partner of the project consortium. Additionally, all partners including the sub-contracted partners were jointly responsible for Task 6.

JRC organized the kick-off meeting at JRC, Ispra (VA, Italy) on 10th July 2007, the second interim meeting was also organized at JRC, Ispra (VA, Italy) during 21-22 January 2008. The project team met at JRC again on 29th January 2009, namely at the project Month 20. Wit this occasion most of the project activities were focused on the pilot countries/regions and the specific issues of Task 6.

The draft of the final technical report providing the results of all tasks set out in Project Proposal was delivered within Month 22 after signature of the contract by the last party. The final technical report containing the description of work was delivered within Month 24 after signature of the contract by the last party and described the progress in the following project tasks:

- analysis of LULUCF/AFOLU reporting requirements and current status (Task 1);
- feasibility study of using parameters from monitoring networks for assessing carbon sequestration in forests (Task 2);
- feasibility study on using parameters from national forest inventories (Task 3)
- compilation and analysis of information on expanding timber volume to biomass carbon stock in forests (Tasks 4);
- concept study on aggregating NFI plot level data at Eurogrid 10x10 km (Task 5);
- pilot studies on gap filling strategy for estimating carbon stock change in forest land in the EU 27 (Task 6).

The teams of the major partners had the following collaboration responsibilities with respect to the sub-contracted partners:

- Alterra is responsible for work with Italy and Lithuania, devoted to application of the Eurogrid aggregation;
- BGR is responsible for work with Greece, focused on soils and dead organic matter;
- SLU is responsible for work with Romania, focusing on how the statistical national forest inventories can be improved to enhance its usefulness for UNFCCC/KP reporting, and

- IFER was responsible for work with Slovakia, concentrated on biomass expansion factors.

While each partner provides data and analysis for its own task, the overall collaboration and project execution was supervised and coordinated by IFER. The project built on continuous consultation with JRC during the project duration. To effectively utilize of funds and time, the meetings also served as interim project meetings for the project partners and as one of the means to follow the implementation and progress towards the project objectives.

1. LULUCF Reporting Requirements under UNFCCC and Kyoto Protocol

David Neil Bird
JOANNEUM RESEARCH, Austria
Email: neil.bird@joanneum.at

Abstract

In the *Good Practice Guidance for Land Use, land-Use Change and Forestry – GPG-LULUCF* (IPCC 2003) the Intergovernmental Panel on Climate Change released comprehensive methodologies and common reporting format tables for reporting emissions and removals from land use, land-use change and forestry (LULUCF). These methodologies and tables provided a more complete reporting approach than in *Revised 1996 IPCC Guidelines for National Greenhouse Inventories* (IPCC, 1997). The *Good Practice Guidance for Land Use, land-Use Change and Forestry* is the current standard adopted by most Parties for reporting LULUCF.

In 2007, Annex – I parties made their initial submission to the United Nations Framework Convention on Climate Change (UNFCCC) under the Kyoto Protocol. This submission used a common reporting format adopted by the Conference of the Parties (Decision 15/CP.10 Annex 1). These tables are somewhat more convoluted than the new common reporting format adopted in the *GPG-LULUCF* because of the complicated accounting required because of the negotiations of the Kyoto Protocol. This paper highlights the changes from the *Revised 1996 IPCC Guidelines* adopted in the *GPG-LULUCF* and reviews the reporting requirements as part of the Kyoto Protocol. The Kyoto Protocol emissions represent an activity-based subset of the emissions from all lands particularly since only lands that have been converted from non-forest to forests or vice versa since 1990 (afforestation, reforestation and deforestation), management activities on forest land (FM), cropland (CM), grazing land (GM) and activities that increase carbon stocks on non-forest land (RV) since 1990 are considered. Since FM, CM, GM, and RV will only be reported if it is favourable to the Party, the Kyoto Protocol inventory underestimates the emissions from LULUCF. In 2007, the IPCC also released the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2007). These guidelines attempt to account for emissions from all lands within AFOLU, but since use of the new guidelines is not mandatory at this time, a summary of these CRFs is given as an appendix.

1.1. *Introduction*

In 2003, the Intergovernmental Panel on Climate Change released the *Good Practice Guidance for Land Use, Land-Use Change and Forestry* – hereafter referred to as *GPG-LULUCF* (IPCC 2003). This document delivered a common reporting format tables for agriculture, forestry and other land use different than the *Revised 1996 IPCC Guidelines for National Greenhouse Inventories* (IPCC, 1997) and introduced new sources of emissions from this sector.

In 2007, the Intergovernmental Panel on Climate Change released the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2007). The new guidelines incorporate improvements in knowledge of GHG emissions introduced in the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* – hereafter referred to as *GPG2000* – and the *Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF)*. The use of the new guidelines is not mandatory at this time[1].

[1] FCCC/SBSTA/2007/L.5

As well in 2007, Annex – I parties made their initial submission to the United Nations Framework Convention on Climate Change **(UNFCCC**) under the Kyoto Protocol. This submission used a common reporting format adopted by the Conference of the Parties (Decision 15/CP.10 Annex 1), but these submissions do not report the same emissions or use the same format as in the *GPG-LULUCF* or *2006 IPCC Guidelines*.

In 2007, the IPCC also released the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2007). This guide delivered a more comprehensive common reporting format tables for agriculture, forestry and other land use (AFOLU) than in the *GPG-LULUCF*. The new guidelines incorporate improvements in knowledge of GHG emissions introduced in the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* – hereafter referred to as *GPG2000* – and the *GPG-LULUCF*. Since use of the new guidelines is not mandatory at this time, a summary of these CRFs is given as an appendix.

The paper concludes with a schematic mapping of the Kyoto Protocol emissions within the emissions reported under *GPG-LULUCF*. This mapping suggests that with a little manipulation, the common reporting formats of both the Kyoto Protocol and the *2 GPG-LULUCF* could be modified to clearly identify the overlap between the two systems and reduce the amount of rework and the potential for error that results both.

1.2. *Reporting Under the UNFCCC*

In 2003, the IPCC released the *GPG-LULUCF* (IPCC 2003). A main difference between these guidelines and the previous reporting guidelines (IPCC, 1996) is that agriculture and land use, land-use change and forestry (LULUCF) are reported in one common reporting format (CRF).

These key features of the *GPG-LULUCF* are:

- Adoption of the six land-use categories;
- Reporting on all emissions by sources and removals by sinks from managed lands, which are considered to be anthropogenic;
- Generic methods for accounting of biomass, dead organic matter and soil C stock changes in all land-use categories and generic methods for greenhouse gas emissions from biomass burning that can be applied in all land-use categories;
- Incorporating methods for non-CO_2 emissions from managed soils and biomass burning, and livestock population characterization and manure management systems from agriculture
- Adoption of three hierarchical tiers of methods that range from default emission factors and simple equations to the use of country-specific data and models to accommodate national circumstances;
- Introduction of the basis for future methodological development for estimation of harvested wood products[2];
- Incorporation of key category analysis for land-use categories, C pools, and CO_2 and non-CO_2 greenhouse gas emissions;
- Adherence to principles of mass balance in computing carbon stock changes;
- Greater consistency in land area classification for selecting appropriate emission and stock change factors and activity data;
- Improvements of default emissions and stock change factors, as well as development of an Emission Factor Database (EFDB);

[2] New in the *GPG-LULUCF*

- Introduction of the basis for future methodological development of non-CO2 emissions from drainage and rewetting of forest soils[3].

1.2.1. Land-use categories

The *LULUCF* sector reports on emissions and removals of CO_2 and non-CO_2 GHGs separately from six land-use categories. The six land use categories are:

1. Forest land
2. Cropland
3. Grassland
4. Wetlands
5. Settlements; and
6. Other land.

Each land category is further subdivided into land remaining in that category and land converted from another category.

1.2.2. Carbon pools

In the *GPG-LULUCF*, carbon stock changes in five carbon pools are reported for the UNFCCC. The five pools are:

1. Above-ground biomass (all biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds and foliage);
2. Below-ground biomass (live roots > 2 mm diameter);
3. Dead wood (including all non-living biomass above and below ground with diameter > 10 cm);
4. Litter (including all non-living biomass with diameter > 2 mm and less than 10 cm); and
5. Soil organic matter (including all live roots < 2mm diameter, litter with diameter < 2 mm, and all dead roots < 10 cm diameter).

The definitions may vary based on national circumstances, but they should be clearly documented and used consistently over time.

1.2.3. Other CO_2 and non-CO_2 emissions

In *GPG-LULUCF* only other CO_2 from liming of soils and non-CO_2 emissions from burning of biomass are considered. Other CO_2 emissions and non-CO_2 emissions from specific agricultural activities are reported at the national scale and not by land-use category as part of the emissions from agriculture. For example, non-CO_2 emissions from livestock are reported by major animal type and animal waste management system. Non-CO_2 emissions from soil management such as nitrous oxide (N_2O) from fertilizer use are also estimated at the national level.

1.2.4. Key Categories

The concept of *key source categories* was introduced in the *GPG2000* and in the *GPG-LULUCF* is extended to include both sources and sinks. In the *GPG2000* a key category is defined as:

> *"one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both"*

For the LULUCF sector, a key category analysis is required to identify:

[3] New in the *GPG-LULUCF*

- which land-use and management activities are significant;
- which land-use or category is significant;
- which CO2 emissions or removals by sinks from various carbon pools are significant;
- which non-CO2 gases and from what categories are significant; and
- which tier is required for reporting.

1.2.5. Reporting Tiers

Parties can use one of three tiers (or a combination of tiers for different land use types or emission categories, if needed) when creating the LULUCF inventory. Higher tiers give a more accurate representation, but are more complex and costly to adopt. The CRF and *GPG-LULUCF* focus on Tier 1 reporting (the simplest). To adopt Tier 2, a country should replace the Tier 1 default data with country-specific and regional data while still using the methodology outlined in the CRF and *GPG-LULUCF*.

1.2.6. Common Reporting Format Methodology

In general, the Tier 1 methodology is quite simple. The country supplies land use area and land use change area estimates for the given reporting year. These are multiplied with a series of constants and the combined to create the stock changes or emissions under consideration. For the UNFCCC, emissions and removals from stock changes on all lands and all land use changes are included in the calculation. The following is a concise summary of salient points for each land use category

- For forest land, and lands converted to forest land, the gains and losses in all five pools are estimated. The *annual increases in carbon due to biomass increment, annual losses due to fellings, fuel wood gathering and other disturbances* are estimated using volume increments, biomass density, biomass expansion factors (BEFs) and root-to-shoot ratios. The annual change in dead wood is estimated in using per hectare factors for dead wood transferred into and out of the forest land. Litter and soil are more complicated because the transition between forest states occurs over a transition period of 20 years.
- In the case of cropland remaining cropland, only the changes in above and below ground biomass of woody perennials and changes in soils, divided into mineral and organic soils are considered.
- In the case of grassland remaining grassland, changes in above and below ground biomass of woody perennials, below-ground biomass of grasses and changes in soils, divided into mineral and organic soils are considered. For lands converted to grassland, the CRF does not include dead biomass even though table GL-2a has the label Annual change in carbon stocks in living and *dead* biomass
- For wetlands that remain wetlands (peat extraction), the CO_2-C emissions from peat extraction from nutrient rich and nutrient poor soils, on-site changes in biomass stocks and off-site emissions from the horticultural use of the extracted peat are estimated. As well, the N_2O emissions from the draining of nutrient rich peat lands are included. This includes the conversion from other land categories to wetlands used for peat extraction.
- For wetlands that remain wetlands (flooded land) a draft methodology for consideration is listed in an appendix. It includes CO_2 and CH_4 emissions from the flooded land using measured or estimated daily emission rates of each gas.
- The emissions from land converted to wetlands by flooding are calculated simply by accounting for the change in biomass stocks before and after flooding. The methane emissions from biomass that remains on site also estimated in the *GPG-LULUCF* CRFs.
- For settlements, the annual change in living biomass in settlements remaining settlements and lands converted to settlements are now estimated.
- Lands converted to Other lands have emissions from carbon stock changes in living biomass and mineral soils

- Non-CO_2 trace gas emissions that result from the burning of biomass on all lands that remain in their initial state (for example, forest lands remaining forest lands) and lands that undergo a land use change are calculated.
- Emissions from CO_2 emissions from the liming of soils on all land use types are included.
- Emissions from agricultural practices are not considered in the LULUCF CRF but are still part of the *1996 IPCC Guidelines*. These include:
- Fertilizer use and manure management in agriculture that create N2O emissions.
- Rice cultivation which causes CH4 emissions and
- Enteric fermentation in ruminants

1.3. *Reporting Under the Kyoto Protocol*

Reporting under the Kyoto Protocol is more convoluted than under the UNFCCC. Under the Kyoto Protocol, an Annex-I Party must report annually on all emissions from the six sectors identified by the IPCC: energy, industrial processes, solvents and other product use, agriculture, LULUCF and waste. Of these, all sectors except LULUCF are considered Annex A sources. In particular, for this discussion, the agricultural sector report includes emissions from;

- Enteric fermentation
- Manure management
- Rice cultivation
- Agricultural soils
- Prescribed burning of savannas
- Field burning of agricultural residues; and
- Other.

All Annex A inventory estimates must be prepared using methods that are consistent with the *1996 IPCC Guidelines* and the IPCC good practice guidance. The GHG inventory can be prepared using national methods, provided that these methods are consistent with the IPCC guidance and result in more reliable estimates. In LULUCF most Parties have adopted the *GPG-LULUCF* CRFs in their reporting.

1.3.1. LULUCF – Activity Based Reporting

Instead of land-use based reporting structure, reporting under the Kyoto Protocol is activity based. This is a result of the Kyoto Protocol negotiating process. During the negotiation of the Kyoto Protocol, inclusion of emissions from LULUCF was limited to specific activities from specific lands as defined under Article 3 paragraphs 3 and 4. Therefore, the emissions are a subset of the emissions and removals reported under the UNFCCC.

Article 3, Paragraph 3 Activities

Article 3, paragraph 3 covers direct emissions from land use change only on lands where the conversion occurred after 31 December 1989. The land use change is limited to:

- **Afforestation and reforestation (AR)**: the conversion of non-forest land to forest land with the distinction that if the land had not been forest for more than 50 years then the conversion is referred to as afforestation[4].
- **Deforestation (D)**: the conversion of forest land to non-forest land.

An Annex-I party is required to report on all Article 3, paragraph 3 emissions.

Article 3, Paragraph 4 Activities

Specific anthropogenic activities, that have occurred since 1990, but have not caused a conversion of land since 1990, are covered under Article 3, Paragraph 4. These activities are limited to:

- **Forest management (FM)**: a system of practices for stewardship an use of forest land;
- **Cropland management (CM)**: as system of practices on land on which agricultural crops are grown or on land that is set aside or temporarily not being used for agricultural production;
- **Grazing land management (GM)**: a system of practices on land used for livestock production; and
- **Revegetation (RV)**: an activity that increases carbon stocks on sites but the activity does not create a forest.

Since reporting of Article 3, paragraph 3 activities is mandatory, it has precedence over an article 3, paragraph 4 activity. So that if land use change since 1990 was involved then the emissions and removals from this land is reported under Article 3, paragraph 3 even if the land incurred an activity that would be considered under Article 3, paragraph 4.

Precedence is also given to the deforested category. Land can theoretically switch from AR to D if the land was subject to AR since 1990 and subsequently deforested, but once land is deforested it remains classified as deforested land during the entire reporting period.

A given land area can only be classified under one particular activity, and once included in the KP inventory, it must be accounted for the remainder of the commitment period and subsequent periods[5].

Finally, since reporting of Article 3, paragraph 4 is optional, there will be a bias towards using Article 3.4 to a Party's advantage (i.e. the Party will elect to report on Article 3.4 only if it believes that it will create increased emission removals)[6]. As a result, only emissions from these activities will appear in the KP inventory.

1.3.2. Carbon pools

Unlike the UNFCCC, which requires reporting of stock changes in all pools, under the Kyoto Protocol, a Party may omit any carbon pool with due justification[7].

Carbon stock changes in harvested wood products (HWP) are not reported.

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[4] Though there is a distinction between afforestation and reforestation in the KP, it is not necessary to distinguish between the land use changes that are afforestation and those that are reforestation in the KP common reporting format (CMP.3, Good practice guidance for land use, land-use change and forestry activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol)

[5] Decision 16/CMP.1, Annex, paragraph 19, also *GPG-LULUCF* page 4.15

[6] Canada elected not to report FM under Article 3.4 because the risk of FM being a net source primarily due to losses from forest fire was more than the risk of FM being a net sink.

[7] Decision 15/CP.10 Annex 1, paragraph 3.1.2.

1.3.3. Other CO_2 and non-CO_2 emissions

Other CO_2 and non-CO_2 emissions are reported from lands that are included as Article 3.3, or Article 3.4 if elected. These emissions include:

- N_2O from fertilizer use, drainage of soils under forest management, and other disturbances associated with land use conversion to cropland,
- CO_2 from liming of soils; and
- CO_2, CH_4 and N_2O emissions from biomass burning. Note, that Parties should be careful not to double report the CO_2 emissions from biomass burning if they were already included under changes in carbon stocks.

1.3.4. Key Categories

Reporting under the KP requires a key category analysis following the methodology described in section 5.4 of the *GPG-LULUCF*.

1.3.5. Additional Reporting Requirements

There are a few additional reporting requirements of the Kyoto Protocol. A Party must:

1. Define “forest” using the parameters; area, canopy closure and tree height;
2. Define activities elected under Article 3.4;
3. Describe the methodology used to develop the land transition matrix for Kyoto Lands;
4. Provide information on whether or not indirect and natural emissions and removals have been factored out;
5. Provide information on the methodology to distinguish deforestation from harvesting or other forest disturbance followed by forest re-establishment;
6. Estimate the size and location of forest area that have lost forest cover but are not yet classified as deforested; and
7. Provide information relating to CM, GM and RV, if elected, for the base year.

Most Annex-I countries will already have supplied this information as part of their initial report under the Kyoto Protocol.

1.3.6. Common Reporting Format Methodology

In general, the CRF[8] for the Kyoto Protocol is organized by activity. Summary tables collate the national information by activity and are supported by supplementary information. The supplementary tables are required for each activity. These tables are subdivided by geographic area with the geographic identification of each parcel of land. This can be provided in map form or a database with each land unit having a unique geographic identification code.

For each the carbon stock changes for each pool are calculated. As well, one should calculate an implied carbon stock change factor by pool and implied total emission factor per area.

Requiring separate calculation and tabulation are the emissions from:

- N_2O from fertilizer use, drainage of soils under forest management, and other disturbances associated with land use conversion to cropland,
- CO_2 from liming of soils; and
- CO_2, CH_4 and N_2O emissions from biomass burning

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[8] CMP.3. Good practice guidance for land use, land-use change and forestry activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol

In all cases, lands that have AR activities are further subdivided into lands that have been harvested during the commitment period, and lands that have not.

1.4. *Conclusions*

The *GPG-LULUCF* represents a great improvement in the consistency and completeness of reporting of greenhouse gas emissions. They are organized in a consistent land use based manner and have introduced a more complete inventory. Reporting under the Kyoto Protocol remains a convoluted mish-mash of activity based emissions due to the negotiation of the Protocol. Figure 1-1 and Figure 1-2 attempt to map the reporting requirements from the *2006 IPCC Guidelines* into the Kyoto Protocol format. It is recommended that a unified method to accomplish this, by modifying the reporting formats of both systems, is developed. The advantage of such a mapping would be improved transparency in both reports, a decrease in the amount of rework by Parties, and the reduction in the potential for error in both reports.

Figure 1-1 Relationship of reporting under UNFCCC and Kyoto Protocol – CO_2 emissions and removals

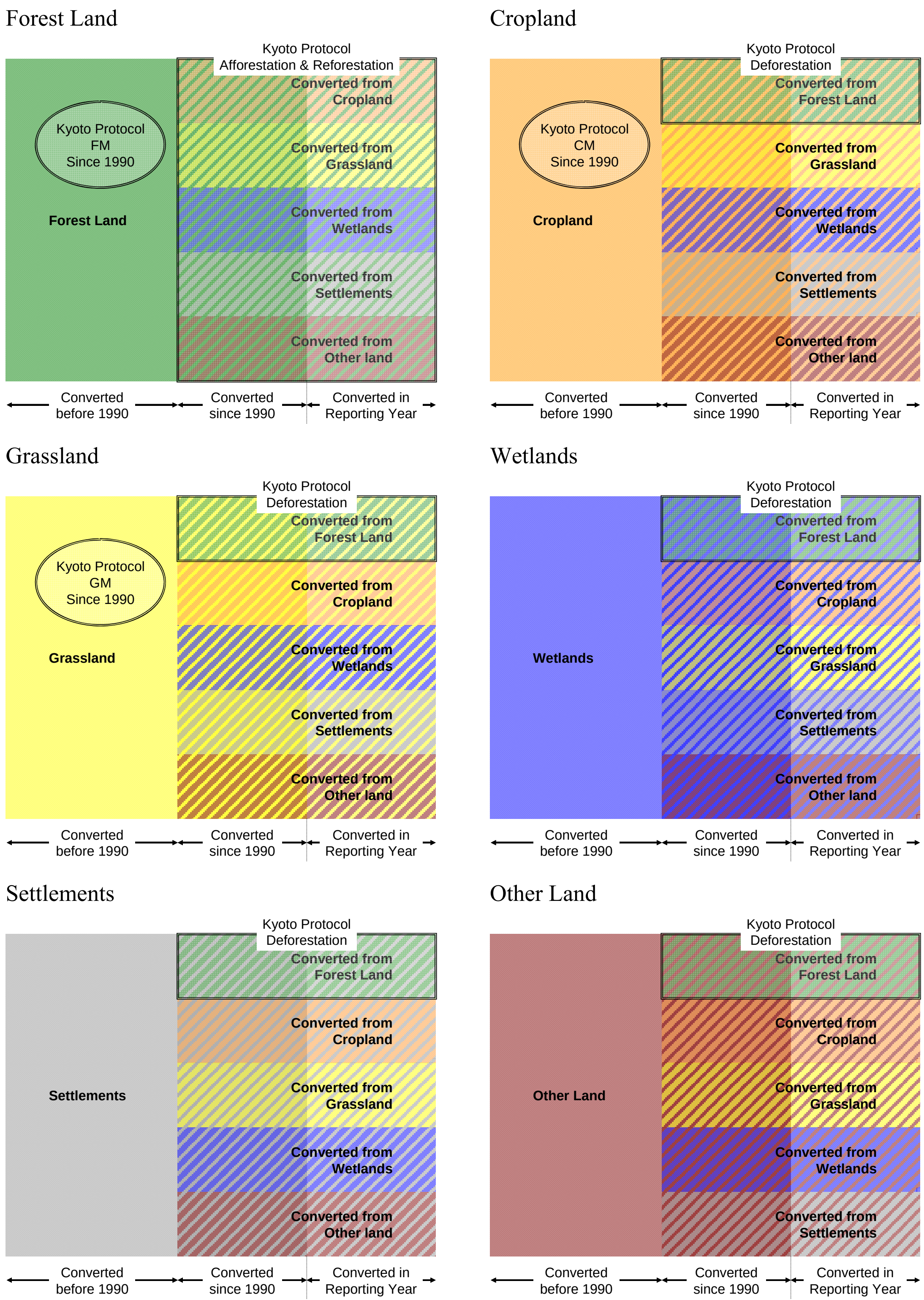
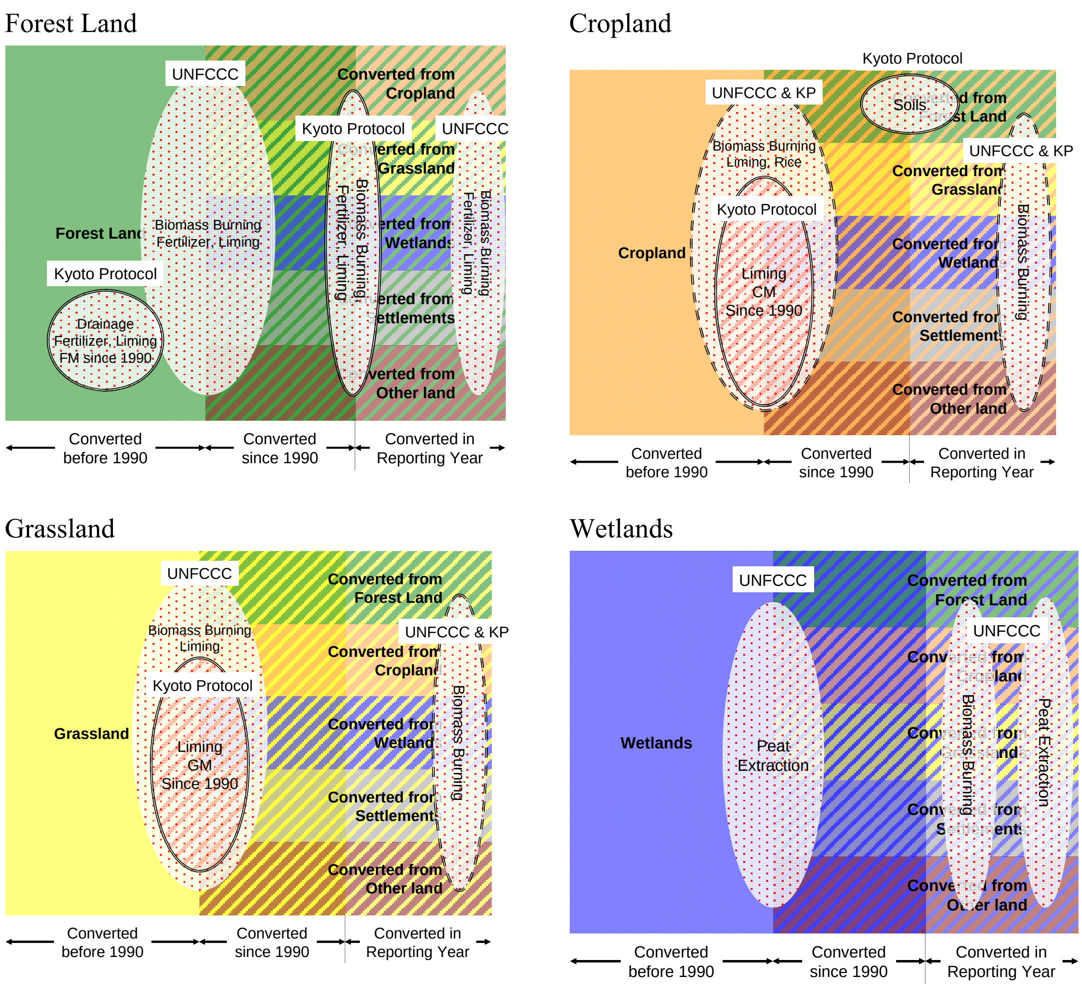


Figure 1-2: Relationship of reporting under UNFCCC and Kyoto Protocol – Non-CO2 emissions



Explanatory Note for Figure 1-1:

The coloured portions represent land use categories that may have emissions and removals reported under the UNFCCC. The size of the rectangles is not representative of amount of area or emissions and removals. The categories are subdivided along the horizontal axis by time of conversion.

The KP reports on a subset of these emissions and removals. For example, the KP reports on emissions from all lands converted since 1990 (deforestation) and emissions ad removals from all lands converted to forest land since 1990.

Explanatory Note for Figure 1-2:

The coloured portions represent land use categories that may have emissions and removals reported under the UNFCCC. The size of the rectangles is not representative of amount of area or emissions and removals. The categories are subdivided along the horizontal axis by time of conversion.

Within these areas, the ovals represent emissions from a variety of sources. Some emissions are reported only under the Kyoto Protocol, others only under the UNFCCC, while some are reported for both.

Emissions from biomass burning under the Kyoto Protocol only are reported from forest lands that have been converted since 1990 (AR) or due to forest management since 1990.

Emissions from fertilizer use are shown only on forest land because in the Kyoto Protocol only emissions on lands that are new forests (AR) since 1990 or due to forest management since 1990 are included. In all other land categories emissions from fertilizer are calculated in the same manner in both systems.

Emissions from enteric fermentation, manure management and urea application are not shown because they are reported in both systems in the same manner.

1.5. *References*

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1.6. *Comments on 2006 IPCC Guidelines for National Greenhouse Gas Inventories*

In 2007, the IPCC released the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2007). A main difference between these guidelines and the previous version (IPCC, 1996) and *GPG-LULUCF* is that agriculture and land use, land-use change and forestry (LULUCF) are now reported as one category Agriculture, Forestry and Other Land Use (AFOLU). The integration is intended to make the inventories more consistent and complete. As well, the new guidelines incorporate improvements in knowledge of GHG emissions introduced in the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (*GPG2000*) and the Good Practice Guidance for Land Use, Land-Use Change and Forestry (*GPG-LULUCF*).These key features of the *2006 IPCC Guidelines* are:

- Adoption of the six land-use categories used in *GPG-LULUCF*;
- Reporting on all emissions by sources and removals by sinks from managed lands, which are considered to be anthropogenic;
- Generic methods for accounting of biomass, dead organic matter and soil C stock changes in all land-use categories and generic methods for greenhouse gas emissions from biomass burning that can be applied in all land-use categories;
- Incorporating methods for non-CO_2 emissions from managed soils and biomass burning, and livestock population characterization and manure management systems from agriculture

- Adoption of three hierarchical tiers of methods that range from default emission factors and simple equations to the use of country-specific data and models to accommodate national circumstances;
- Description of alternative methods to estimate and report C stock changes associated with harvested wood products[9];
- Incorporation of key category analysis for land-use categories, C pools, and CO_2 and non-CO_2 greenhouse gas emissions;
- Adherence to principles of mass balance in computing carbon stock changes;
- Greater consistency in land area classification for selecting appropriate emission and stock change factors and activity data;
- Improvements of default emissions and stock change factors, as well as development of an Emission Factor Database (EFDB); and
- Incorporation of methods to estimate CO_2 emissions from flooded land with methods for CH_4 emissions[10].

1.6.1. Land-use categories and carbon pools

Identical to *GPG-LULUCF*.

1.6.2. Other CO2 and non-CO2 emissions

Other CO_2 and non-CO_2 emissions from specific activities may be reported at the national scale and not by land-use category if only aggregate data are available. For example, non-CO_2 emissions from livestock are reported by major animal type and animal waste management system. Non-CO_2 emissions from soil management such as nitrous oxide (N_2O) from fertilizer use and CO_2 emissions from liming and urea application are also estimated at the national level.

Carbon stock changes in harvested wood products (HWP) are also reported using the *2006 IPCC Guidelines* based on national-level data, but the final method that will be used is still under negotiation.

1.6.3. Key Categories and Reporting Tiers

Identical to *GPG-LULUCF*.

1.6.4. Common Reporting Format Methodology

In general, the Tier 1 methodology is quite simple. The country supplies “activity” data (i.e. number of head of a specific cattle type, areas of a certain land use, or areas of a certain land use change). These are multiplied by an “emission factor” (i.e. emission factor for nitrogen fertilizer application, or above ground biomass increment) and one or more conversion factors to arrive at a consistent unit for the activity.

For the UNFCCC, emissions and removals from stock changes on all lands and all land use changes are considered in the calculation. The following is a concise summary of salient points for each land use category

- For forest land, and lands converted to forest land, gains and loses in all five pools are estimated (no change from *GPG-LULUCF*)

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[9] Introduced in *GPG-LULUCF* but expanded in the *2006 IPCC Guidelines*

[10] New in the *2006 IPCC Guidelines*

- In the case of cropland remaining cropland, only the changes in above and below ground perennial woody biomass and changes in soils, divided into mineral and organic soils are considered. All five pools are considered for lands converted to cropland.
- Only the carbon stock changes from mineral and organic soils are included on lands that remain grassland. All five pools are considered for lands converted to grassland.
- For wetlands that remain wetlands, the CO_2-C emissions from peat extraction from nutrient rich and nutrient poor soils, on-site changes in biomass stocks and off-site emissions from the horticultural use of the extracted peat are estimated. As well, the N_2O emissions from the draining of nutrient rich peat lands are included. This includes the conversion from other land categories to wetlands used for peat extraction.
- The emissions from land converted to wetlands by flooding are calculated simply by accounting for the change in biomass stocks before and after flooding. The methane emissions from biomass that remains on site after flooding are not considered at this time. Available information on CH_4 emissions is provided in but the *2006 IPCC Guidelines* do not recommend a default methodology. Countries seeking to report CH_4 emissions from flooded lands should, where feasible, develop domestic emission factors.
- For settlements, the annual change in carbon stocks in organic soils for settlements remaining settlements and the annual change in carbon stocks for all five pools on lands converted to settlements are now estimated.
- Lands converted to Other lands have emissions from carbon stock changes for all pools but losses of dead organic matter are not considered. Even though the *2006 IPCC Guidelines* state: *All biomass carbon stocks are assumed to be emitted in the year of conversion, thus there is no accumulation of DOM stocks*, and they do not seem to be calculated.
- Non-CO_2 trace gas emissions that result from the burning of biomass on lands. In the 2006 IPCC Guidelines this are calculated in a consistent manner with burning on lands that do not undergo a land-use change, and then on lands that undergo a land-use change. Previously, the emissions from the burning of agricultural residues and grasslands that did not incur a land-use change were part of the agricultural report. The burning of forests and grasslands that were cleared for agriculture and burning of forests that remained forest were part of the LULUCF chapter.
- Emissions from liming of soils and the use of urea are part of the *2006 IPCC Guidelines*.
- Fertilizer use and manure management in agriculture create N_2O emissions. In the *2006 IPCC Guidelines* these are included under the AFOLU category.
- Finally, rice cultivation cause CH_4 emissions, which previously were part of the agricultural sector, are now reported under the AFOLU category.

2. LULUCF Inventory of the European Union - State of the Art, Gaps and Recommended Improvements

Giuliana Zanchi
JOANNEUM RESEARCH, Austria
Email: giuliana.zanchi@joanneum.at

Abstract

Annex I countries are required to yearly report green house gas emissions and removals to the UNFCCC from six sectors (Energy, Industrial processes, Solvents, Agriculture, LULUCF, Waste). The Parties submit their inventories in two main documents: a description of used methods, the National Inventory Report (NIR) and a series of tables containing quantitative information, the Common Reporting Format (CRF). Here the aim is to discuss the information on the Land Use and Land-Use Change sector reported by EU Member States in the UNFCCC GHG inventories. The NIRs and CRFs submitted by Annex I countries of the European Union in 2007, 2008 and 2009 were analysed. An overview of data sources, methodologies used by the countries and a summary of the development of emission and removal estimates in the LULUCF sector are given. The analysis focuses on the completeness of reporting, identifies the most important data gaps and suggestions for improvement are provided. The results are also used to understand if EU countries are ready to report for the LULUCF activities under the Kyoto Protocol and the most important gaps were identified.

2.1. *Introduction*

Annex I countries are required to annually report green house gas emissions and removals to the UNFCCC from six sectors (Energy, Industrial processes, Solvents, Agriculture, LULUCF, Waste). The Parties submit their inventories in two main documents: the National Inventory Report (NIR) and the Common Reporting Format (CRF). The NIR contains a description of used methodologies and data sources, of the uncertainties and the quality assurance and quality control system at the national level; it gives also an overview of the emission/removal trends of the green house gases (GHGs) in the different sectors. The CRF is a series of tables containing quantitative information on GHG emissions and removals organised by sector[11].

Comprehensive methodologies and common reporting format tables for reporting emissions and removals from land use, land-use change and forestry (LULUCF) were released in the *Good Practice Guidance for Land Use, land-Use Change and Forestry – GPG-LULUCF* (IPCC 2003) by the Intergovernmental Panel on Climate Change (IPCC). This guidance is the current standard **a**dopted by most Parties for reporting LULUCF under the UNFCCC. In 2006 the IPCC produced new guidelines, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2007), but the document is not mandatory at this time[12] and still not used by EU Annex I country.

The sections and tables on the LULUCF sector in the NIRs and CRFs submitted by EU Annex I countries in 2007, 2008 and 2009 were analysed. An overview of data sources and methodologies is given. The emission and removal trends in the different land use categories, the reported carbon pools and the development of reporting in the last three years are briefly described. The analysis focuses on the completeness of reporting and tries to identify the most important data gaps. Particular attention is given to the Forest Land category which is the main contributor to the emissions and removals in the LULUCF sector in the European Union.

[11] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/4303.php

[12] FCCC/SBSTA/2007/L.5

The data reported in the GHG inventories were also used to understand if countries are ready to comply with Kyoto Protocol reporting. EU Member States (MS) will use the same or similar data sources for reporting under UNFCCC and the Protocol and therefore the UNFCCC GHG inventories are a good overview of the state of art of MS reporting methods. The most relevant gaps that MS will have to fill to report for LULUCF activities under the Protocol are identified.

2.2. *LULUCF emission and removals: level of completeness*

The carbon balance in the LULUCF sector in Europe is a net sink. In 2007 the amount of GHG removals in EU Annex I countries was about -408 Tg of CO_2 eq. (EU-25). A net sink occurred in forest land and grasslands, while cropland, wetlands, settlements and other lands were a net source of 115 Tg of CO_2 eq.

The net GHG balance changed substantially from the estimates submitted for 2006 in the 2008 GHG inventories, when the net sink was about -500 Tg of CO_2 eq in EU-25. The change is due to a decrease of the removals from 2006, but mainly to recalculations. In the 2009 GHG inventories the net GHG balance for LULUCF in 2006 was equal to -425 Tg of CO_2 eq. against the -495 Tg of CO_2 eq. reported in the 2008 GHG inventories. The most significant changes occurred in the assessment of emissions and removals in cropland, grasslands, wetlands and settlements (Table 2-1).

Table 2-1 GHG emissions and removals in the LULUCF sector in EU-15 and EU-25 in 2006 and 2007. The figures reported in the GHG inventories 2009 for the year 2006 are compared to the figures reported in the GHG inventories 2008 for the same year

EU	Land-use	EC GHG 2009		EC GHG 2008
		2007	2006	2006
		(Tg CO_2 eq.)		
EU-15	5. LULUCF	-259.0	-287.4	-353.1
	A. Forest Land	*-353.6*	*-393.8*	*-418.9*
	B. Cropland	*66.1*	*70.1*	*43.6*
	C. Grassland	*-4.8*	*1.7*	*5.3*
	D. Wetlands	*5.0*	*4.9*	*2.6*
	E. Settlements	*27.4*	*27.2*	*12.3*
	F. Other Land	*1.4*	*1.4*	*2.6*
	G. Other	*-0.5*	*1.1*	*-0.6*
EU-25	5. LULUCF	-407.7	-424.8	-494.8
	A. Forest Land	*-515.6*	*-544.2*	*-554.2*
	B. Cropland	*75.4*	*79.3*	*37.1*
	C. Grassland	*-6.8*	*-0.2*	*4.1*
	D. Wetlands	*11.1*	*11.0*	*3.3*
	E. Settlements	*27.4*	*27.2*	*12.3*
	F. Other Land	*1.3*	*1.0*	*3.1*
	G. Other	*-0.5*	*1.1*	*-0.6*

The quality level of a GHG inventory is strictly dependent on the accuracy of the estimates of sinks and sources that mainly contribute to the national carbon balance. The reliability of the emission and removal estimates is first of all dependent on the completeness of the submitted inventories. Therefore it is important to have the most complete overview as possible of carbon fluxes in each sector. The completeness of the 2007, 2008 and 2009 GHG inventories was analyzed, considering all the land use categories and the carbon pools in the most important land use categories (Forest land 5.A, Cropland 5.B, Grassland 5.C). The analysis covers all the EU Annex I countries (EU-25 in this report). Part of the data is derived from the EC GHG inventories and form synthetic files developed by the European Environmental Agency.

2.2.1. Reported categories

The LULUCF section in the UNFCCC inventories is structured in 5 main land uses and each of them is divided in two sub-categories: land remaining in that category and land converted from another category.

The Forest land is the predominant emission/removal category of the LULUCF sector in Europe and it is also the most frequently reported land use. Nearly all the countries reported for the category 5.A.1, "Forest remaining Forest" (92%) and most of them for the category 5.A.2, Land converted to Forest" (more than 70%). Some countries did not separate the Forest sub-categories and included 5.A.2 in 5.A.1 (Finland) or 5.A.1 in 5.A.2 (Great Britain). The other land-uses are reported less frequently because of lack of activity data or because their GHG emissions and removals are negligible. The most complete is 5.B.1 "Cropland remaining Cropland" which was reported by 75% of the MS. Some improvements were done in the 2009 GHG inventories especially for the category 5C "Grassland" and 5D "Wetlands". The number of countries that reported for 5C and 5D increased of 10-15% in 2009 (Table 2-2 and Table 2-3).

Until 2008, the land use "remaining" in the same category was better covered than the "conversions" to other land uses. In 2009 the "remaining" categories are better represented for Forest land and Cropland, while the "conversion" categories are predominant in the other land uses, "Grassland", "Wetlands" and "Settlements".

One of the consequences of the incomplete reporting for land-uses different than Forest land is a lack on information on deforestation. The gap is particularly relevant for the compliance of MS with Kyoto Protocol reporting. Only 7 MS reported the emissions due to deforestation in the Summary Table 5 in the CRFs.

The improvement of completeness in 2009 led to a substantial change of the assessment of the carbon sequestration in the LULUCF sector in Europe. The progressive inclusion of additional land-use categories in the GHG inventories corresponds to an equally progressive reduction of the total net GHG sequestration in LULUCF. The increased level of reporting for land-use categories as Cropland, Grasslands, Wetlands and Settlements is likely to increase the emissions in the LULUCF sector, because these categories or the conversion to these land-uses are a net GHG source in most of the countries.

2.2.2. Reported pools

The most frequently reported pool is "Biomass" (B) over all land-use categories, while SOM (soil organic matter) and DOM (dead organic matter) are often lacking (Table 2-4 and Table 2-5). In the 2007 submissions, Belgium, Czech Republic, France, Hungary, Lithuania, Spain, and Great Britain used CRF tables where the organic soil pool was not separated from the mineral soil pool. From 2008 all the countries used CRF tables where this distinction is done, but few countries reported emissions/removals for organic soils. A noteworthy increase of reported pools was identified in Czech Republic and Sweden in 2008 and in Estonia and Poland in 2009. Major changes in the trend of emissions or removals were reported by MS in the 2009 inventories. Several carbon pools that increased in the 2008 inventories, changed to decreasing trends in the 2009 inventories. In most of the cases the change occurred in DOM and soil pools in Forest land.

The inclusion of new carbon pools as the inclusion of new land-use categories in the national GHG inventories concur to explain the relevant changes of the LULUCF GHG balance in the EU observed between the 3 inventories.

Table 2-2 **Land use categories reported in the 2009 GHG inventories.** R: the category is a net-sink; E: the category is a net-source; empty cells: not reported category. The gray cells indicate a new reported category or a category not reported anymore in 2009. The bold letters indicate a change of trend in comparison to the previous inventory (e.g. the category that was a net-source in the 2008 inventory and it is a net-sink in the 2009 inventory is indicated with "R" in bold letters)

Country	Reporting category											
	Forest land		Cropland		Grassland		Wetland		Settlements		Other land	
	5.A.1.	5.A.2.	5.B.1.	5.B.2.	5.C.1.	5.C.2.	5.D.1.	5.D.2.	5.E.1.	5.E.2.	5.F.1.	5.F.2.
Austria	R	R	E	E	E	R		E		**E**		E
Belgium	R		E		E							
Bulgaria	R		R				E					
Czech Rep.	R	R	E	E	E	R		E		E		
Denmark	R	R	E		E		E	R				
Estonia	R		E		E	R	R					R
Finland	R		E		E			E				
France	R	R	E	E		R		E		E		E
Germany	R	R	E	E	E	**E**	E	E	E	E		E
Greece	R	R	R									
Hungary	R	R	**E**									
Ireland	R	R	R	E	E	R	E			E		
Italy	R	R	R			R				E		
Latvia	R	R	E		R		R		R			
Lithuania	R	R					E					
Luxembourg												
Netherlands	R	R		**E**	E	E		E		**E**		E
Poland	R	R	E		E	R	E	E	R			
Portugal	R	R	R	E		R		E	E	E		E
Romania	R											
Slovakia	R	R	E			R					E	
Slovenia	R											
Spain	R	R				R						
Sweden	R	R	E	R	R	R	E		**R**	**R**		
UK (GB)		R	E	E	E	R				E		

Table 2-3 **Land use categories reported in the 2009 GHG inventories.** R: the category is a net-sink; E: the category is a net-source; empty cells: not reported category. The gray cells indicate a new reported category or a category not reported anymore in 2008. The bold letters indicate a change of trend in comparison to the previous inventory (e.g. the category that was a net-source in the 2007 inventory and it is a net-sink in the 2008 inventory is indicated with "R" in bold letters)

Country	Reporting category											
	Forest land		Cropland		Grassland		Wetland		Settlements		Other land	
	5.A.1.	5.A.2.	5.B.1.	5.B.2.	5.C.1.	5.C.2.	5.D.1.	5.D.2.	5.E.1.	5.E.2.	5.F.1.	5.F.2.
Austria	R	R	**E**	**E**	E	**R**		E		**R**		E
Belgium	R		E		E							
Bulgaria	R		R				E					
Czech Rep.	R	R	E	E	E	R		E		E		E
Denmark	R	R	E		E		E	R				
Estonia	R											
Finland	R		E		E			E				
France	R	R	E	E		R		E		E		E
Germany	R	R	E	E	E	R						E
Greece	R	R	R									
Hungary	R	R	**R**									
Ireland	R	**R**	**R**	E	E	R	E			E		R
Italy	R	R	R	E						E		
Latvia	R	R	E		R							
Lithuania	R	R					E					
Luxembourg												
Netherlands	R	R		R	E	**E**				R		E
Poland	R	R	E						R			
Portugal	**R**	R	R	E		R		E	E	E		E
Romania	R											
Slovakia	R	R	E			R						E
Slovenia	R											
Spain	R	R										
Sweden	R	R	E	R	R	R	E		**E**	E		
UK (GB)		R	E	E	E	R				E		

Table 2-4 Reported carbon pools in GHG inventories 2009 in the most important LULUCF categories. I: increase of carbon stock; D: decrease of carbon stock; empty cells: not reported pool; B: biomass; DOM: dead organic matter; Min Soil: mineral soil; Org Soil: organic soil. The gray cells indicate a new reported pool or a pool not reported anymore in 2009. The bold letters indicate a change of trend in comparison to the previous report

Country	Reporting category																							
	Forest land								Cropland								Grassland							
	5.A.1.				5.A.2.				5.B.1.				5.B.2.				5.C.1.				5.C.2.			
	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil
Austria	I	**I**			I		**I**		D		I		I		D				D		D		I	
Belgium	I		**D**								D								D					
Bulgaria	I								I															
Czech R.	I				I		**D**		I		I		D		D				I		**D**		I	
Denmark	I				I	D			I		**D**	D								D				
Estonia	I			I					D			D								D			I	
Finland	I	**D**	**D**	**I**					I		I	D							D	D				
France	I	**I**	**D**		I	**D**	**D**						D	D	D						D	D	I	
Germany	I				I							D	**D**		D	D				D	D		I	D
Greece	I	D			I				I		I	D												
Hungary	I				I				**D**		**I**													
Ireland	I	**D**			I	**D**	**I**	**I**			I				D					D	I		I	D
Italy	I	**D**	**D**		I	**D**	**D**		I			D									D		I	
Latvia	I	**D**		D	I				I			D					I			D				
Lithuania	I			D	I	D																		
Luxemb.																								
Netherl.	I	**D**			I								D	D					D		D	D		
Poland	I		**D**		I		**D**		I		D	D								D			I	
Portugal	I	**I**	**D**		I	**I**	**D**		I	D	D		D	D	D						D	D	I	
Romania	I																							
Slovakia	I					**D**																I		
Slovenia	I																							
Spain	I				I																		I	
Sweden	I	D	**D**	**I**	I				I	**I**	D	D	I				I	D	I		I			
UK (GB)					I	**D**	**D**	**D**	I			D	D		D					D	I		I	

Table 2-5 Reported carbon pools in GHG inventories 2008 in the most important LULUCF categories. I: increase of carbon stock; D: decrease of carbon stock; empty cells: not reported pool; B: biomass; DOM: dead organic matter; Min Soil: mineral soil; Org Soil: organic soil. The gray cells indicate a new reported pool or a pool not reported anymore in 2008. The bold letters indicate a change of trend in comparison to the previous report

Country	Reporting category																							
	Forest land								Cropland								Grassland							
	5.A.1.				5.A.2.				5.B.1.				5.B.2.				5.C.1.				5.C.2.			
	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil	B	DOM	Min Soil	Org Soil
Austria	I	I			I		I		D		I		I		D				D		D		I	
Belgium	I		I								D								D					
Bulgaria	I								I															
Czech Rep.	I				I		I		I		I		D		D						I		I	
Denmark	I				I		I		I		I	D								D				
Estonia	I																							
Finland	I	I	I	D							I	D							D	D				
France	I	D	I		I	I	I						D	D	D						D	D	I	
Germany	I				I				D		D		I		D				D		D		I	
Greece	I	D			I				I		**I**	D												
Hungary	I				I				I		D													
Ireland	I	I			I	I	D	D			I				D					D	I		I	D
Italy	I	I	I		I	I	I		I			D	I		D									
Latvia	I	I			I				I			D					I			D				
Lithuania	I			D	I																			
Luxembourg																								
Netherlands	I	I			I										I				D		D		I	
Poland	I		I		I		I		I		D													
Portugal	**I**	D	I		I	D	I		I	D	D		D	D	D						D	D	I	
Romania	I																							
Slovakia	I					I																I		
Slovenia	I																							
Spain	I				I																			
Sweden	I	**D**	**I**	D	I				I	D	D	D	I				I	D	I		I			
UK (GB)					I	I	I	I	I			D	D		D					D	I		I	

2.3. *Definition of land use categories*

The MS adopt different definitions of forest and other land uses that usually adapt to national conditions. The discrepancies between countries are often a source of inconsistencies when harmonised statistics or reporting are required. At the national level, the data on land use are obtained from national sources as National Forest Inventories (NFIs) and agricultural statistics. The introduction of international agreements as UNFCCC and the Kyoto Protocol increased the need to adapt the national classifications to international standards

The UNFCCC GHG inventories showed a progressive effort by MS to adapt to these international standards and to harmonise information on activity data. These efforts have been particularly evident for forest land. Most of the European countries tried to elect a forest definition for UNFCCC and KP that would be consistent with the national definition in forest inventories or statistics. On the other hand, MS that are recently developing NFIs take into account definitions adopted for international agreements. Several MS decided to elect the FAO definition for NFI, UNFCCC and KP to improve consistency. In addition some studies to harmonise data have been promoted by MS when definitions are not consistent over time or between different sources (e.g. Finland). In the Table 2-6 national forest definitions applied in the NFIs, under UNFCCC and KP are compared.

In international standards, forest is the only land use that is defined within a certain range of values (e.g. minimum area 0.05-1 ha, minimum height 2-5m, minimum crown cover 10-30% under the Kyoto Protocol). The other land-uses are usually defined only by the use and quantitative parameters are not included (Table **2-7**). This type of definitions is more flexible and it can easily produce inconsistencies in time series and between data sources.

Table 2-6 Definition of forest adopted by the MS under UNFCCC, Kyoto Protocol and in the National Forest Inventories

Member State	NIR 2009				Initial Report under KP(IR-KP)				National Forest Inventory (NFI)				
	Cr. cover (%)	Height (m)	Area (ha)	Width (m)	Cr. cover (%)	Height (m)	Area (ha)	Width (m)	Cr. cover (%)	Height (m)	Area (ha)	Width (m)	Other information
Old Member States													
Austria	30	2	0.05(%	-	30	2	0.05	10	30	2	0.05	-	
Belgium	20	5	0.5	-	20	5	0.5	-	10	5	0.1	-	
Denmark:													The data from the NFI apply to the period 2000-2006. Data for forest are mainly derived from the Census, integrated with NFI data for recent years
▪ Forest Census	-	-	0.5	-	-	-	-	-	-	-	0.5	-	
▪ New NFI	10	5	0.5	20	10	5	0.5	20	10	5	0.5	-	
Finland	10	5	0.5	20	10	5	0.5	20	Before 1998: productive forest land is where the potential annual increment is at least 1 m3/ha/yr. After 1998: FAO definition applies (except for minimum area)				Inconsistencies with FAO definition exist: the 0.5 ha minimum area is not used in NFI field assessments. A method to estimate the effect of the FAO area definition on old NFI data is under development
France	10	5	0.5	20	10	5	0.5	20	10	-	0.05	15	
Germany	Qualitative definition (type of vegetation included)				10	5	0.1	-	Qualitative definition (type of vegetation included)				Based on the definition of "forest" used by the Federal Forest Inventory (BWI). The forest definition qualifies for used in decision 11/CP.7 of Marrakesh Accords (source: NIR 2009) Adopted definition in agreement with FAO forest definition (source: IR-KP)
Greece	10	-	0.5	30	25	2	0.3	-	10	-	0.5	30	NFI: Forests are forest trees (high and coppice forests) that produce or are able to produce ≥ $1 m^3 ha^{-1} yr^{-1}$ of commercial timber.
Ireland	20	5	0.1	20	20	5	0.1	20	20	5	0.1	20	Definition consistent with FAO reporting and IR-KP; NFI started in 2004
Italy[1]	10	5	0.5	-	10	5	0.5	-	10[2]	5	0.5	-	FAO definition adopted
Luxembourg	10	5	0.5	-	10	5	0.5	-	10	5	0.5	-	FAO definition adopted
Netherlands	20	5	0.5	30	20	5	0.5	30	20	5	0.5	30	
Portugal	10	5	0.5	20	10	5	1.0	20	10	5	0.5	20	IR-KP: a higher area size (1ha) had to be adopted because it is the most detailed information available from the national cartography of land-use and forest areas for 1990. NFI : FAO definition (source: JRC database)
Spain	10	-	-	-	20	3	1.0	-	5	-	0.25	20	IR-KP: the higher crown cover allows excluding the land mainly used for agricultural purpose; the choice of 1 ha is based on the existing cartography. NFI source: JRC database
Sweden	10	5	0.5	-	10	5	0.5	10	-	0.25	-	-	NFI: forest land is defined as land suitable for forest production , with an average production ≥ $1 m^3 ha^{-1} yr^{-1}$ during a 100 year period
UK (GB)	20	2	0.1	20	20	2	0.1	20	20	2	0.1	20	Definition agreed with the Forestry Commission (NFI)

Member State	NIR 2009				Initial Report under KP(IR-KP)			National Forest Inventory (NFI)					
	Cr. cover (%)	Height (m)	Area (ha)	Width (m)	Cr. cover (%)	Height (m)	Area (ha)	Width (m)	Cr. cover (%)	Height (m)	Area (ha)	Width (m)	Other information
New Member States													
Bulgaria	-	-	-	-	10	5	0.1	[illegible]	-	-	0.1	-	Forest is defined in the Forest Act (>0.1 ha). The Forest Act will be amended to adapt the national definition to the one adopted under KP (source: IR-KP)
Czech Rep.	[illegible]	2	0.05	-	[illegible]	2	0.05	[illegible]					The definition comply with the national definition of timberland (Czech Forestry Act 84/1996)
Estonia	30	2	0.1	-	30	[illegible]	0.5	[illegible]	30	[illegible]	[illegible]	-	NIR 2009: the Forest Act definition is applied except for the minimum height that had to be corrected to comply with the annex to decision 16/CMP.1 (2-5 m)
Hungary	30	5	0.5	-	30	5	0.5	[illegible]					
Latvia	-	-	-	-	20	5	0.1	-	-	-	-	-	NIR 2009: Forest definition given in the Annex to Decision 16 /CMP.1 is used for reporting, starting from 2007 It is planned to amend the definition of the Forestry Law to comply with international obligations (minimum height) (source IR- KP)
Lithuania	-	5	0.1	[illegible]	10	5	0.1	[illegible]	-	-	-		
Poland	[illegible]	2	0.1	[illegible]	10	2	0.1	[illegible]	-	-	-	-	The values are not in contradiction to forest definition in the Polish Law (National Forests Act No. 84 of 1998) (source: IR-KP)
Romania	-	-	-	-	10	5	0.25	[illegible]	-	-	-	-	No quantitative indications in the NIR 2009. Land use types follows national definitions
Slovakia	-	-	-	-	20	5	0.3	[illegible]	-	-	-	-	No informationin the NIR 2009 IR- KP: consistent with the reporting to FAO and MCPFE
Slovenia[1]	-	-	0.05	-	30	2	0.05	-					NIR 2008: definition according to the Forest Act. In December 2007 Slovenian forest act was changed to “ forest is land covered with forest trees in the form of stands with minimal tree height 5 m and with minimal area of 0.25 ha”

[1] The definitions are the one reported in the NIR 2008when definitions in the NIR 2009 were not available

Table 2-7 Definitions of cropland and grasslands reported by MS in the NIR 2009

Country	NIR 2009	
	Cropland	Grassland
Old Member States		
Austria	Arable land including annual and permanent crops	Total grassland includes cut meadows, cultivated pastures, litter meadows, rough pastures, alpine meadows and pastures and abandoned grassland
Denmark:	-	Area with permanent grass given in the annual census from Statistics Denmark
Finland	It includes area under cereals, grass (≤ 5 years), other arable crops, set-aside and permanent horticultural crops Forestry	It includes grasslands and meadows more than five years old together with the abandoned agricultural area which cannot yet be included in the Forest land (FAO forest definition). Small roads and other small areas with tree cover less than 10% inside cropland are also placed to the Grassland category
Germany	It includes annual and perennia crops	-
Greece	It includes all annual and perennial crops as well as temporary fallow land. Forest plantations – mainly consisted of poplar trees - are considered as Cropland. Pastures that have been fertilised or sown are considered as cropland	It includes rangeland and pasture with vegetation that falls below the threshold of forest definition and are not expected to exceed without human intervention.
Ireland	Permanent crops and tillage areas (including setaside) recorded by the Central Statistics Office (CSO)	Areas of improved grassland (pasture and areas used for the harvesting of hay and silage) and unimproved grassland (rough grazing) in use as recorded by CSO annual statistics
Netherlands	All arable and tillage land, including rice-fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category	Rangeland and pasture land that is not considered as croplands
Spain	Cultivated land, including cultivated areas in the Dehesa with trees. Annual crops, perennial crops and mix of annual and permanent crops are included, except when they qualify as forest	Pasture land, including grazing land not included in cropland. It includes also pastures and meadows in the Dehesathat do not comply with the definition of forest
Sweden	Regularly tilled agricultural land	Agricultural land that is not regularly tilled
Belgium, France, Italy, Luxembourg, Portugal, UK (GB)	Not available	Not available
New member States		
Bulgaria	-	-
Czech Rep.	Arable land, hop-fields, vineyards, gardens and orchards	Grassland as define in the cadastre, mostly used as pasture for cattle and meadows for growing feed. Permanently unstocked Forest land is included
Estonia	Land where the soil is regularly cultivated, and where annual and perennial crops are growing (crops, fodder crops, annual forage crops, multiannual forage crops, other temporary grasslands (seeded once in less than five years), fallow and orchards)	The NFI grassland (natural grassland) and unused arable land and seeded once over five years grassland are defined as IPCC grassland. Abandoned cropland is also defined as grassland
Hungary[1]	Arable lands, kitchen garden, orchards and the vineyard areas.	Meadows and pastures
Latvia	-	-
Lithuania	Arable land and orchards and berry plantations	Meadows and natural pastures
Poland	Arable and tillage land, and agro-forestry systems (orchards) where vegetation character is not consistent with the selected of national definitions for forest land category	Rangelands and pasture land that are not considered as croplands. In Poland there is no perennial woody biomass on area of grassland
Romania, Slovakia, Slovenia	Not available	Not available

[1] More detailed definitions are given in the NIR 2009 for all the categories included in cropland and grasslands

2.4. *Methodologies*

The methods used by the MS to calculate emissions and removals in the LULUCF sector vary a lot between countries but also between land-use categories. Table 2-8 is a summary of the type of methodology and emission factors used in the GHG inventories 2009 and 2008 for the LULUCF sector. The most developed methods and factors are generally used to assess GHG emissions and removals in categories 5.A, 5.B and 5.C and to assess fluxes of CO_2. Only few countries use Tier 3 methods and usually for the most significant categories (Austria, Finland, Ireland, Sweden and Great Britain). Concerning the transparency of reporting, it is not always clear what kind of method or emission factor has been used to evaluate emissions and removals. For instance, Belgium and Bulgaria did not report information in the CRF summary table 2009 on methods and emission factors and Bulgaria didn't give any detailed information in the NIR either.

Some countries progressively improved their methods between 2007 and 2009. Denmark, Germany, Ireland, Lithuania, Poland, Portugal, Romania, Sweden and Great Britain improved or specified the type of methodology and factor to estimate CH_4 and N_2O emissions/removals. Improvements in used methods or in transparency were made in Germany, Hungary, Lithuania, Poland, Spain and Sweden to report for CO_2 emissions for the LULUCF sector.

Some countries reported a lower Tier in 2009 than in 2008 (e.g. Lithuania, Luxemburg). Most likely these countries did not apply a less accurate method or factor but they corrected previous errors in the definition of the method/factor adopted. In general, transparency and accuracy on explaining methods and factors could be improved by several MS. For instance, the method could be defined only by the Tier level adopted (T1,T2,T3) and the emission factors could be classified as default, country specific, etc. (D, CS, CR, OTH, PS). This would help avoiding redundant information (e.g. D and T1 at the same time to define the method) and would help supporting comparability between MS.

2.4.1. Activity data

Activity data to estimate GHGs emission and removals come mainly from national statistics. These data are the area for each land-use and land-use change category, land affected by disturbances and amount of harvest. The most important sources are national forest inventories, agricultural and forest statistics and forest management plans. Thematic maps are sometimes used to integrate the information form tabular data sources (national maps, Corine Land Cover). In very few cases FAO statistics are a source of activity data when other information was not available (Table **2-9**).

The NFI is for several MS the main data source to calculate GHG emissions and removals occurring in Forest land (5.A). The availability of a NFI is less frequent in New EU Members which utilise other national annual statistics. The lack of a harmonised system is often due to the political changes that those countries had to face in the 90's. On the other hand the implementation of a NFI system was recently developed in several new MS (Czech, Latvia, Romania, Slovenia). Detailed information of the type of inventory or data source used in the GHG inventories and the frequency of data gathering are reported in Annex I.

Table 2-8 Type of methods and emission factors (EF) used by countries to calculate emission and removals of different GHGs in LULUCF. Differences between methods or emission factors in the 2009 and 2008 GHG inventories are highlighted. T1, T2, T3: Tier 1, 2, 3; D: default; CS: country specific; CR: CORINAIR; NA: not applicable; OTH: other; PS: plant specific (Source: CRFs 2009 and CRF 2008)

Country	2009						2008					
	CO_2		CH_4		N_2O		CO_2		CH_4		N_2O	
	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF
Austria	T1,T3	CS,D	T1	CS,D	T1	CS,D	T1,T3	CS,D	T1	CS,D	T1	CS,D
Belgium			NA	NA	NA	NA			NA	NA	NA	NA
Bulgaria			NA	NA	NA	NA	T1	CS	NA	NA	NA	NA
Czech	CS,T1,T2	CS,D	CS,T1	CS,D	CS,T1,T2	CS,D	CS,T1,T2	CS,D	CS,T1	CS,D	CS,T1,T2	CS,D
Denmark	CS,T1	CS,D	T1	CS	CS	CS	CS,T1	CS,D	D	D	CS	CS
Estonia	T1	CS,D	T1	D	T1	D	T1	CS,D	T1	D	T1	D
Finland	D,T1,T2,T3	CS,D	D,T2	CS,D	D,T1,T2	CS,D	D,T2,T3	CS,D	D,T2	CS,D	D,T1,T2	CS,D
France	CR,CS,T2	CS	CS,T2	CS	CR,T2	CS	CR,CS,T2	CS	CS,T2	CS	CR,T2	CS
Germany	CS,D,T2	CS	NA	NA	CS	CS	CS,D,T2	CS,D	NA	NA		
Greece	CS,D,T1,T2	CS,D	T1	D	T1	D	CS,D,T1,T2	CS,D	T1	D	T1	D
Hungary	D,T1,T2	CS,D	T1	D	T1	D	T1	D	T1	CS,D	T1	CS,D
Ireland	D,T1,T2,T3	CS,D	D,T1	D	D,T1	D	D,T1,T2,T3	CS,D	D,T1	D	D,T1	D
Italy	T1,T2	CS,D	T1	D	T1	D	T1,T2	CS,D	T1	D	T1	D
Latvia	D,T1,T2	CS,D	T1,T2	CS,D	T1,T2	CS,D	D,T1,T2	CS,D	T1,T2	CS,D	T1,T2	CS,D
Lithuania	T1,T2	CS,D	T1,T2	CS,D	T1,T2	CS,D	T1	CS,D	T1	D	T1	D
Luxembourg**	T1	D	NA	NA	NA	NA	CS	CS	NA	NA	NA	NA
Netherlands	CS,D	CS,D	NA	NA	NA	NA	CS,D,T2	CS,D	NA	NA	NA	NA
Poland	D,T1	CS,D	D,T1	CS,D	D,T1	CS,D			CS,T1	D	CS,T1	D
Portugal	CS,D,T2	CS,D	D	D	D,T2	CS,D	CS,D,T2	CS,D	D	D	D,T2	CS,D
Romania	T1,T2	CS,D	T1	D	T1	D	T1,T2	CS,D	T1	D	OTH,T1	D,OTH
Slovakia	CS,T1,T2	CS,D,PS	T2	PS	T2	PS	CS,T1,T2	CS,D,PS	T2	PS	T2	PS
Slovenia	D,T2	CS,D	NA	NA	NA	NA	D,T2	CS,D	NA	NA	NA	NA
Spain	CS,D,T1	CS,D	CS	D	CS	D			CS	D	CS	D
Sweden	T1,T3	CS	T1	CS	CS,T1	CS	T1,T3	CS,D	T1	CS,D	CS,T1	CS,D
UK (GB)	CS,D,T3	CS	D	CS	D,T1	CS	CS,D,T3	CS	D	CS	D,T1,T2	CR,CS

Table 2-9 **Data sources of activity data in NIR 2009.** NFI: national forest inventory; NS: national statistics (agricultural and forest statistics, management plans, cadastral data); NM: national maps; CLC: Corine Land Cover; IS: international statistics (e.g. UNECE-FAO).

Member State	Reporting categories								
	5A				5B		5C		Other LU categories
	5.A.1	5.A.2	Harvest	Disturb	5.B.1	5.B.2	5.C.1	5.C.2	
EU-15									
Austria	NFI	NFI	NFI, NS	NFI	NS	NS	NS	NS	NS
Belgium	NFI		NS		CLC, NS		CLC, NS		NS
Denmark	NS, NFI	NS,NFI	NS,NFI		NS, NM		NS,NM		NS
Finland	NFI		NS		NS		NFI, NS		NFI, NS
France	NFI, NM	NFI, NM	NS	NS	NS, NM	NS, NM	NS, NM	NS, NM	NS, NM
Germany[a]	NFI	NFI		NS	NS, NM, CLC	NS, NM, CLC	NS, NM, CLC	NS, NM, CLC	NS, NM, CLC
Greece	NFI, NS	NS	NS	NS	NS		NS		
Ireland	NFI, NS	NS, NM, CLC	NS	NS	NS	NM	NS	NM, CLC	NS, CLC
Italy	NFI, NS	NS	NS	NS	NS	NS	NS	NS	NS, CLC
Luxembourg									
Netherlands	NFI, NM	NFI, NM	NS		NM	NM	NM	NM	NM
Portugal	NFI, CLC	CLC, NS	NS	NS	CLC	CLC	CLC	CLC	CLC
Spain	NFI, CLC, NM	NS		NS	CLC, NS	CLC	CLC	CLC	CLC
Sweden [a]	NFI	NFI	NFI	NFI	NFI	NFI	NFI	NFI	NFI
UK (GB)		NS	NS	NS	NS	NS	NS	NS	NS
New Members									
Bulgaria	NS		NS						
Czech Rep.	NS, NM	NS, NM	NS		NS, NM	NS, NM	NS, NM	NS, NM	NS, NM
Estonia	NFI, CLC		NFI, NS		NS, CLC	NS, CLC	NS, CLC	NS, CLC	NFI, NS
Hungary	NFI	NFI	NS		NS, NM, CLC		NS, NM, CLC		NS, CLC
Latvia	NFI, IS	NFI	NFI	NFI	NS, NFI		NS, NFI		NS, NFI
Lithuania	NS, NFI	NS, NFI	NS	NS, IS	NS	NS	NS		NS
Poland	NS	NS	NS						NS
Romania	NS		NS	NS	NS				
Slovakia	NFI	NS	NS	NS		NS		NS	
Slovenia [b]									

[a] The National Inventory of Forests includes National Forest Inventory and Forest Soil Inventory

[b] Detailed information on the methods used were not available

2.4.2. Emission factors

The analysis of the NIRs 2009 provided more detailed information than previous submissions on the emission factors (EFs) used by MS. Different EFs are used to assess emissions and removals in the categories 5.A, 5.B and 5.C and in the biomass, soil and dead organic matter pools (Table 2-10)and (Table 2-11). The information on the living biomass pool refers mainly to the biomass expansion factors (above and belowground). The carbon fraction is a default value (0.5) while information on wood densities is not reported here. Country specific wood densities are sometimes used together with national specific biomass expansion factors, but default values are applied by most of the MS.

The Annex I countries should spend efforts to enhance the knowledge on the soil and the dead organic matter pools. The lack of country specific methods/factors for these pools is particularly evident in the new Member States. However, a general improvement of adopted emission factors could be observed from 2007 to 2009 when the rate of country specific factors constantly increased.

2.5. *Uncertainty estimate*

Most of EU Annex I countries make some reference to uncertainties associated to the estimates of GHG emissions/removals in the LULUCF sector. While some MS provide calculations of uncertainty al the level of land-use category for all or some of the categories (Austria, Germany, Denmark, Czech Republic, Estonia, Finland, Great Britain, Hungary, Ireland, Latvia, the Netherlands, Slovakia and Romania), others give a total uncertainty value for the entire LULUCF sector (Belgium, Bulgaria, France, Lithuania, Poland, Spain, Slovenia). Most of the MS applied an error propagation approach to estimate uncertainty in LULUCF, and few countries used a Monte Carlo simulation. When countries report disaggregated values of uncertainty for the land use categories, the information is sometimes incomplete (e.g. only for some activity data or emission factors). Where reported, the uncertainty level in the LULUCF sector is high: the numerous factors that are needed to assess carbon stock changes and the high variability of these factors are responsible for a significant propagation of the error and the consequent increase of uncertainty. As an order of magnitude, the MS reported sectorial values between 10 – 67 %. The heterogeneity of the reporting methods and the incompleteness of the estimates make it rather difficult to assess an uncertainty at the EU level.

Table 2-10 Emission factors applied in the GHG inventory 2009 by EU-15 Member States. CS: country specific; D: default; M: maps; OTH: other factors (e.g. selection of factors from similar countries); 0: no changes in the pools reported (Tier 1); empty cells: no information reported/ no reported pool

Country	Reporting category																	
	5A1			5A2			5B1			5B2			5C1			5C2		
	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM
Austria	CS	0	CS	CS	CS		0,CS	CS		CS	CS		0	CS		CS	CS	
Belgium	CS,OTH	M	0				0	CS,M					0	CS,M				
Denmark	CS,OTH			CS,OTH		CS	0,CS	M						M,OTH				
Finland	CS	M	M				0,CS	D,CS						D,CS				
France	CS	0	CS,0	CS	CS	CS,D	0	0		0	0,CS	0,CS	0	0	0	0	0,CS	0,CS
Germany	CS	0	0	CS	0	0	D,0	0,CS		CS,D	CS		0	0,CS		CS,D	CS	
Greece	CS,D	0	0,CS	D		0	0,CS	D					0,CS	0	0	0		
Ireland	CS,M	0	0,D	CS,M	D	0		D		D	0,D		0			D	D	
Italy[a]	CS	CS	D,OTH	CS,D	CS	D,OTH	0,D	0,D,CS								0,D	0,D,CS	
Luxembourg																		
Netherlands																		
Portugal[b]																		
Spain	CS,D	0	0	CS,D	0	0	D,0						0			0	D	
Sweden	CS	CS	CS	CS	CS	CS		M,CS	.	.	M,CS			CS			CS	
United Kingdom				CS,M	CS, M		CS	CS		CS	CS,M			CS		CS	CS,M	

[a] Information obtained from other sources than NIR 2009

[b] Information not available at the present (May, 2009)

Table 2-11 **Emission factors applied in the GHG inventory 2009 by New EU-Member States.** CS: country specific; D: default; M: maps; OTH: other factors (e.g. selection of factors from similar countries); 0: no changes in the pools reported (Tier 1); n.e.: no explanation reported; empty cells: no information reported/ no reported pool

Country	Reporting category																	
	5A1			5A2			5B1			5B2			5C1			5C2		
	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM	B	Soil	DOM
Bulgaria	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.												
Czech Rep.	CS,D	0	0	CS,D	CS,0	0	D,0	CS,D		CS,D	CS		0	CS,D		CS,D	CS	
Estonia	D	0,D								D	D						D	
Hungary	CS,D	0	0	CS,D		0	D	D					0	D				
Latvia	D	n.e.	n.e.	D	n.e.	n.e.	D	D					D	D				
Lithuania	D,OTH	0,D	0	D,OTH		OTH	0	0	0									
Poland	D,CS	0	D	D,CS			(D)[b]	D						D			D	
Romania	D	0	0															
Slovakia	CS	0	0		CS						CS						CS	
Slovenia[c]																		

[b] Not clear from the NIR 2009 which kind of factor was adopted

[c] Information not available at the present (May, 2009)

2.6. *Compliance with Kyoto Protocol reporting*

Starting from 2010, the Annex I countries that ratified the Kyoto Protocol (KP) will have to report for LULUCF activities of Art. 3.3 and for the elected activities under Art. 3.4 of the Protocol.

The statistics and data sources used by countries for reporting emissions and removals in the LULUCF sector will in most of cases be the same under UNFCCC and KP. Therefore the data provided in the CRFs and the information in the NIRs can help to understand which gaps the MS will have to fill in order to comply with the Kyoto Protocol reporting. The results of previous assessment are analyzed by applying a different perspective to identify the needs and most important gaps for the future reporting under the Protocol.

2.6.1. Art. 3.3-3.4 activities and UNFCCC land-use categories

Kyoto protocol activities can be considered a subsample of the land-use categories in the Convention. Consequently, the countries need to extract information from the broader approach of UNFCCC to be able to report for activities of Art. 3.3 and 3.4. Table 2-12 shows in which of the UNFCCC land-use and land-use change categories the KP activities will more likely occur and therefore where the activity data for the KP will be derived from.

Table 2-12 Synthetic relationship between the activity data under the Kyoto protocol and the UNFCCC land-use categories. AR: afforestation/reforestation; D: deforestation; FM: forest management; CM: cropland management; GM: grassland management; RV: Revegetation; F-F: forest land to forest land; F-L: forest to other land-uses; C-C: cropland to cropland; G-G: grassland to grassland; L-C, L-G: other land-uses to cropland or grassland

Kyoto Protocol	UNFCCC	
Activity	Land-use	CRF category
AR (Art 3.3)	F-F	5.A.2
D (Art 3.3)	F-L	5.B.2.1, 5.C.2.1; 5.D.2.1, 5.E.2.1, 5.F.2.1
FM (Art 3.4)	F-F	5.A.1
CM (Art 3.4)	C-C	5.B.1
GM (Art 3.4)	G-G	5.C.1
RV (Art 3.4)	C-C, L-C, G-G, L-G,...	5.B.1, 5.B.2, 5.C.1, 5.C.2,...

While afforestation, reforestation and deforestation (ARD) must be reported by all EU Annex I countries, only MS which elected Forest Management (FM), Cropland Management (CM), Grazing Management (GM) and Revegetation (RV) are required to report for them. A quick comparison of the tables summarizing the level of completeness in UNFCCC inventories with the activities that countries must or elected to report under KP can highlight where the most important gaps in KP reporting will likely occur.

Other adjustments of the activity data could be required when the definition of forest used for UNFCCC reporting would be different than the one elected under the KP.

Table the mandatory KP activities of Art.3.3 are compared to the corresponding UNFCCC land-use and land-use change categories that were reported in the GHG inventories 2009. All the MS are required reporting for human-induced afforestation, reforestation and deforestation started since 1990. About 30% of the EU countries still did not report any emission or removal from areas converted to forest land since 1990. In addition, a distinction will have to be made for the KP between areas converted to forest by direct-human activities and areas where forest is expanding naturally. Only the first one can be accounted. It has also to be clarified for how long the converted areas are reported in the category 5.A.2 “Land converted to Forest land”. From the CRFs it seems that most of the MS report only the area that was converted in a single year, while emissions and removals form afforestation and reforestation will have to be accounted for all area converted since 1990 during the period 2008-2012.

The reporting of emissions and removals from areas converted from forest to other land-uses in the UNFCCC GHG inventories is quite poor. Only 40% of the MS reported deforestation to some extent and less than 30% reported it for all land-use change categories (Table 2-13). A reason for the lack of data on deforestation in Europe is that deforestation usually occurs on small areas and therefore the national monitoring systems can often not detect it.

Other adjustments of the activity data could be required when the definition of forest used for UNFCCC reporting would be different than the one elected under the KP.

Table 2-13 **Mandatory activities under Art. 3.3 of the KP and corresponding land-use categories reported in UNFCCC GHG inventories 2009** (source: CRF 2009). Coloured cells indicate MS that must report for the KP activities and the MS which reported for UNFCCC categories in the GHG inventories 2009

Country	KP	UNFCCC	KP	UNFCCC				
	AR	5.A.2	D	5.B.2.1	5.C.2.1	5.D.2.1	5.E.2.1	5.F.2.1
Austria								
Belgium								
Bulgaria								
Czech Rep.								
Denmark								
Estonia								
Finland								
France								
Germany								
Greece								
Hungary								
Ireland								
Italy								
Latvia								
Lithuania								
Luxembourg								
Netherlands								
Poland								
Portugal								
Romania								
Slovakia								
Slovenia								
Spain								
Sweden								
UK (GB)								

A high share of MS elected Forest Management as a voluntary activity under Art. 3.4 and they will have to account for emissions and removals due to human-induced activities in forest land that was forest also before 1990. The analysis of the UNFCCC GHG inventories showed that Forest remaining Forest scores the most complete reporting level. All the countries that elect for FM seems to have information on emissions and removals in category 5.A.1. UK aggregated all emissions and removals in forests converted since 1920 in the category 5.A.2 “Land converting to Forest”. However, data for areas that became forest after 1990 and that could be classified as AR activities can probably be extracted easily.

Very few countries elected Cropland and Grazing land Management: Denmark, Portugal and Spain (Table 2-14). Portugal and Spain will need to assess emissions and removals respectively from grazing land and cropland in the near future. In addition data on specific human-induced activities that increased the carbon stock in cropland and pastures will have to be collected by these countries. Most likely the information will be derived from policy activities developed for this purpose. Only Romania elected Revegetation as a voluntary activity. Romania only reported for category 5.A.1 “Forest remaining Forest” in the UNFCCC inventory and the data needed for Revegetation will have to be collected from specific sources of studies ad-hoc.

Table 2-14 Voluntary activities under Art. 3.4 of the KP and corresponding land-use categories reported in UNFCCC GHG inventories 2009 (source: CRF 2009). Coloured cells indicate MS that elected to report for the KP activities and the MS which reported for UNFCCC categories in the GHG inventories 2009

Country	KP FM	UNFCCC 5.A.1	KP CM	UNFCCC 5.B.1	KP GM	UNFCCC 5.C.1
Austria						
Belgium						
Bulgaria						
Czech Rep.						
Denmark						
Estonia						
Finland						
France						
Germany						
Greece						
Hungary						
Ireland						
Italy						
Latvia						
Lithuania						
Luxembourg						
Netherlands						
Poland						
Portugal						
Romania						
Slovakia						
Slovenia						
Spain						
Sweden						
UK (GB)						

2.7. *Analysis of the European Community GHG inventory*

The European Union yearly submits the European Community Greenhouse Gas Inventory to UNFCCC (EC GHG inventory) which is a collation and a critical analysis of the national GHG inventories submitted by Member States (MS). The MASCAREF project partially contributed to the collection of information reported in the EC GHG inventory for the LULUCF sector by analysing national inventories. In addition, the development over time of the LULUCF chapter in the EC GHG inventories is analysed in this section to highlight changes and improvements and to give recommendations for the future EC GHG inventories. The LULUCF EC GHG inventories of 2007, 2008 and 2009[13] are compared.

A general improvement of reported information could be observed during the last 3 years. The LULUCF section of the EC GHG inventory progressively became a more comprehensive overview of emissions and removals in the LULUCF sector in Europe and a deeper analysis of methods used by MS.

In 2007 the LULUCF EC GHG inventory was mainly a description of emissions and removals in the different land-use categories in EU-15. Only general information on completeness, methods adopted, uncertainty, consistency and recalculations were given and a critical analysis of the data submitted by MS was missing.

In the following years the information included in the EC report on the LULUCF sector was progressively improved, in particular concerning the overview on methods adopted. In this way the EC inventory changed from a mere summary to a critical overview of the MS inventories, contributing to a better identification of gaps and inconsistencies and forming a basis for future improvements of GHG reporting at the European level.

The EC inventory has been also extended to EU-27[14] (from 2008) and the data on the different land-use categories became more balanced. The Forest land category remains the main contributor to the emissions/removals in the LULUCF sector and for this reason it is more carefully analysed. Over time, the information on other categories was gradually improved and in 2009 Cropland and Grassland are equally reported in separate chapters, while Wetlands, Settlements and Other land are still described in a single section. However, the analysis of the inventories of New MS is only limited to a description of emissions and removals trends and to a section on main recalculations occurred in the inventory 2009.

Significant is the introduction of a section on the contribution of land-use changes in the LULUCF GHG balance. In the same way detailed sections for UNFCCC categories of land converted to a certain land use are included for EU-15. The land-use changes are particularly relevant under the Kyoto Protocol (KP) and a better overview of their contribution to European GHG balance and the methods adopted to assess it could contribute to comply with KP reporting. Unclear is the calculation of the increase/decrease of land converted to forest (Section 7.2.1.2, EC GHG inventory 2009). Attention must be paid to the different ways in which MS report the areas under conversion. For instance the Netherlands and Germany (and probably Denmark) seems to report cumulative areas converted to forest since 1990, while most of the MS report the area that is converted yearly. These differences must be taken into account when assessing the trend of afforestation rates at the national level to avoid a wrong estimation of the average rate at the European level. A larger section on methods, data sources, definitions was introduced in 2009. The reported information gives a better overview on the differences between countries, land-use categories and pools and it

[13] A draft of the EC GHG inventory 2009 was available at the end of the MASCAREF project (May 2009)

[14] The EC GHG inventory includes all MS of the EU, including Malta and Cyprus which are not Annex I countries of the Kyoto Protocol

helps to understand possible sources of inconsistency. At the moment the section is quite descriptive and it could improve when the information would be reported in a more synthetic and comparable way (e.g. tables). More detailed information of the contribution of different pools to the GHG balance in the LULUCF sector was also added in the method section.

The new section “Other emissions from land uses” shows the progress of Member States’ state of knowledge on GHG emissions other than CO2 emissions and the progresses on forest fires, lime application, organic soils and harvest wood products. The description of methods used to calculate “Other emissions” could be improved, but it is strongly dependent on the transparency with which MS reports for them (still quite low). The last two described sections are completely missing for New MS. Interesting in the last EC GHG inventory was the attempt to evaluate the effects of different forest definitions on the calculation of the European LULUCF GHG balance. This kind of analysis should be more broadly implemented (e.g. impact of different methods, included pools, etc.)

2.8. *Recommendations*

The analysis of the most recent GHG inventories under UNFCCC helped to identify the most important gaps in the reporting and suggests possible improvements for the future inventories

- A constant effort should be made to improve completeness of reporting in land use category other than Forest land, in particular for the land converting to other categories. The improvement of the information on land use changes is important also for the implementation of Kyoto Protocol reporting. The analysis of the NIRs and CRFs 2009 highlighted a lack of data on deforestation, a mandatory activity under the Protocol.
- The reporting of the soil carbon pool should be enhanced, in particular of organic soils which are a great reservoir of carbon and therefore a potential significant source of GHGs (e.g. peatlands). The assessment of carbon stocks in soils is important to identify significant stocks of carbon at the national level and consequently invest in policies and activities that would support their conservation. The long term answer of the soil carbon pool to activities that would increase it, suggests that it is more important to protect the existing stocks.
- Another area of possible improvement is the reporting of emissions from disturbances in Forest land. At the present the countries report for them with very different level of accuracy, depending on the availability of activity data and emission factors. The high interannual variability of the disturbances and the lack of knowledge on their effects on the carbon cycle limit the capability of countries to report for them.
- More transparency on the methods, emission factors and recalculations is needed especially from the New Member States. A compilation of these data in a synthetic form would help to evaluate the changes, identify further gaps and suggest improvements (e.g. summary tables).
- The way in which MS report areas under conversion (yearly or cumulative changes since 1990) should be more transparent.
- Key (source/removal) category analysis should be extended by the use of qualitative approach in LU activities, both on trends and levels.
- Transparency on uncertainty estimate in the LULUCF sector should be increased. A possible way may be to organize working groups on reporting categories/key sources/sinks.
- Increase institutional connections and effectiveness of communication between GHG inventory agency and resource management agencies, to allow a better access to existing data and information, and to develop research for new data or methods.
- A public validation of national submission should be requested at national level to encourage cross checking, the awareness on the emission/removal trends and to improve estimate accuracy and precision.

The following recommendations are given to improve future EC GHG inventories:

- Try to achieve a better balance between the information reported for EU-15 and EU-27. Continuity with previous inventories will require keeping separated the information on EU-15 and EU-27, but the two sections could be joined to some extent to favour a better balance. This could be achieved by creating sub-sections on EU-15 and New MS in the existing main sections.
- It should be made clear how countries are reporting for activity data on land under conversion (cumulative area or yearly converted area). This would help to increase transparency and comparability of trends of land-use changes at the EU level.
- The inventory would benefit from more separate sections on emission/removal trends and methods/definitions. The information and data reported in the EC GHG inventory were progressively increased in the past three years and for this reason clear structured sections are necessary to avoid repetitions and to gain transparency. For instance all the sections on methods should be reported in the second part of the inventory (e.g. Section 7.1.5 "General methodological information" should be aggregated with the method/definition section) and the contribution of different pools to the GHG balance in different land use categories should be moved to the first part on emission/removal trends.
- The extended section on methods, definitions and data sources would benefit from the introduction of synthetic tables rather than full descriptions. Synthetic data would help comparability between countries and support the filling of existing gaps. The full descriptions could be reported in an Annex.
- A better overview on how (or if) MS account for disturbances would help to identify possible gaps in the assessment of GHG balance. One way could be to include a synthetic description of methods to assess the impact of disturbances adopted by MS.
- The assessment of uncertainties should be improved but it is strongly dependent on progresses made by MS.
- Very useful would be to assess the impact of including new land-use categories/pools and of recalculations on emission/removal trends. This type of analysis would help distinguishing real changes of emission/removal trends from changes due to methodological improvements.

2.9. *Conclusions*

The analysis of GHG inventories submitted by EU Annex I countries in 2007, 2008, 2009 highlighted a progressive improvement of the completeness and of the methodologies used to assess GHG emissions and removals.

Nevertheless, additional efforts should be made to improve the assessment of land-use changes (conversion of land), emission and removals in other categories than forest land and in soil and dead organic matter. The implementation of monitoring systems capable to effectively detect land-use changes will be necessary for the accounting under the Kyoto Protocol, especially when referring to the mandatory activities of the Art. 3.3.

The transparency on the methodology and the assessment of uncertainty in the LULUCF sectors are other important aspects where the GHG inventories could be improved.

Relevant improvements could be observed in the EC GHG inventory from the analysis of the last 3 submissions. The most significant were a better balance between different land-use categories and more detailed descriptions of methods adopted by MS. For future inventories it would be necessary to improve the analysis of GHG inventories from New MS. It is also important that the EC GHG inventory keeps providing synthetic information on differences between MS. In this way the inventory would help increasing comparability between countries and allow critical comments that could contribute to improve the reporting under UNFCCC.

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Annex I: Table A-1 - Main sources of activity data for subcategory 5A in EU15

Country	Type of information source	Frequency of survey	Latest survey	Other information
Austria	NFI: sample plot – based, 4 x 4 km grid across all of country	5-10 years	2000-2002	
Belgium	NFI: 1.0 km x 0.5 km grid	Wallonia : permanent sampling (1/10 each year) Flanders:10 years	Wallonia: started in 1994 Flanders: 1997-1999	NFI Wallon region (Lecomte & Rondeux, 1994) NFI Flemish Region (AB&G, 2001).
Denmark	Questionnaire-based Forestry Census since 1881	10 years	2000	From 2002, a new sample-based National Forest Inventory (NFI) has been launched. The new NFI will replace the Forestry Census and measures 1/5 of the plots every year. NFI will be an ongoing sample-based National Forest Inventory. Data to be used in NIR are expected during 2008
Finland	NFI: sample-based (systematic cluster sampling), different grids 6 x 6 km to 10 x 10km according the region, and cover all country in a year	10 years, 5 years from the last inventory	2004-2008 (10^{th} national forest inventory)	
France	Land use changes detected by photo interpretation on sampling points on a 12 x12 Km grid (TERUTI-LUCAS) NFI: sample based, systematic clusters, 1 x 1 km, cover all the country in a year	TERUTI - LUCAS : annual survey IFN: 12 years	IFN : 2004-2006	
Germany	NFI: carried out on a random basis with permanent sample points based on a nationwide 4 km x 4 km grid.	Two NFIs so far (1986-1989; 2001-2002)	2001-2002	NIR 2008: The same data and methods used in the report 2006 have been used for the following NIR/CRF. The resolution of NFI can be increased, at Länder request, on a regional basis
Greece	NFI: sample-based Agricultural statistics and other national statistics	Only one NFI so far (1963-1992)	1992	The national forest inventory of Greece started in 1963 and completed in 1992. About 60% of the land was inventoried from 1963 to 1967, the rest during the period 1975–1985 and the complete inventory was presented in 1992 (Radaglou and Raftoyannis 2000)
Ireland	National statistics: Forest Inventory and Planning System and forest census, increment and harvest statistics	Various	1995	
Italy	NFI: sample-based	First one in 1985, second one is on-going	2003-2008	New forest inventory under development (3-phase sampling approach)
Luxembourg	NFI: simple systematic sampling; points on a 1000x500m grid	Planned every 5-10 years. Only one inventory so far.	1998-2000	
Netherlands	NFI: sample-based	~ 10 years	2001-2002	
Portugal	Corine Land Cover (CLC) NFI: sampling in geographically located points it represents the geographical distribution of forest species	NFI: ~ 10 years	NFI: 1995	The NFI was used to integrate information in the CLC
Spain	NFI: sample based	Planned every 10 years	1997-2007 (2000)	
Sweden	NFI: sample-based since 1983, with an area measured each year	5-10 years	Ongoing	Swedish National Inventory of Forests (RIS) consists of the Swedish National Forest Inventory (NFI) and The Swedish Forest Soil Inventory (MI).
UK (GB)	National statistics: National Inventory of Woodland and Trees (1999-1995), Forestry censuses data, yield table data	Various	1999	Data obtained mainly from the Forestry Commission (UK) and Forest Service (northern Ireland)

Annex I: Table A-2 - Main sources of activity data for subcategory 5A in New Member States of the EU

Country	Type of forest inventory	Frequency of survey	Latest survey	Other information
Bulgaria	National forest statistics, based on a randomly selected sample	10 years (1/10 of territory every year)		
Czech Rep.	Cadastral records and forest taxation data in Forest Management Plans	Cadastre: yearly Management plans: 10 year cycle		A first NFI is available (2001-2004, published in 2007, sample based), but only one NFI could not be used to assess C changes
Estonia	NFI: statistical sampling method National statistics (statistical office of Estonia)	5 years cycle	Started in 1999, under development	
Hungary	National Forestry database	5-12 years		Each stand surveyed every 5-12 years depending on the species, In years between surveys, yield functions are used to update volume stocks. As a result, (aggregated) volume carbon stocks are available for each inventory year
Latvia	National Statistics: Forest statistics and State Forest Registry			Latvia will implement and document of the new method of National Forest Inventory for LULUCF sector starting from year 2008.
Lithuania	Statistical Yearbook of Forestry	Yearly		Forest Inventory (NFI) performed in 1998-2003 is a secondary source of activity data
Poland	Statistical Yearbook for Forestry	Yearly		
Romania	Land statistics from National Forest Fund	1985		A sample plot NFI is under implementation , 5 years cycle; first partial results available in 2009
Slovakia	Not reported			No specific source mentioned for the assessment of 5.A, just national data
Slovenia	National statistics and national maps (MAFF) based on photointerpretation	MAFF: 10 years	MAFF: 2005	Statistically based national forest inventory – NFI 2007 was implemented. The large-scale Forest Condition Survey (national level) is based on the 4 x 4 km sampling grid

3. Using Forest Monitoring Networks for Assessing Carbon Sequestration in Forests

Rainer Baritz

Federal Institute for Geosciences and Natural Resources (BGR), Germany
Email: Rbaritz@pop3.bgr.de

Abstract

Various inventories related to forest monitoring activities exist in Europe, in particular in the frame of the ICP Forests health monitoring and the EU Forest Focus regulation. The purpose of these activities has focused on the effects of pollutant input to forest ecosystems and forest health. The programme is currently under extension with regard to biodiversity monitoring and climate change. In particular, carbon sequestration has been the focus of recent research activities in member states and EU research projects providing experiences (for example about terrestrial hot spots for greenhouse gas emissions), data and methods. In the various EU member states, reporting on Kyoto Protocol Art. 3.4 (KP3.4) is expected to be based on such activities.With regard to the soil carbon pool, one of the main data sources for greenhouse gas (GHG) reporting is probably the EU/ICP Forests Level I inventory, which is currently repeated in most member states through the BioSoil project under the Forest Focus regulation. While the inventory timing of both projects seems to fit the KP reporting schedule, its methodical setup seems to suffer from several restrictions namely changes of sampling design between the initial inventory and its repetition, the lack of studies investigating systematic changes, the incomplete sampling of the litter compartment, and various other aspects analysed and commented in this report. In addition, there is a general lack of data on KP3.3.

3.1. *Introduction*

Various studies have investigated to link between soil inventories and modelling, so that methods exist which help to extrapolate inventory-based CO_2 changes to the current and future KP commitment periods, and which help to estimate changes of other greenhouse gases as well. The Level I and BioSoil data are not only relevant for the national GHG reporting, they also serve as a possible data source for Europe-wide inventories. It will be investigated in this report, to which extend this is actually possible, and which limitations result from differences between countries, data gaps, validation, etc.

It is expected that with regard to direction and degree of change of the soil condition, the results of intensive monitoring and forest ecosystem research will be needed in order to validate the coarse-scale inventory results. Such additional observation plots are also needed to connect inventories such as the Level I to models.

Here we will analyse the available data from the European perspective. The inventories will be presented, and some possibilities for the evaluation of these data sets will be critically discussed. That includes issues like baseline development for the detection of change, representativity of the existing sampling plots, completeness, error aspects, and data integration with other observation systems.

3.2. *Potential contributions from previous monitoring activities under ICP Forests*

Working tasks

- review of the manuals, reports and design descriptions of the inventories
- evaluation of studies under the national programmes (thus related to the inventories evaluated here) relevant for the context of C sequestration
- introduction of specific inventory design indicators such as sampling quality, inventory integration, harmonization and representativity
- concept development considering the GHG reporting requirements, including model input/C Cycle requirements

3.2.1. The ICP Forests Monitoring scheme

The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) has the general objective to periodically provide information on the health of forests in relation to anthropogenic and natural stress factors. The EU has adopted the scheme with the Council Regulation (EEC) 3528/86. The ICP Forests scheme is considered the world's largest biomonitoring network (UNECE 2004). Table 3-1 lists the various activities, with the monitoring of the crown condition of forests starting in 1986. The programme is steered by the ICP Forests Task Force under the leadership of Germany. 41 countries and the European Commission are represented. Each country is represented by its national focal centre (NFC). The detailed organization of the ICP Forests programme can be viewed at http://www.icp-forests.org/BodStruc.htm.

The ICP Forests monitors the forest condition in Europe in cooperation with the European Union, and uses two different monitoring intensity levels. Level I refers to the systematic large-scale transnational grid of 16 x 16 km with 5,961 plots distributed over 39 countries in Europe. Phenology was added in 2000, as an optional assessment. The second monitoring intensity level (Level II) has been installed since 1992 in selected forest ecosystems in Europe, and contains ca. 860 plots in 28 participating countries, Level II is also called intensive monitoring.

The main focus of the Level II monitoring is to identify of cause-effect relationships regarding trends in forest health at the ecosystem level. The survey of the crown condition, of the foliar chemistry and investigations of the soil at Level I is needed for obtaining large-scale trends. That involves the integration of evaluations between the ICP Forests and other programmes. In addition, the Level I network is needed for up-scaling ecosystem-level trends to the regional and European levels (ICP Forests 1997).

Table 3-1 Generalized ICP Forest parameters (acc. to http://www.icp-forests.org/MonLvII.htm)

Survey	**Level I** [# plots]	characteristics	**Level II** [# plots]	characteristics
Crown condition	5,961	annually	797	annually
Soil chemistry	5,289	foreseen: every 10 years	738	every 10 years
Foliar chemistry	1,497		767	every 2 years
Soil solution chemistry			254	continuously
Atmospheric deposition			545	continuously
Ambient air quality			41	continuously
Meteorology			209	continuously
Tree growth			769	every 5 years
Ground vegetation			723	every 5 years
Phenology			data validation ongoing	several times per year
Litterfall			data validation ongoing	continuously
Remote Sensing			at plot location	national data

Test phase (ongoing): stand structure and epiphytic lichens N = 90

An updated combined analysis of available data under the Level II programme was presented by A. Bastrup-Birk (JRC) during the 22nd Meeting of the ICP Forests Task Force meeting 20 – 24 May 2006 in Tallinn, Estonia:

Combined surveys	# plots	% share
total no. of Level II plots	**822**	**100.0**
deposition	536	65.2
deposition + soil chemistry	254	30.9
meteorology	209	25.4
meteorology + soil chemistry	136	16.5
meteorology + deposition	197	24.0
meteorology + deposition + soil chemistry	136	16.5
soil solution	254	30.9

At the same meeting, Nagel and Kraft (Oeko-Data, Germany) gave some more specifications regarding available soil data at Level II plots:

Soil analysis	# plots	% share
Particle size clay content	221	26,9
Silt content	0	0,0
Sand content	0	0,0
Texture class (FAO)	0	0,0
Texture class 1-5	280	34,1
Bulk density	189	23,0
Coarse fragments	221	26, 9
Soil pH($CaCl_2$)	737	89,7
$CaCO_3$ (from 121 plots with calcareous material)	65	53,7
N_tot	737	89,7
C_org	737	89,7
Cation Exchange CEC	711	86,5
Soil solution		
pH	253	30,8
DOC	233	28,4
Concentrations of elements	253	30,8

Regarding the sampling and measurement methodology, both monitoring intensity levels are complimentary to each other. For example, soil chemistry in both levels follows the 'Manual on Methods and Criteria for Harmonized Sampling, Assessment, Monitoring and Analysis of the Effects of Air Pollution on Forests' (UN/ECE ICP Forests 1998; and its updates). However, the location of the plots differ in that the Level I is conducted in a systematic grid, while Level II follows a stratified approach, very often based on existing forest research locations.

Methodical basis

Sub-manual for soil sampling and analysis

The methodological basis for the ICP Forests monitoring is the 'Manual on Methods and Criteria for Harmonized Sampling, Assessment, Monitoring and Analysis of the Effects of Air Pollution on Forests' (UN/ECE ICP Forests 1998). The Manual has a modular structure and is comprised of separate sub-manuals for the different surveys carried out by ICP Forests (see also Table 1). Experiences with the Level I and II inventories, and new requirements (carbon sequestration, biodiversity) have led to various updates. Especially the submanual 'Part IIIa - Sampling and Analysis of soil' has been update twice, in 2003 and 2006 (FSEP and FSCC 2003; 2006) has been recently revised. In 2004, the 20th Task Force meeting of ICP Forests adopted the new submanual on litterfall.

Plot location

On the basis of EEC 3528/86, a theoretical framework for the location of the 16 x 16 km grid was provided. In order to cover the forested area, a shift of grid points to the nearby forested area by a maximum of 0.5 km was allowed (FSCC 2002). In addition, more severe changes of the plot locations occurred because sampling plots used for Level I were already established in parts of several countries, or plot locations were moved in order to optimize the sampling locations for the Level I soil inventory (depending on the selection criteria, for example, if coniferous forests on acidic soils were predominantly investigated, of if the typical main forest type was to be sampled, which led to the exclusion of extra-zonal and azonal site types). In some countries, different grids were used, namely those of the resp. NFIs (Sweden, Austria).

In other countries, such as Poland, only the Level II was used to report for the Level I inventory. Soil sampling in Greece and Italy had been conducted only for a small subset of the Level I crown condition grid due to capacity reasons and because of the focus on certain forest types. When comparing the crown condition data base (hosted at the PCC) and the Forest Soil Condition Database (FSCC), 147 plots were found to have different plot coordinates, but the same plot ID. It is assumed that a FSCC update of the plot coordinates (ca. around 1995 during the Level I evaluations) is responsible for that change.

Level I Programme

The main Level I survey activities concentrate on the crown condition, foliar analysis and soil (soil chemistry). While the crown condition assessment is repeated annually, the foliar and soil condition assessment were only conducted once. A first repetition, originally foreseen after 10 years, is currently conducted within the BioSoil demonstration project (for ca. 4,700 Level I plots).

Table 3-2 presents the parameters investigated during the crown condition assessment (FSCC 2002). It also contains the number of plots with complete data submission. In general, the following aspects are covered by the inventory design: defoliation/crown transparency, discolouration and stand and site characteristics which support the interpretability of the crown condition. The results are expected to serve as a basis for up-scaling Level II results.

Table 3-2 Parameters of the Level I crown condition assessment (acc. to FSCC 2002)

	2001 Crown Condition Database	Completeness
General parameters	Country	100 %
	Altitude	93 %
	Aspect	100 %
	Climate	100 %
Soil related parameters	Observed data	
	Water availability	89 %
	Humus type	80 %
	FAO soil unit	71 %
Crown related parameters	Observed data	
	Tree age	100 %

Table 3-3 presents the optional and mandatory parameters of the soil programme. FSCC (2002) provides the exact proportion of data available in the Forest Soil Condition Database of FSCC. For example, organic carbon in the organic layer (*abbr.* O-layer; *syn.* ecto-organic layer) is available for a total of ca. 85 % of the sites, the O-layer mass for 79 %; mineral soil C is available at 91 % of the sites (Baritz et al. 2009). The mandatory depth at which mineral soil data are available, is 20 cm (Germany: 30 cm). According to the manual, the pedological characterization (detailed soil profile description) was optional for Level I (and mandatory for Level II). On Level I, finger test estimation of soil texture classified according to the USDA-FAO texture triangle is allowed. At Level II, particle size has to be reported according to the tree major particle size classes: percentage clay, silt and sand.

The Level I data of the soil programme were entered into the Forest Soil Condition Database of the FSCC, while the crown condition data are gathered and maintained at the Programme Cordinating Centre of the ICP Forests (PCC Hamburg). FSCC (2002) has intensively analysed the Level I database. Some of the sampling campaigns date back to 1985, others were completed only in 1998 (those plots for which data were only provided after 1995 were not included in Vanmechelen et al. 1997). 2,498 plots were surveyed between 1993 and 1995.

Table 3-3 Chemical and physical analysis conducted in the Level I inventory and in BioSoil (Cools 2005, only parameters relevant for carbon monitoring are presented here)

Parameter	Level I – Mandatory (**X**) and Optional (*X*) Parameters				
	Organic Layer		Mineral Layer		
	L	F+H	0-5 cm	10-20 cm	20-40 cm
Physical soil parameters					
Organic layer weight	*X*	**X**			
Coarse fragments			**X**	*X*	*X*
Bulk density			**X**	*X*	*X*
Particle size distribution			**X**	**X**	*X*
Clay Content			**X**	**X**	*X*
Silt Content			*X*	*X*	*X*
Sand Content			*X*	*X*	*X*
Chemical soil parameters					
pH($CaCl_2$)		**X**	**X**	**X**	*X*
Organic carbon		**X**	**X**	**X**	*X*
Total nitrogen		**X**	**X**	**X**	*X*
Carbonates		**X**	**X**	**X**	*X*
Exchangeable Acidity		**X**	**X**	**X**	*X*
Exchangeable Cations		**X**	**X**	**X**	*X*

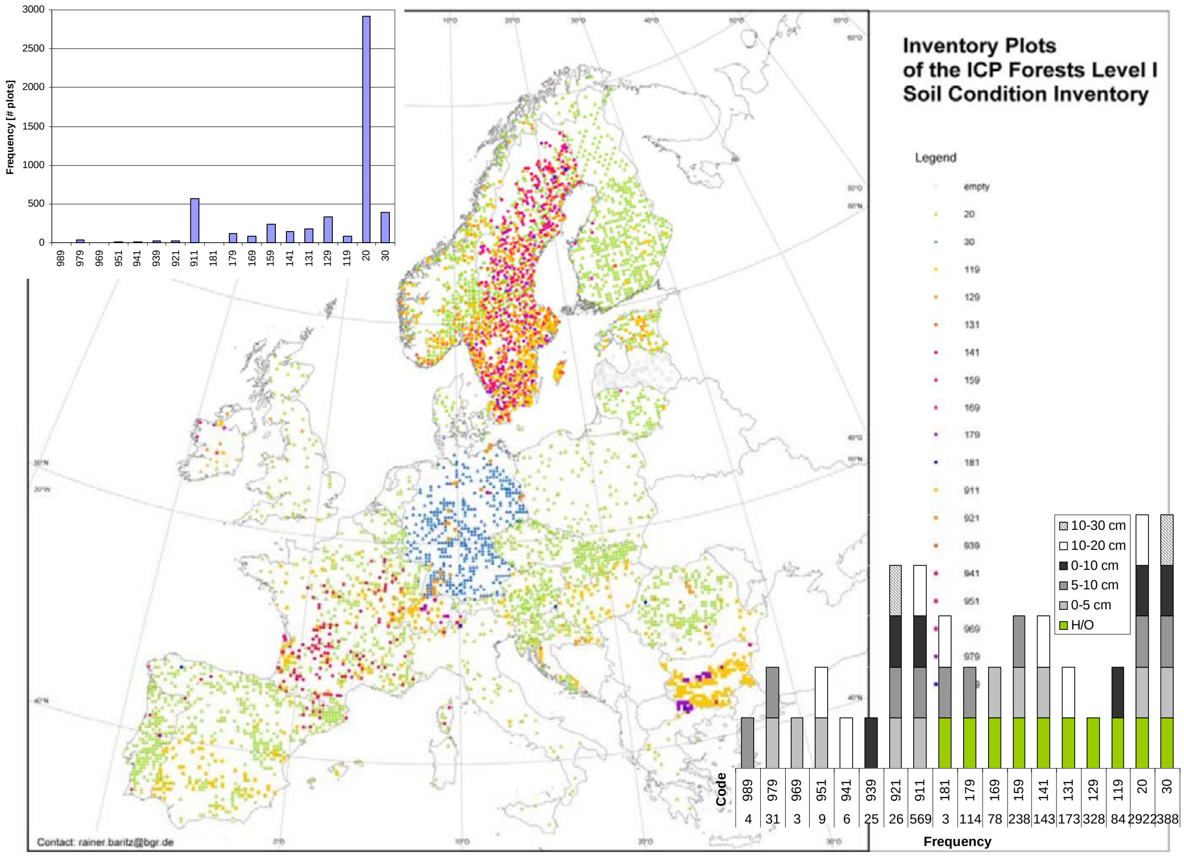

Figure 3-1 Level I soil observation plots: availability of data for the O layer and mineral soil down to 20 cm (The legend for the symbols presents a code that was developed to identify missing values in certain depth classes and O layer)

For 145 plots, soil data were still not available to the forest soil condition data base at FSCC. For 634 plots, data are only available for the forest floor. From 4,804 plots with data for the mineral top soil, 908 plots were missing at least one of the depth classes needed to cover 0-20 cm. For an additional 142 Histosols, no data for the peat layer were provided. In conclusion that means that for more than a third of the whole data set, C stocks (thus changes after repetition of the survey) cannot be assessed for the whole soil profile O+0-20 cm. It can be seen from the distribution of plots with missing data (Figure 3-1) that there will be typical landscapes for which the representativity of the plots is insufficient as to quantify a baseline or trend estimate for soil carbon.

Level II Programme

The Level II programme aims to investigate trends and dynamics of forest ecosystem processes by using intensive sampling and evaluations. In addition, the prognosis of change is needed in order to adapt management to changing environmental conditions. The measurements are conducted at different spatial and temporal resolutions. The evaluations integrate soil physics, soil chemistry, meteorology, forest protection and forest nutrition/health. Originally, cause and effect of the forest decline symptoms was to be investigated, which were wide spread during the 80s and 90s. The programme includes extensive (bi-weekly, on a plot level) and intensive (weekly on individual trees) monitoring.

It assesses only tree species in normally managed forest stands (management varies per country/species/plot). Assessments are made on spring flushing, flowering, leaf/needle decolouration, leaf/needle fall and biotic and abiotic damage.

Soil profile descriptions were mandatory: usually classified acc. to FAO 1988 (for most Level II plots in 1995; with the first data submission to FIMCI). In order to get to WRB (FAO 1998), based on the updated ICP Forests manual, re-classification was often applied without field work. In case of reclassification based on already available data, there are always some data gaps (Cools 2005). Regarding soil sampling and analysis, the list of mandatory parameters is comparable to Level I, however the 20-40 cm and 40 – 80 cm depth classes are mandatory. A further subdivision of the top soil depth classes for both Level I and Level II is advised/optional (0-5, 5-10 cm rather than 0-10 cm). For Level II, a larger number of optional soil chemical parameters is foreseen. Because the three composite samples are mandatory for Level II, it is possible to estimate a standard deviation for each of the assessed parameters. The information on the standard deviation is essential for assessing spatial and/or temporal variability.

Another significant difference between Level I and Level II is the number of subsamples per plot. Several subsamples per plot are often mixed into one or several mixed (composite) samples. The higher the number of subsamples, the better does the composite sample reflect all the variability of a site [15]. It thus becomes less likely to over- or underestimate the typical situation found at a sampled site. The Level I plots are sampled by at least 1 composite sample, based on at least 5 subsamples. Many studies have already proven that this low number of subsamples is insufficient to be free of systematic over- or underestimations (see also Ch. 2.1). Level II plots are sampled more intensively. "*A minimum of 24 subsamples has to be taken, to be combined in at least three composite samples (i.e. at least 3 composites of each 8 subsamples or 4 composite samples of each 6 subsamples)*" (FSEP and FSCC 2006). Thus, there are at least 3 mandatory values reported. Because of the subsamples, the chance for systematic error is minimized; and because of the values reported, the remaining variability can be quantified.

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Each time data are submitted by the end of each year, a Data Accompanying Report (DAR-Q) needs to be prepared which states deviations from the methods described in the manual.

Regarding forest growth-related parameters, according to the UN-ECE ICP Forests manual (1998/2006), the standard Level II plot design also includes 'dbh' measurements to monitor tree increment (5-yearly), the selection of trees for increment measurement bores and disks (to be conducted only once).

Results of the Level I and Level II programmes

Reports

The annual executive reports document the findings about the forest condition in Europe. Thus, these reports can be considered the main output of the ICP Forests programme. However, scientifically, the technical reports of ICP Forests are presenting more detailed experiences with and results from evaluating the Level I and II data. Until the year 2003, separate reports were issued for the inventory levels. Since 2004, the technical reports present results of both levels. Table 3-4 and Table 3-5 list the topics covered by the technical reports. Two earlier reports are considered to be the foundation for the development of the Level II methodology (De Vries et al. 1997, 1998).

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[15] **1)** "**Site**" refers to the part of a management unit (e.g. forest stand) with homogenous local physical, biological and meteorological conditions. For example, the wetter part of an otherwise dry sandy soil would be considered a different site, even though both could belong to the same management unit. A sampling plot is selected to represent a typical site. Subsamples are needed to take in as much of the local within-site variability as possible. However, this issue was treated differently in different countries

Table 3-4 Content of the technical reports (Level II, 1999-2003)

1999	2000	2001	2002	2003
Crown condition	Remote sensing	Species composition of ground vegetation	The vascular species composition of ground vegetation	Ozone exposure and ozone injury symptoms
Forest growth	Atmospheric deposition	Assessment of water fluxes through the forest ecosystem	Critical loads &present deposition thresholds for N and acidity and their exceedances	Ground vegetation species composition
Atmospheric deposition	Crown condition	Assessment of element fluxes through the forest ecosystem	Critical loads for heavy metals and their exceedances	Carbon pools and carbon pool changes
Meteorological parameters	Foliar condition			Impacts of N deposition on C sequestration by forests in Europe
Soil solution chemistry	Soil condition			Modelling the long-term impact of deposition scenarios for N and acidity
	Soil solution chemistry			
Annex 1: A comparison of results obtained by zero tension lysimeters, suction cups and centrifugation in different studies	Annex1: calculation of the required changes in element concentrations and element pools to derive significant changes	Annex 1: suggested themes/topics in the coming Technical Reports	Annex 1: Country results on ground vegetation	
	Annex 2: Calculation of the time period that is needed to derive a significant difference in element pools	Annex 2: Field intercomparison of bulk deposition and throughfall data at Speuld and Schagerbrug	Annex 2: Analysis of the effect of bulk deposition, throughfall or total deposition on the relationship with ground vegetation composition	
	Annex 3: Procedures and results of data quality checks for atmospheric deposition and solution	Annex 3: Data assesment methods for deposition and soil solution monitoring		
		Annex 4: The use of canopy exchange of weak acids in the calculation of total deposition of ammonium and acidity		
		Annex 5: Comparison of modelled deposition estimates with throughfall data at 223 Plots		
		Annex 6: Relationships between soil nitrate concentrations and environmental factors		

Table 3-5 Content of the technical reports "Forest Condition in Europe" (2003, Level I, 2004-2007 Level I and Level II)

2003 (Level I)	2004	2005	2006	2007
Methods of the surveys in 2002	**Large-scale crown condition surveys**			
Results of the transnational survey in 2002	– Methods of the surveys in 2003 – Results of the trans-national survey 2003	– Methods of the surveys in 2004 – Results of the trans-national survey 2004	– Methods of the surveys in 2005 – Results of the trans-national survey 2005	– Methods of the surveys in 2006 – Results of the trans-national survey 2006
Results of integrative studies	**Intensive monitoring**			
Forest nutrition of the Finish and Austrian Level I plots in 1987-2000	– Deposition – Forest growth studies (DEFOGRO, PROGNEU, RECOGNITION) – Results of epiphytic lichen diversity assessment	– Deposition and its trends – Dynamic modelling – Nitrogen retention and release in European forests – Ozone exposure and ozone induced symptoms	– Deposition and its trends – Evaluation of ground vegetation with special respect to deposition effects – Dynamic models for acidification and eutrophication	– Deposition and its trends – Modelling of acidification and eutrophication in forest ecosystems
National survey reports in 2002	National survey reports in 2003	National survey reports in 2004	National survey reports in 2005	National survey reports in 2006

3.2.2. Relevance of the ICP Forests scheme for observing carbon sequestration in European forests

In the following the data assessment of the various surveys is investigated with regard to specific pools, and with regard to an integrated carbon monitoring in European forests. During the 11th FSEP (2003), the soil carbon issue has received special attention (SOM Decline in the EU Soil Thematic Strategy; UNFCCC reporting on terrestrial sinks). A special evaluation by De Vries et al. (2003) has elaborated into the ability of the EU/ICP Forests Level II as to quantify the size of carbon storage pools in forests and its change.

The study has focused on changes in stem wood volume and the related carbon pools in stem wood. The carbon pool size was determined based on repeated measurements of both diameter at breast height (dbh) and tree height (all trees in the plot, by tree species). The single tree volumes were combined with literature-based wood densities and tree carbon contents: thus, an estimate for the carbon pool stored in the stem was derived and extrapolated to carbon pools per hectare.

The following Level II data were used:

measured	estimated
diameter at breast height	form factors (to derive tree volume from dbh and tree height)
tree height	stem wood density
soil "thickness" (volume)	carbon concentration in stem wood (ca. 50%)
soil carbon concentration	soil bulk density

For some countries, volume data were already submitted (Finland, Norway, Sweden, United Kingdom, Belgium Germany, Austria, Switzerland, Czech Republic, Poland, Spain, Italy and Greece), for others, volumes were calculated by FIMCI: Denmark, France, Hungary, Ireland, Netherlands and the Slovak Republic. Carbon pool changes could be calculated for 646 plots.

With these data, the carbon stocks for the following above-ground biomass compartments could be estimated:

- **living standing stock**: stem wood volume of living trees.
- **total standing stock**: stem wood volume of living and dead trees.
- **total stock**: stem wood volume of living, dead and removed trees.

De Vries et al. (2003) found that the annual C sequestration in trees is around 10 times higher than that in soils. For the change estimate, data of repeated measurements about tree diameter (at breast height) and tree height, and – if available – the reported changes in stem wood were used. The calculation of the SOC change is not described. The estimated biomass sink (5 yr period) came to 0.3 Gton/year. If harvesting and forest fires were included, the sink became reduced to 0.1 Gton/year.

In a second study (same report: De Vries et al. 2003), the current carbon sequestration in trees and soil in European forests for the year 2000 has been estimated based on an empirical model about the interaction between carbon and nitrogen. The likely impact of N deposition on C sequestration in the last 40 years (the period 1960-2000) has been studied in order to develop the necessary assumptions. Data on N retention, N uptake and C/N ratios were derived from more than 100 Level II plots. The Level I data was used to extrapolate to a total area of approximately 2 million km^2 of forests in Europe (including parts of Russia).

Table 3-6 Relevance of Level I and Level II parameters for carbon monitoring

Survey	Level I relevance for C sequestration	Level II relevance for C sequestration
crown condition	tree species composition, age	tree species composition, age, tree volume (or dbh and height)
soil chemistry (solid phase)	carbon concentration (O layer, mineral soil); bulk density usually estimated based on pedo-transfer functions; stones see Level II; only sampling of top soils	carbon conc. as in Level I, but higher plot sampling density (→ uncertainties) reduces sampling error; soil texture class derived from particle size analysis, stone content from the soil profile description (visual assessment); sampling depth extends to whole solum
foliage	(indirect effects: decomposition)	(indirect effects: decomposition)
soil solution chemistry		soluble organic and mineral carbon (DOC)
deposition		(indirect effects: decomposition)
ambient air quality		(indirect effects: decomposition)
meteorology		direct effect of climate to growth, litter production, and decomposition
tree growth		1994/95 and 1999/2000; tree height and wood volume;Retrospective analysis of tree height increment: tree ring analysis (requires felling of sampling trees; carried out in the buffer zone of 46 Level II plots); trend in biomass change
ground vegetation		– input of more easily decomposable herbaceous and grass litter (leaves, roots) – effects the decomposition of more heavily decomposable (needle) litter (priming effect) – adds to a more diverse structural decomposer habitat (e.g. intensive rooting of the O layer)
phenology		direct effects of climate change/length of growing season
litter fall		dynamics; pool size of the leave/litter layer
remote sensing		

A comprehensive analysis of the integrated use of the various ICP Forests subprogrammes for carbon monitoring has not yet been conducted. However, such studies exist for the integrated assessment of forest damages, deposition, climate, tree growth and soil condition (see literature list attached in the Bibliography). Table 6 gives a first overview of the possible usefulness of existing Level I and Level II parameters for C monitoring in forests.

Soil C (SOC)

According to IPCC (2003, 2006), reporting on carbon in soils distinguishes mineral and organic soils, and separate guidance is provided for both of them. Soil organic carbon in mineral soils refers to carbon stored in a soil compartment having a certain amount of fine earth at a specified depth (default for Tier 1 and 2 is 20 cm, but can also be country-specific if applied consistently through the time series). The change of the pool size is received from repeated measurements (inventory-based) or by applying a change rate (process-based). Carbon from organic soils is emitted following drainage. Usually, it is not quantified as size change of a storage compartment (or pool), it is reported using emission factors, and thus the fluxes of CO_2 from the soil are estimated. If C stock changes are reported for organic soils, Tier 3 approaches may be chosen. Mineral soils are characterized by < 15% organic matter, while organic soils have > 20-30 % organic matter[16]. This includes peat (in contrast to IPCC 2006, this is still explicitly mentioned in IPCC 2003; see definitions of the carbon pools). The accounting of organic soils needs to not just look at CO_2 dynamics, but must also consider CH_4 fluxes.

IPCC (2006) also states some minimum stratification requirements. Changes for soil C under "Forests Remaining Forests" should be stratified by climate region and soil types[17]. Stratification according to soil types may help to clearly separate between mineral and organic soils. However, drainage of peatland has often led to changes of soil types. For example, after cultivation, a former shallow Histosol could degrade to a Humic Podzol or Humic Gleysol in a sandy Pleistocenic environment. That means that if drained, organic soils should not be confined to Histosols, but should also include carbon-rich wet soils. Such soils could be found by overlying soil maps with geomorphographic maps and land use maps. With regard to the EU/ICP Forests sampling system, the gains or losses from such wet soils may not be detectable after the inventory repetition (BioSoil project) due to methodical restrictions and country-specific procedures.

The CAROBINVENT project (→ List of Abbreviations) has intensively studied the usability of the LEVEL I programme as to assess regional soil C change (Baritz et al. 2006c, d). The SOC pool and storage in the O-layer was investigated; the biomass pools were investigated based on NFI data. Regarding the soil C pool, the EU/ICP Forests Level I can certainly provide a baseline - in connection with the BioSoil inventory - a trend assessment. However, some frame conditions for trend assessment need to be addressed properly. The issue mostly refers to the role of systematic errors, which are usually not addressed because difficult to quantify.

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[16] Definition of organic soils acc. to FAO (1998) (see IPCC 2003, Glossary; see also Ch. 2.2 footnote [4)])

[17] **Histosols** are soils developed from the accumulation of organic material of at least 10 cm thickness if developed on rock or permafrost. For deeper developed soils, the organic material needs to be accumulated close to the soil surface (at least within 40 cm), and if down to a depth of 1 m, having at least 60 cm accumulated thickness (if developed from moss), or 40 cm, if developed from other organic materials.

A ***histic*** **horizon** can be developed with other soils if the horizon is saturated with water for at least 30 consecutive days, and if it is at least 10 cm thick (if < 20 cm, than the top 20 cm of soil including the organic layer must have at least 20 % organic matter). A ***folic*** **horizon** must be an organic layer of at least 10 cm, but not wet (well-aerated). Therefore, the folic horizon includes the OF and OH horizons.

Table 3-7 Conclusions from different studies regarding the use of EU/ICP Forests Level I data for baseline development and trend detection for Europe

Sampling design	
Representativity (number of samples required to represent spatial variability)	The number of subsamples proposed and conducted in the EU/ICP Forests Level I inventory is insufficient for preventing systematic over- or underestimation of the values for each sampling plot: – De Vries et al. (2000) and Wilding et al. (2001) propose that a set of at least four to six subsamples (mixed into one composite sample) must be taken in order to represent a pedon. – If the variability of the forest floor is considered, the number of required subsamples is even higher: Kirwan et a. (2003) for Level II sites (UK intensive forest health monitoring) estimate that the required sample density amounts to 25-36 pits (to represent the variability of a 0.3 ha forest plot). Green et al. (2005) and Arrouays et al. (2001) come to similar conclusions. Tamminen and Starr (1990) have used 10-30 subsamples depending on O-layer thickness. – Flemish test study (Cools 2005): to cover the within-plot variability, a repetition of three bulk density measurements per layer is not sufficient, so that at least five core samples per layer are recommended to be sampled (in BioSoil). – For sampling litter, IPCC (2003) proposes that at least 10-15 data (sampling) points should be collected, ensuring that the full range of the expected litter depth is sampled (IPCC 2006: Ch. 4.3.3.5.3 “Dead organic matter”)
C content (or C concentration)	
Carbon analysis	4th and 5th FSCC Interlaboratory Comparison: – The results for organic carbon seem to be comparable throughout Europe. – in the context of soil C: measuring the organic carbon content in samples with low organic carbon content seems problematic; the same holds for $CaCO_3$.
Amount of fine earth (needed to calculate C stocks)	
Bulk density	The recommended method to estimate on the basis of the soil organic matter content is the PTF of Adams (1993) (see also De Vos 2005).
Stone content	Flemish test study (Cools 2005): The Finnish method or rod penetration method for the estimation of the stone content must be tested and calibrated before it can be applied on other soils besides Finish till soils for which the method has been developed (Cools 2005). Similar results were also found by Baritz et al. (2006c).

Litter

According to IPCC (2006), litter includes all lying non-living biomass in various states of decomposition above the mineral soil, with a threshold diameter chosen by the country (for example 10 cm). The definition of litter follows that of regular soil nomenclatures[18]. In contrast, the earlier definition for litter in IPCC (2003) still mentioned fumic and humic layers being part of the litter pool (IPCC 2003: Ch. 3.1.3 "Definitions of Carbon Pools"; see also Glossary)[19]. Now with IPCC (2006), it seems that it is up to each country to determine, whether fumic and humic layers (OF and OH horizons in forest soils) would be included under soil organic matter, and thus not counted as litter (IPCC 2006: Ch. 1.2.1 "Science background"). In IPCC 2006 Chapter 5.2.1 ("Change in carbon stocks in dead organic matter"), litter accumulation is described as a function of the annual amount of litter fall, which includes all leaves, twigs and small branches, fruits, flowers, and bark, minus the annual rate of decomposition. The pool description also refers to early (fresh litter, early forest stand developmental stages) and late stages of decomposition but does not explicitly refer to "ecto-organic" soil horizons such as organic horizons of the forest floor (O-layer). In Ch. 2.3.3.1 ("Soil C estimation methods"), litter C stocks are also referred to as 'residues'. The description of the litter dynamics in Ch. 4.2.B ("Dead Organic Matter", IPCC 2006) seems to exclude the fragmented and humified organic layers (OF and OH).

H horizons of wet soils are similar to the "ecto-organic" OF and OH horizons of upland soils, but are saturated with water for prolonged periods (FAO 2006a). According to IPCC (2006), H horizons > 30 cm qualify as Histosols (see also FAO 2006b), thus are counted as organic soils (the threshold should be corrected to 40 cm; see footnote Ch. 2.1 this report). There is no further rationale on organic soils in terms of nomenclature and more detailed definitions.

In the EU/ICP Forests Level I (1990-95), sampling of the L horizon was optional. In fact, the L horizon was mostly excluded from sampling. The OF and OH horizons were often sampled together as one mixed sample. Any coarse material (material > 2 mm: twigs, branches, cones) and living biomass has been excluded during sampling.

If the IPCC definition of litter is correctly interpreted, then the OF and OH horizons qualify as litter because they are accumulated on top of the mineral soil. However, IPCC (2006) remains less precise than IPCC (2003). Therefore, it will be mostly up to the national definitions as long as they are applied consistently throughout the reporting. If OF and OH are counted into the litter pool, then the Level I inventory may serve as a baseline for trend assessment of the litter pool. However, a data gap still remains for the more or less intact leaves and needles on the ground (OL horizon[3]) and for fine woody debris (below a threshold which separates it against the dead wood pool). In order to be consistent in the national/European GHG reporting (if Level I data are used), the data gap must be either filled using data from other sampling programmes (such as NFI, or Level II), or,

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[18] Definition of the litter layer (Jabiol et al. 2004; adopted and cited by the UN-ECE ICP Forests manual on sampling and analysis of soil):

"*OL-horizon (Litter, Förna): this organic horizon is characterised by an accumulation of mainly leaves/needles, twigs and woody materials (including bark), fruits etc. This sublayer is generally indicated as litter. It must be recognized that, while the litter is essentially unaltered, it is in some stage of decomposition from the moment it hits the forest floor and therefore it should be considered as part of the humus layer. There may be some fragmentation, but the plant species can still be identified. So most of the original biomass structures are easily discernible. Leaves and/or needles may be discoloured and slightly fragmented. Organic fine substance (in which the original organs are not recognisable with naked eye) amounts to less than 10 % by volume*."

This horizon is generally called the litter layer in soil inventories, while the underlying organic horizons are called the fragmented layer (OF) and the humus layer (OH).

[19] IPCC (2003; Glossary) also defines a litter horizon consisting of relatively fresh dead plant material, it may be colourised, but does not contain excrements from soil fauna. It is not or only partly fragmented.

if available, data from the literature, or the pool must be re-defined (e.g. litter being confined to the OF and OH horizons).

Proposal how to deal with the litter pool in GHG reporting

Support to the definitional problem of the OF and OH horizons (whether they are part of the litter compartment or not) is received from earlier work on the dynamics and the classification of humus types in forests (review and summary in Baritz 2003). The dynamics of the litter pool (defined as any dead organic material < threshold diameter on top of the mineral soil) can be described separately for two different categories of forest sites:

rich (loamy) soils:

- unstable L horizon and FWD
- bioturbation causes break down of litter in the mineral soil; decomposition activity is mostly in the mineral soil
- therefore diagnostic criteria of the humus dynamics are derived from the top mineral soil (this excludes soils with available OH)

moderately poor to poor (sandy) soils

- unstable L horizon and FWD
- accumulation of organic material on top of the mineral soil from reduced decomposition
- diagnostic criteria of the humus dynamics are derived from the OH horizon (or mixed OF-OH, if the horizons cannot be separated, of if OH is too thin and/or discontinuous)
- decomposition activity is mostly outside the mineral soil (*this especially makes it reasonable to treat the OF and OH horizons as litter, and not count them as part of the (mineral) soil*).

With regard to the GHG reporting, it is important, that some additional criteria are fulfilled in order to report on a pool/pool change in a meaningful way.

- **Sensitivity to management activities**: management affects the thickness thus storage of carbon in OF and OH horizons through tree species selection, harvesting operations, regeneration activities, and the steering of the canopy closure from selective cutting operations, etc
- **Lack of full correlation with another pool** (e.g. C in litter with C in dead wood, or with mineral soil C): if the size/change of a pool is highly correlated to another pool, a separate quantification may not be needed; *or it is reported as a stable fraction of another pool*. This aspect should be investigated after careful stratification of the national inventory data bases. What makes a pool to develop that way? In many parts of Europe (with intensively managed forests, and changed tree species selection), the factors which drive humus dynamics in the O layer are at least partially different from those in the mineral soil or in the dead wood pool (Baritz et al. 2006d).

In general, it is hypothesized that FWD, and the L, OF and OH horizons of the forest O-layer are fractions (or sub-pools) of the litter pool. Using the proposal above, reporting of litter would exclude rich soils (where a continuous OH horizon is lacking).

The dynamics influencing the size and changes of the FWD and the L sub-pools are extremely difficult to monitor. Data for the most typical forest ecosystems are completely lacking. Data bases from long-term stand replacement studies (probably mostly historic non-digital data) investigating the dynamics of mortality and growth of forests under different silvicultural regimes are not available. The mentioned sub-pools are extremely unstable due to a very high degree of temporal and spatial variability. Thus, reliable change estimates or default values which would be used for GHG reporting cannot be produced. Further investigations are needed.

Dead Wood

According to IPCC (2006), dead wood includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used in the country.

In Level I/II, each assessment tree which has died, or which has been removed, is recorded (mandatory only in Level II). The reporting considers the cause of its death, or if appropriate the reason for its removal. However, the evaluation of mortality in Level I/II is problematic because it is treated differently (Lorenz et al. 2006): in some countries, completely defoliated trees are removed, in others they are kept in the data base and repeatedly reported as dead. During the reporting years 2000 to 2005, annual mortality rates between 0.27 and 0.4 % were determined. The years after the summer drought 2003 did not show a clear increase. These data show that the mortality in Level I probably does not represent the real trend for all managed forest land. This conclusion can only be validated if upscaled NFI data on dead wood become available. Simply because living dominant and co-dominant trees are selected as assessment trees in the crown condition survey, it cannot represent the dead wood dynamics of a forest.

In addition, a full assessment of the carbon stock in dead wood is only possible if all dead trees (for example suppressed trees) and also lying wood is included, and if the decomposition status is known. The level of decomposition determines the rate of carbon released (and is also connected to the calculation of the current C stock in dead wood). Meyer et al. (2003) conclude that information about decompositional stages and decay dynamics for dead wood is still a knowledge gap for European forest tree species. The level of decomposition is not assessed in the crown condition surveys.

Wirth et al. (2004) have conducted a literature review on dead wood stocks in European forests. They found that large uncertainties about carbon in dead wood are related to the measurements of the grounded dead wood with progressed decomposition and the fine wood debris, which is usually excluded from the dead wood surveys (and also from the Level I/II surveys). It is fairly unknown which part of dead wood is released by heterotrophic respiration into the atmosphere, turned into fungal biomass, transferred into fine woody debris compartments by fragmentation of the decaying bole, or be transferred into the humus layers directly.

A very extensive review on dead wood in forest inventories and monitoring has been conducted by Oehmichen (2007) with the objective to propose a method which could be included in the German forest soil condition survey. The report covers definitional and methodical aspects for dead wood carbon monitoring. It analyses the inventory methods developed and applied in various forest inventories (Germany, federal state of Baden-Wuerttemberg, Austria, Switzerland, USA), but also covers the methodologies tested in the Forest Focus monitoring projects (ForestBIOTA, BioSoil; see also Chapter 7 this report).

The ICP Forests Level I/II survey methodology does not monitor dead wood. The decomposition status is not assessed, which means that the volume of dead wood cannot be calculated (maybe in relation to the volume of the tree when it was still alive and part of the crown condition survey), and neither its carbon content. Therefore, within the ICP Forests monitoring, a more or less complete data gap exists for this pool. This is the reason for launching a project to develop a methodical basis to incorporate this pool into future inventory schemes (see title 3.4.1 ForestBIOTA project).

3.2.3. Conclusions

Current work consisted in compilation of meta information about the EU/ICP Forests Level I and II sampling programmes. An overview of the regular reporting activities for both programmes is given, with an in depth-review of soil carbon-related results. References to the results of other European or national research projects with a focus on soil carbon are partly already included (e.g. CarboInvent) but are discussed as well in this chapter (e.g. CarboEurope).

From the sampling designs, it can be concluded that Level II offers some crucially important extensions of Level I. Mainly, this refers to the extended sampling intensity, but also the measurement of additional parameters related to decomposition, nutrient and soil water dynamics. This allows estimating input/output balances (element cycling) and cause-and-effect relationships. However, the full range of intended parameters and compartments (soil and vegetation) are only measured at around 200 out of the more than 800 plots (these could be considered **"core"** sites). Without full element budgets, the net gain or loss of carbon detected in the Level I programme are difficult to explain and to verify.

The data requirements to monitor the soil and the litter pools were analyzed and compared to the data available under Level I and II. It appeared that national definitions have to be applied as for what exactly is contained in the litter pool. Can the fermented and decomposed organic horizons of the O-layer of forests soils be counted as litter or is it part of the (mineral) soil carbon pool? IPCC (2003) and IPCC (2006) do not give a clear answer. A possible solution is presented and justified. It is proposed that OF and OH horizons would be counted as litter, and L and FWD would be omitted. This is also investigated in the MASCAREF case study in Greece and its follow-up (full Level I-soil inventory including L and FWD).

3.3. *Potential contributions from previous and ongoing forest ecosystem research networks*

3.3.1. Role of forest ecosystem research for carbon monitoring

The GHG reporting for changes of the soil organic matter and litter pools under KP 3.4 will first require some (re-)definitions depending on how the existing inventory data meet the GHG reporting requirements (for example: soil depth; for litter). Most of the EU member states (and many other Annex I countries which elected KP 3.4) will then use inventory data to compare measurements from two sampling times – thus to look for possible carbon sources within the population of plots sampled. After testing and applying some stratification, the annual change rates will be calculated for each stratum from the difference between the sampling years, divided by the number of years between the two inventories. In case the sampling dates fall into 2008 and 2012, the mean change can be directly used for the commitment period. The development and application of Tier 3 model-based projections is probably going to be quite exceptional at least in Europe.

The application of models in Tier 3 approaches as well as the verification of inventory-based change rates will require more data than available in the existing large-scale inventories. Models also need to be calibrated and validated for the area of application. Such data need to be of high quality, with only minimal sampling errors. Data from well-described forest ecosystem research sites or intensive monitoring sites can be used for that. Such sites are usually intensively sampled with an analytical programme which depends on the monitoring/research objectives: biodiversity, pollutant input and soil condition, growth/ecosystem productivity, etc. In contrast to the inventories presented above, measurements already cover various aspects of (forest) carbon cycle; some of them cover all relevant compartments in order to calculate the carbon balance of the forest ecosystem.

In case the forest ecosystem research has established a focus on carbon changes[20], the main methodical approaches taken are flux measurements (soil respiration) and chronosequence studies. Depending on the specific sampling programme, the carbon stored on the various storage pools, e.g. dead wood, litter, is assessed. While data from these sites are of great value for improving and validating GHG reporting, no systematic assessment of such sites has been conducted for Europe (except partially through ENFORS), and very little meta information is (easily) available about such sites.

Results from such sites must be investigated first with regard to the representativity of each site for landscape- and site-specific typical properties and pool sizes. Ecosystem studies are also crucial for the validation of pool change from mass balance approaches (based on pool size assessments), model calibration, and gap filling in the EU/ICP Forests Level I and Level II. In some cases, where repeated inventories are lacking, and thus, only baseline values are available, forest ecosystem research studies can also fill gaps with regard to trend assessment and extrapolations.

A literature analysis of the use of chronosequence studies in improving soil C assessments has been conducted in the CarboInvent project (Baritz et al. 2006b). However, a thorough look as to which pools are covered at which level of representativity is still lacking.

3.3.2. Forest Research Networks

The following list of research/monitoring networks excludes individual national research programmes (for an extensive list of projects see http://afoludata.jrc.ec.europa.eu/index.php/public_area/home).

SOMNET has not received a separate chapter, because it does not cover forests. The main focus is on fertilizer experiments in agriculture. Currently, the meta data of 30 long-term experiments can be accessed (www.ufz.de/somnet; 3 sites are accessible, 27 sites are not public). Another meta data site can be found at http://saffron.res.bbsrc.ac.uk/cgi-bin/somnet (Rothamsted research). It contains detailed information on long-term experiments and SOM models (for Europe, 86 experiments, and 20 models). SOMNET started in 1995 in the UK as a network of SOM modellers and long-term dataholders. Shortly after, it became a Core Project under the IGBP's GCTE programme. Long-term datasets and models selected from SOMNET were used to test nine leading SOM models. Only four models were able to simulate all land-uses (RothC, NCSOIL, CENTURY and SOMM).

EFERN/ENFORS

EFERN was established in 1995 as a pan-European network initiative based on a resolution of the "Ministerial Conference on the Protection of Forests in Europe", Strasbourg 1990. During 1996-1999, a concerted action within the EU FAIR Program aimed to develop a database with European institutions, scientists and projects within the field of forest ecosystem research (so-called "EFERN S6"). EFERN also became a unit under the IUFRO Division Forest Environment (8.01.05 – European forest ecosystem research network EFERN). The results of EFERN became available at ifff.boku.ac.at/efern.

EFERN has succeeded in launching a COST Action E 25 "European Network for long-term Forest Ecosystem and Landscape Research – ENFORS". An overview about field facilities in forest ecosystem research in Europe has been developed, and a meta data base compiled. The activities have stagnated ever since the end of the COST action.

ENFORS includes nearly 300 field facilities. Of these, 90 sites (so-called "Core" or "ENFORS" facilities) qualify for the full range of site selection criteria (for example: representativity for typical catchments/landscapes; if local plots are included, then extra value must given such as long-term time series). Only those facilities were considered for which sufficient documentation, data, time series, and field facility were available so that these sites could be brought together into one

[20] →http://afoludata.jrc.ec.europa.eu/index.php/public_area/home

research and observation framework. It was also intended to link these national research facilities (better: observation sites) with other observation systems such as ICP Forests Level II. The selection criteria were defined on the basis of the following aims of ENFORS:

Aims of COST E25:

- to establish a pan-European network of field research facilities of relevance for sustainable forest management; integration forest ecosystem research programmes (national, ICP Forests Level II, ICP Integrated Monitoring) under one common programme (representativity at the catchment/landscapes level; long-term measurements, common methodologies).
- to develop a common scientific research programme/ strategy on forest ecosystems also focusing on the landscape level and the long-term perspective.
- to build a European database on field experiments relevant to sustainable forest management.

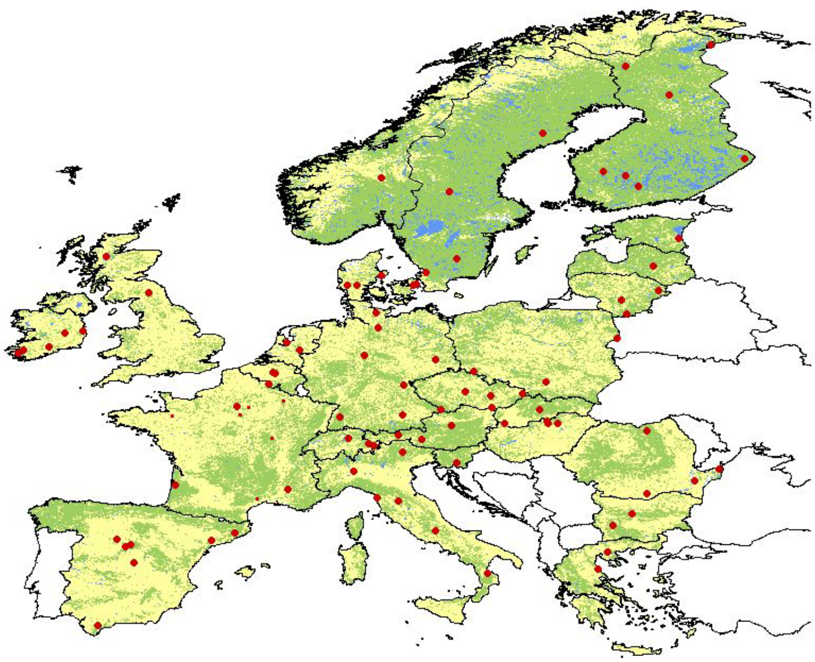

Figure 3-2 Distribution of ENFORS 90 field facilities

ENFORS has built a data infrastructure (Information System), which contains

- a meta-database with information about nearly 300 European field research and monitoring facilities related to sustainable forestry
- a collection of national data bases with information at a national level on long-term forest ecosystem and landscape research and monitoring
- an Information system on sustainable forestry (plans) which connects data sources for retrieving information on institutions, scientists, projects, experiments and publications.

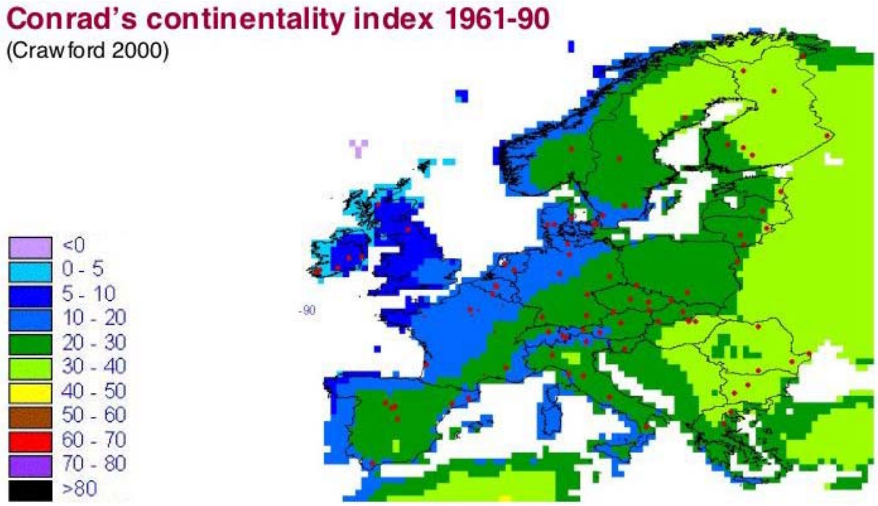

Figure 3-3 Representativity of the ENFORS facilities [The continentality index is based on the average annual temperature range and latitude.]

ENFORS has also developed guidelines for the national inventories of field research facilities (Mårell et al., *Technical Report 2*). The *Technical Reports* 3 and 4 (Mårell and Leitgeb, eds.) provide an overview of different country reports and contain field facility descriptions. On that basis it can be assessed, for example, how much overlap exists with EU/ICP Forests Level II plots.

LTER-Europe

LTER Europe is a pan-European long-term ecosystem research and monitoring network in Europe. It includes national networks of long-term ecosystem research. The establishment of LTER-Europe comes from the FP6 (6th framework programme of European research) Network of Excellence ALTER-Net, founded in 2007. ALTER-Net is a "A Long-Term Biodiversity, Ecosystem and Awareness Research Network" (http://www.alter-net.info/).

LTER is characterised by being site-based research and/or monitoring that takes place over a long (10 or more years) time scale. Generally there is a strong element of repeated monitoring. Examples include regular measurement of climate variables, repeat vegetation surveys, bird and butterfly monitoring. For more information see also: http://www.lter-europe.ceh.ac.uk/index.htm.

Figure 3-4 Status of LTER-Europe presents the current status of LTER Europe. For example, the national park Bayerischer Wald has provided plots for investigating dead wood dynamics in managed and unmanaged forest ecosystems. The data were used in the CarboInvent project.

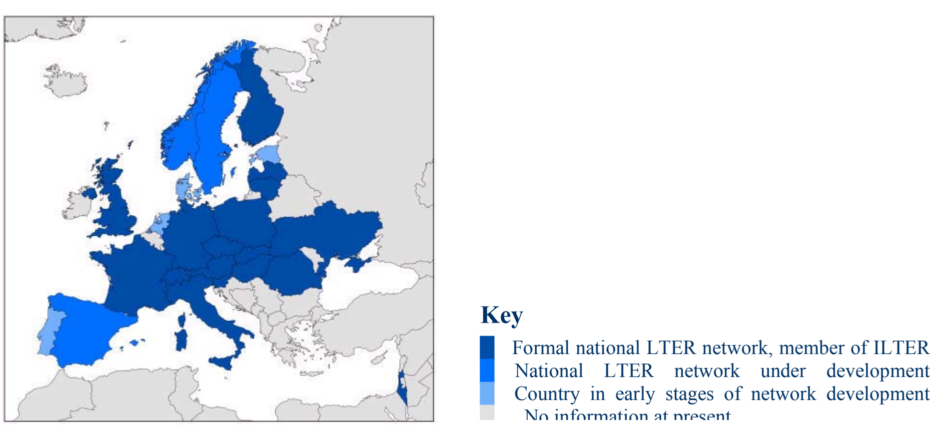

Figure 3-4 Status of LTER-Europe

In the context of soil and carbon monitoring, not very much information is offered with regard to distribution of plots, meta data about what is measured and how. The network offers a reporting form in order to receive an overview over LTER activities in Europe. The results are foreseen to enter the LTER-Europe InfoBase (database of sites and networks).

However, the questions raised in the LTER reporting form are very general and do not offer the information needed here. Therefore, at this point, mentioning LTER in the context of GHG reporting is only to provide a broad overview of existing ecosystem research sites.

CarboEurope

The objective of the CarboEurope project cluster (FP5) and Integrated Project (FP6) is to observe, to better understand and to verify the European carbon balance, with an emphasis on regional and continental scale. Regarding soil carbon, results seem to indicate that soil inventories alone are not suited for Kyoto monitoring, and that stock changes in soils are very hard to observe.

CarboEurope Cluster:

- In the framework of EUROFLUX, fluxes of carbon dioxide, water vapour, and energy exchange have been measured at 13 forest sites encompassing the entire range in European climate types, species distribution, and site conditions. The selected sites are proposed to be representative of the regional features of the European basin.
- The CarboEurope Cluster brings together six projects designed to better understand, quantify and predict under current and future scenarios the carbon balance of Europe, from local ecosystem to regional and continental scale. Two of these projects, CARBOEUROFLUX and CARBODATA are of direct relevance to terrestrial observing systems.
- CARBOEUROFLUX: at 30 study sites representative of European ecosystems, carbon, energy and water exchanges is investigated together with ecological processes controlling the ecosystem biospheric exchanges. The net flux of carbon entering or leaving the ecosystem will be measured, to provide the annual estimate of Net Ecosystem Exchange.
- CARBODATA: This project is designed to exploit and to make widely available the results of the mentioned EU funded research projects which have produced data on C fluxes and C stocks in European ecosystems.
- CarboAge investigated the role of European forests as carbon sinks over the life-time of forest stands. Stocks of carbon were measured at five sites over Europe, including carbon in biomass and soil. CO_2 fluxes were measured for different forest compartments with different methods over an age chronosequence which included existing EUROFLUX sites. The age-related changes in net primary production (NPP) and net ecosystem production (NEP) were then modeled.
- FORECAST has investigated changes in stocks and fluxes along chronosequences to quantify the effect of harvest and reforestation on net C-fluxes in managed forests (9 core sites, 3 partly funded sites, 2 externally funded sites). Some of the aspects covered are C/N pools in the organic and mineral soil layers, litter decomposition and C-transfer to soil organic matter, and relations between soil respiration and soil water and temperature. The data were applied in modelling exercises.

The cluster projects mentioned are continued under the FP6 Integrated Project (IP) in order to develop an operational monitoring system, to better consider interannual variability and the role of feedbacks between carbon and nitrogen cycles. In addition, the basis for future projections needs to be improved. The CarboEurope IP includes:

- CO_2 flask network and inversion modeling
- satellite measurements
- micrometeorological towers
- biomass and soil surveys

- biogeochemical Modeling

Data from flux towers are used, whereas ecosystem models relate flux tower measurements to remote sensing data (MODIS derived products). The eddy covariance method is used to measure fluxes of CO_2, water vapor and energy exchange according to:

NEE = soil + vegetation C flux = flux covariance + storage

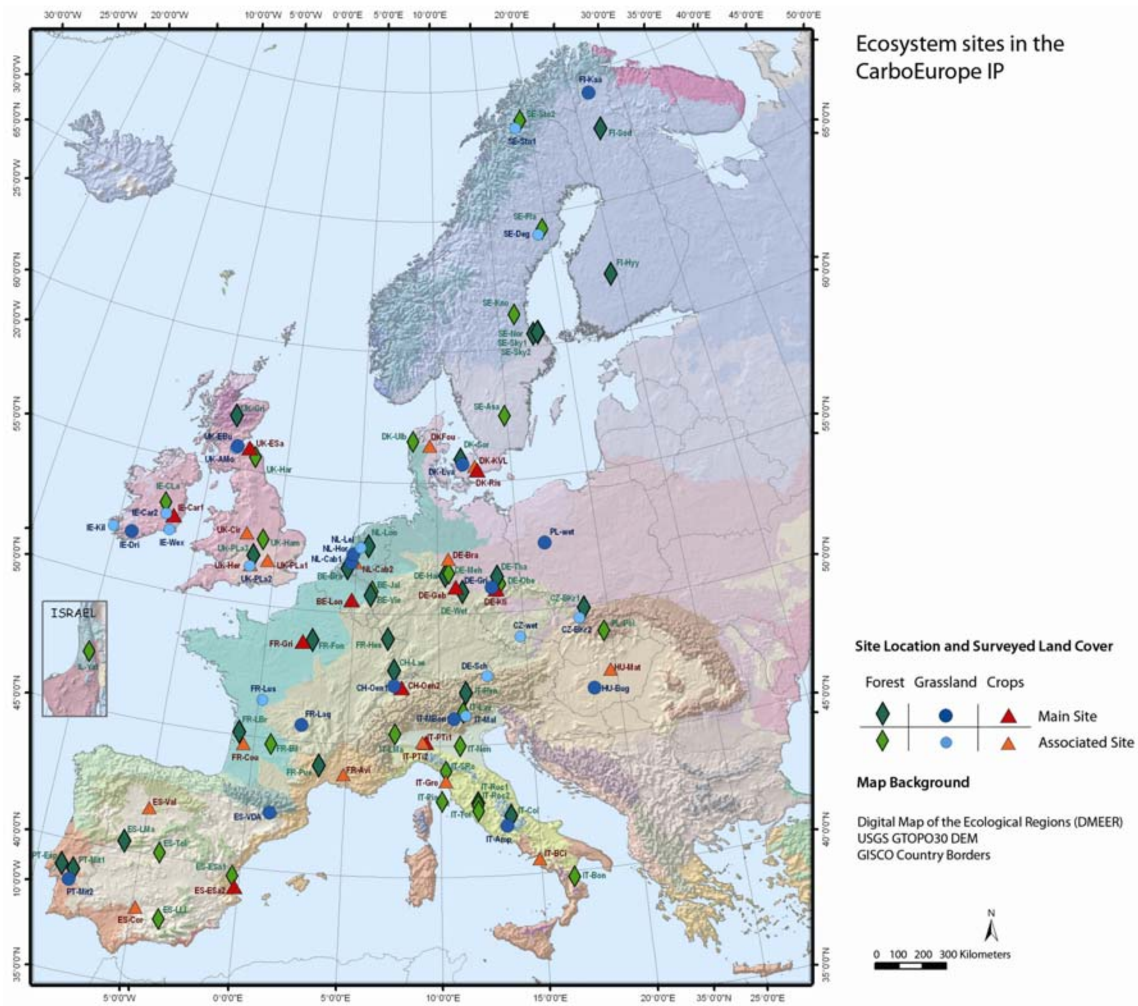

Figure 3-5 Ecosystem sites of the CarboEurope IP

National/regional forest research/monitoring projects

Research forests are established all over Europe to conduct long-term silvicultural, dendrological and ecological experiments (stand-replacement dynamics, mortality, intra/interspecies competition, yield table development). Forest research seeks to develop and test silvicultural treatments which differ from ordinary forest management methods. For example, METLA in Finland is currently conducting roughly 6,000 field experiments in 15 research forests (plus regional research stations) on 7,500 hectares. The research includes forest tree nursery studies and forest regeneration studies, research on forest genetics, development of practical applications of forest tree improvement techniques, as well as studies about the management of exotic tree species.

For all of Europe, it impossible to compile the status of these research activities because no international network includes such sites based on agreed sampling and/or evaluation procedures.

However, very often, long-term forest stand development, regeneration and thinning studies (dendrological experimental sites) belong to existing networks, such as ICP Level II, or ICP IM. With regard to ecosystems of high ecological value, such sites are included in LTER Europe. However, only large areas (protected zones or watersheds) belong to this category.

Another very diverse set of forest inventory/monitoring programmes includes **natural forests** (or forest reserves; protected forests). Similar to forest stand-level research, the programmes differ quite a lot throughout Europe. An initial assessment of the status of monitoring was conducted by the COST action E4 'Forest Reserves Research Network' (1995-1999). The objective was to create a European network of forest reserves in order to collect information on ongoing research, unify research methodologies, and produce a central data base for the exchange of research results. The results are published in Parviainen et al. (2000), Parviainen and Frank (2003).

In some areas, observation/inventory plots in protected forests also belong to nature conesrvation networks (NATURA 2000), in others, investigations are of regional interest only, for example to develop reforestation strategies after storm events. Even though GHG reporting focuses on managed forests, the inventory programmes developed for forest reserves could tremendously help for example to develop ecosystem-specific default values for dead wood, taking into account dynamics related to natural stand development. If such data would be compared with NFI data, stock change factors for management could be derived (IPCC 2006, Vol. 4. Ch. 2 Generic Methodologies (…), Ch. 2.3.3.1 Soil C estimation methods). In addition, it seems feasible to derive transfer rates between C storage compartments (IPCC 2006, Vol. 4. Ch. 2 Generic Methodologies (…), 2.3.1.1 Land remaining in a land-use category, B. Methods for estimating transfer of carbon in Biomass).

Integrated monitoring (ICP IM)

The ICP Integrated Monitoring has started its activity mid to late 80s (pilot programme 1989-1991; Environment Data Centre 1993). In fact, the first manual has served as orientation to set up the Level II programme (De Vries et al 1997, 1998). Therefore, the programmes resemble each other, with Level II plots often found in IM watersheds. IM monitoring is set up in order to

- monitor both biogeochemical trend and biological response in small (ca. 10 ha) hydrologically defined areas
- investigate natural variation, including succession, in order to better identify anthropogenic causes of forest development (or degradation)
- develop and apply tolls, such as models, in order to assess region-specific dynamics and to predict long-term effects.

Figure 3-6 presents the distribution of IM observation sites. It must be considered that not all monitoring programmes are installed and conducted at every site. The following optional and mandatory subprogrammes are part of IM:

- SC soil chemistry (SOC)
- SW soil water chemistry (DOC)
- FC foliage chemistry
- LF litter chemistry
- VG vegetation
- VS vegetation structure (*optional*)
- MB microbiological decomposition (*optional*)
- BV vegetation inventory

There are currently 46 sites (watershed with subplots) established and maintained. Because the sampling design stresses spatial variability, data from IM sites could support trend detection by providing data for representative forest or site types. It became clear from the discussion of evaluations towards change detection using Level I and Level II, that information about the within-site variability of parameters is crucial. Soil chemistry (SC) has been measure at 33 sites (one assessment, mostly between 1990 and 1995).

Figure 3-6 Distribution of IM sites in Europe

Global activities

The **Man and Biosphere Programme (MAB)** of the Division of Ecological and Earth Sciences of the UNESCO's Natural Science Sector also involves a variety of observation plots. The programme was launched in 1970 with 14 project areas, which then developed to World Network of Biosphere Reserves. It can be expected that for Europe, these sites are also found in the LTER Europe. The main focus are biodiversity issues.

Another global activity is the **Global Change and Terrestrial Ecosystems (GCTE)**, which is a core project of the International Geosphere-Biosphere Programme (IGBP). It was established in 1986 by the International Council of Scientific Unions (ICSU). The IGBP attempts to predict the effects of climate change, atmospheric pollutants and land use on terrestrial ecosystems. Regarding carbon, the activities were partly grouped with the International Human Dimensions Programme (IHDP) and the World Climate Research Programme (WCRP) into "The Carbon Challenge", a joint research programme. However, this is not an observation network.

Rather, experiences from a wide variety of researchers and projects were compared and combined. Under the IGBP, a transect approach has been chosen to as a tool for global change research, for example the North East China Transect. Each transect consists of a set of study sites along a gradient of ca. 1,000 km length. It is wide enough so that remote sensed data can be applied together with terrestrial data in grid-based modelling exercises, such as running dynamic global vegetation or general circulation models. The only transect in Europe is the Scandinavian – Northern Europe transect (SCANTRAN).

The **Global Terrestrial Observing System (GTOS)** is an FAO programme for observations, modelling, and analysis of terrestrial ecosystems to support sustainable development. The programme provides access to information on terrestrial ecosystem through the following activities:

1. TEMS Database
2. Climate observations
3. Terrestrial carbon
4. Terrestrial Networks
5. Regional Networks

3.3.3. Conclusions

A variety of networks were reviewed which provide metadata on forest research observation plots. Very often, countries participate with their Level II plots already (for example, in the ENFORS and IM networks). The ENFORS has been built to observe ecosystem change throughout Europe. Looking at the specific history of the network, the sites included mostly represent existing research plots, thus very specific project-based sampling and analytical schemes. Comparability of results is thus very limited. The roots of the IM go back to the CLRTAP, similar to the ICP Forests. It has formed the basis for selecting Level II sites in many cases. Even the measurement programme of Level II resembles that of IM subplots in many ways.

The 12 verification sites of the CarboEurope IP form a good basis to support the inventory approach from a large research network. Because stocks changes of the soil C pool have been studied together with flux measurements, the sites are very interesting to enter a validation and verification scheme of soil C change from inventories.

At this point the EU/ICP Forests Level II provides data on environmental stress factors, such as atmospheric deposition, air quality and soil chemistry. This includes the distribution carbon concentration and stocks, dissolved soil organic carbon and nitrogen and - if the BioSoil results and future activities under Live+/FutMon project are included – change assessments. However, continuous CO_2 flux measurements are only available on CarboEurope sites. Fluxes of the other greenhouse gases CH_4 and N_2O (important for GHG reporting) are included in the NitroEurope. Compared to the Level I and II monitoring networks, the ecosystem sites of the CarboEurope (Figure 3-5) and the NitroEurope can be considered process-based networks with the aim of full element cycling, model development and application, calibration and validation. A large-scale monitoring network such as Level I is important for the extrapolation of the results (see also Fischer ed. 2008). In fact several approaches to upscale to Europe have already been done that way. On the other hand, the data of forest ecosystem sites are needed to validate change assessments from coarse-scale inventory data (such as Level I).

3.4. *Potential contributions from current monitoring schemes under Forest Focus*

Forest Focus is a scheme for long term monitoring of European forest ecosystems established by EC regulation No.2152/2003. It started on 1.1.2003 and will run until 31.12.2006. The proposed scheme focuses on implementing monitoring and protection activities in the fields of atmospheric pollution, fires, biodiversity, climate change, carbon sequestration, soils and protective functions of forests. In the framework of the Forest Focus regulation, several demonstration projects have been initiated to study the appropriate methods to measure e.g. biodiversity, carbon stock and soil parameters in forests[21]. The two most prominent ones are **ForestBIOTA** (Forest Biodiversity Test Phase Assessments) and **BioSoil**.

Working tasks

- Elaboration on the differences between the initial Level I soil and BioSoil, including the role of the optional parameters
- Elaboration on the improvements of the parameters needed (e.g. dead wood, soil physical parameters) for both Level I and II; evaluation of relevant carbon-related research under the national programmes of Forest Focus
- Development of a scheme to improve the connectivity of the Forest Focus project data (e.g. soils) with NFI data (→ see also Chapter 11)
- concept development to improve carbon sequestration assessment including trend assessments

3.4.1. Forest Focus Demonstration Project ForestBIOTA

ForestBIOTA is joint action of 14 countries (number of plots included in the project is given in parenthesis), which was launched in 2003: Czech Republic (3), Denmark (4), Finland (8), France (15), Germany (18), Greece (4), Italy (12), Netherlands (6), Russia (13), Spain (12), Slovak R. (7), Slovenia (2), Switzerland (16) and Ukraine (3). The project started in summer 2005, and includes a total of 97 Level II sites. The objectives of the project are presented in Table 3-8. The main thematic areas are:

- ground vegetation
- epiphytic lichen
- dead wood
- stand structure
- forest type classification

(see also www.forestbiota.org). With regard to the MASCAREF project, the main focus of the parameter analysis will be given to dead wood and forest stand structure.

Table 3-8 The ForestBIOTA project

ForestBIOTA (www.forestbiota.org)	**Benefits with regard to carbon sequestration**
The project pursues the following objectives: 1) development and testing of additional assessments such as dead wood that can be applied in monitoring programmes 2) correlative studies of key factors of forest biodiversity based on existing monitoring (Level II) plots 3) recommendations for biodiversity indicators that could be applied in national forest inventories (collaboration with ENFIN).	availability of testing data to quantify: - the typical amount of dead wood in various forest and disturbance types (depending on the representativity of the sample plots) - effects of mixed age class / forests - coverage and density of forest understory including tree regeneration and saplings in forests with multi-layered canopies

[21] The Level I network was originally designed to monitor air pollution effects.

Dead wood survey scheme

Dead wood is assessed at 91 Level II plots (stand structure at 89 plots). A first working report with results about dead wood has been made by Travaglini and Chirici (2006). The survey scheme is built as follows. Dead wood compartments are assessed (a) for the whole of a squared survey unit (50 m length), and (b) for each of the 4 circular subplots (r=7m).

<u>Measurements/subpools for (a):</u>

- **standing dead trees:** snags (in contrast to stumps) ≥ 1.3 m height; dbh (or half-hight diameter if total length < 4m) ≥ 5 cm
- **downed trees:** dbh ≥ 5 cm; the thick end must be inside the square

<u>Measurements/subpool for (b):</u>

- **stumps:** ≥ 10 cm surface diameter of the cut, or broken top; ≥ 50 % of the stump lies within the subplot
- **lying downed pieces:** diameter at the thick end ≥ 5 cm; the thick end must be inside the subplot

In addition to the measurements listed above, the decay class according to Hunter (1999) is used. For each plot, the forest type has been assessed (see web page).

Volume tables are used to estimate hectare values. The mentioned study has compared the total volume of the "subpools" according to forest types. In addition, coarse and fine woody necromass was distinguished (> 10 cm and ≤ 10 cm, respectively). Decompositional stages were not yet included.

The study concludes that

- The total dead wood volume is not significantly different among the forest types
- The distribution among coarse and fine woody necromass and among necromass components (except snags) is highly dependent on forest types

With regard to the feasibility of this approach in GHG reporting, or adoption into existing monitoring schemes or integrated evaluations, the following conclusions can be made:

- no alternative sampling scheme was tested; the upscaling method (from plot to hectare volumes) remains unclear
- it seems that forest type-specific defaults for Tier 2 assessments are possible (already on this data basis)
- due to lack of data, the influence of forest management is limited to the forest type classification; it would be necessary to include developmental stages, thinning and disturbance regimes, as well as additional site factors (within forest types), before defaults can be derived
- the study excludes the fine woody debris (dead wood pieces < 5 cm at the thick end of branches and other "coarse" necromass entering the litter pool).

3.4.2. Forest Focus Demonstration Project BioSoil

Objectives and organization of the BioSoil demonstration project

The BioSoil Demonstration Study has two components:

1. **Soil** (Level I and II)

2. **Biodiversity** (Level I)

Ad 1. The detailed objectives of the soil component are related to the feasibility of soil monitoring in Europe:

- (statistical) detection of changes in selected soil parameters
- applicability of the adopted manual for harmonized soil sampling at EU scale
- reproducible methods, and comparable results
- possibility to derive a common European baseline of forest soils for environmental applications

Some additional aspects will look at the spatial variability and temporal changes of forest soils, QA/QC procedures, applicability to European information systems (forest, soil), and the use of a standard international soil nomenclature to facilitate harmonized soil data sets.

Ad 2. The "Biodiversity" component is the first standardised Pan-European assessment of forest biodiversity, with 21 countries participating. The project is accompanied by additional 10 national projects on forest and soil biodiversity. It has the following objectives:

- to establish a common European database of forest biodiversity for environmental applications
- to evaluate the applicability of the proposed methodologies
- to quantify spatial variability on the basis of information available
- to finalise a common European methodology for forest biodiversity monitoring
- to assess structural forest diversity based on measurements of dbh, coarse woody debris, standing and lying dead trees and snags, stumps, canopy closure and layering

Additional aspects cover the development of a forest type classification and compositional forest diversity focuses on woody species composition.

Figure 3-9 gives an overview of the BioSoil "soil" objectives. The methodology is described in Bastrup-Birk et al. (2006). In contrast to the ForestBIOTA project, this component concentrates on Level I. Dead wood is assessed with a threshold diameter of > 10 cm. The assessment of dead pieces 5-10 cm diameter is optional. The stage of decomposition is described according to Hunter (1990).

Table 3-9 The BioSoil project

BioSoil (http://ibw.inbo.be/fscc/)	**Benefits with regard to carbon sequestration**
The project pursues the following objectives: 1) testing and implementation of a repeated Level I inventory 2) testing and implementation of soil profile description and classification according to World Soil Reference Base (WRB) 3) testing and implementation of new methodological aspects (e.g. revised manual, extension of mandatory parameters)	- developing default values of soil organic matter stored for various forest and disturbance types - improved spatial accuracy of plot locations (important for applying spatial statistics) - improved quantification of carbon stocks on the basis of measured soil physical parameters such as bulk density - improved uncertainty analysis

The BioSoil project will demonstrate the feasibility of systematic forest soil monitoring at European scale by conducting a second survey on ca. 4,700 Level I plots (and some Level II) plots. So far the ICP-Forests (Level I) soil condition monitoring consisted of only one assessment, and was thus lacking consecutive or repeated sampling. BioSoil has started in 2005 as a three-year project. With regard to the initial inventory 1990-95, various improvements of the manual, and the quality of the field and laboratory work were introduced. The inventory is coordinated by FSCC and JRC, and accompanied by the development of a database and the activity of a central laboratory (to analyse the benchmark sites[22]). The data are expected to become available by the end of 2009 at the earliest.

A BioSoil expert group was established in Dec. 2004. Because JRC is responsible for the management and coordination of the scientific and technical aspects of the Forest Focus regulation 2152/2003, it hosts the so-called Scientific Coordination Body of Forest Focus. The BioSoil expert group is thought to support JRC.

In preparation of a repeated assessment of Level I (and Level II), the 'Submanual on Sampling and Analysis of Soil' was revised during the 11th FSEP, and was adopted during the ICP Forests Task Force in 2003. In the discussion during the 11th FSEP, it was emphasized that some aspects still need improvement, such as the sampling of the F and H layers which must be better explained. It was then agreed, that a pilot test of the practicability of the manual should be conducted. The results are presented by Cools (2005).

The changes proposed for the manual are important for improving the assessment of C sequestration in soils. However, there are still limitations: the connectivity to NFI / biomass / increment information, and the consistency of BioSoil Level I to the initial inventory. Systematic errors may substatially reduce the capacity of BioSoil to assess soil C changes.

Table 3-10 Participation in BioSoil"soil"

country	Level I	Level II
Austria	139	
Belgium	10	2 (Flanders)
Cyprus	15	2
Croatia	does not participate	
Czech rep.	146	8
Denmark	25	3/8
Estonia	96	
Finland	636	31
Germany	413	21
Greece [23]	0	4
Ireland	35/37	3
Italy	238	8
Latvia	95	
Lithuania	62	2
Poland	530	6
Portugal	113	
Slovakia	112	7
Slovenia	44	
Spain	620	
Sweden	780	
Turkey	ca. 800	40-50
UK	167	
Total (without Turkey)	4,276	97

[22] Benchmark site in the BioSoil project: sites in the BioSoil inventory, where also the stored samples from existing archives are being re-analysed by the same lab, which also analyses the new BioSoil samples (see also Cools and Mikkelsen 2007).

[23] The issue of Level I in Greece is included in the MASCAREF study cases.

Improvements of the EU/ICP Forests Level I sampling methodology

In this chapter, the improvements of the soil sampling methodology in the Level I and Level II observation networks for observing carbon sequestration (FSCC and FSEP 2006) are presented and analyzed. These methodical changes need to be known in order to evaluate the results for detecting soil carbon changes (by comparing the Level I 1990-1995 with the BioSoil results). While soil carbon stocks could be estimated more accurately by applying the revised manual, additional systematic errors may be introduced from changes in sampling and analysis.

The following analysis contains results from an in-depth review of the different versions of the Manual on Soil Sampling and Analysis (FSCC and FSEP 2006), but also references to the results received from the testing of the 2003 update (Cools 2005). With these improvements, the evaluations for soil carbon are expected to be substantially improved.

A) Sampling

Location of sample plots

- Both on Level I and II there should be at least 5 m interdistance between two subsample locations (12th FSEP meeting).
- The location of the profile pit should be representative for the dominant soil type in the plot area but is not necessarily located within the plot area. If the profile pit has already been described before but essential information is lacking, the pit has to be reassessed, preferably at exactly the same location. In case all the information is available from the previous survey, the existing data should be reported using the new reporting forms.

O layer sampling

- With regard to the sampling of the forest floor, Cools (2005) propose to combine the sampling of the F and H horizons can be sampled together, but the thickness of the F and H is to be reported separately. Sampling of the L horizons remains optional.

Stony soils

Level I: It is recommended to make 5 pits (recommended till 80 cm; min. depth 20 cm) if not limited by a lithic or paralithic contact.

It can be concluded from a preparatory study in Germany, that there is generally no optimal approach for taking undisturbed samples in stony soils. A relatively good correlation was found between the bulk density determined using a root auger and the 250 cm^3 bulk density sampler. The conclusion was that a combined algorithm gives the best estimation of the fine earth fraction:

- undisturbed samples (100 cm^3) with stones of size 2-20 mm
- disturbed samples (2-5 kg) for stones 20 mm up to 63 mm
- estimation at the profile itself, on stones larger than 63 mm

B) Peat

The sampling design of peat lands as proposed by FSCC was accepted. This design is based on the WRB definition of Histosols (= peat soils) which requires an H horizon > 40 cm thickness. As long as the peat layer is less than 40 cm the existing sampling design for mineral forest soils shall be applied (separate sampling of the organic layers and mineral soil according to the fixed depth layers). From the moment the peat is > 40 cm, the peat layer shall be sampled according to the peat land sampling design. This means that the peat layer is sampled at fixed depths, mandatory 0 – 10 and 10 – 20 cm and optionally at 20 – 40 and 40 – 80 cm. In the reporting forms a new name for the peat layers shall be used, namely H01, H12, H24 and H48 in the records for the organic layer. If the conditions allow for it (lower water table), the mineral soil below the peat soil (> 40 cm) can be further sampled according to the standard depths (M01, M12, M24, M48; see also UN-ECE ICP Forests 2006). If there is a litter layer on top of the peat, it should be counted with minus values.

C) Parent material

In the BioSoil project, the nomenclature for parent material acc. to FAO is proposed (FAO 2006; which has used the SOTER manual as a basis). The ICP Forests manual proposes the coding system of the Soil Geographical Database for Eurasia & The Mediterranean (Lambert et al. 2003).

Without this modification, the parent material of the ICP Forests differs from that in the European soil data base. Combined evaluation is currently only possible on the level of parent material groups (Wiedemann et al. 2001).

D) Determination of Bulk Density

5 core samples have to be taken, but they can be bulked and 1 average value can be reported. If pedotransfer functions (PTFs) are used, they have to be regionally calibrated and reported to FSCC. Based on the discussion during the 11th FSEP, the PTF of Adams (1973) is proposed for bulk density.

E) Sample preparation/methods

Pre-treatment of Samples

Different treatments of the samples affect the analysis. In the 2003 version of the soil submanual, some issues regarding drying temperature, sieving, grinding and milling still remain to be clarified and investigated (Cools 2005). Fact is that quite a variety of different approaches were taken in the Level I survey (Baritz et al. 2009).

Cools (2005) suggests the following solutions:

Sieving for heavy textured soils should be done when moist (ISO 11464).

Milling: The ICP Forests sub-manual part IIIa does not mention for which analyses milling is required. The ISO 11464 (1994) however mentions that this is the case for the analyses on sample material less than 2 g. In that case, milling to < 250 micrometer is required [see ISO 11464 (1994)]. Therefore a second sieving/milling is necessary for N analysis, CEC and total elements.

Mineral soils: the sample material needs to be sieved to 2 mm, then milled for TOC and TON; Organic samples only consist of the < 2 cm fraction. The sample is dried and further milled to < 2 mm. Samples should be well-homogenised prior to analysis. Note that the manual does not provide instructions concerning the preparation of the organic samples. The general rule for the preparation of humus rich samples (such as ecto-organic material of the forest floor) is that living material is removed, and the samples must be milled on a 2mm sieve. For the mineral soil, damp sieving should be added to the manual (12th expert panel).

Soil Moisture Content

The organic samples will be dried by 105°C. For peat samples the sample should be dried for 24 hours.

Particle Size Distribution

The Pipette method is the only reference method.

It is recommended to include the description of the finger test into the manual and/or in the field guidelines of the BioSoil project. The report form should take into account the two methods for assessing soil texture. Note also that only the clay content is mandatory at Level I (not the silt or sand content). This can be estimated by the finger test as well. However, since BioSoil asks for mandatory and optional parameters, the soil texture should be analysed.

Coarse Fragments

In stony soils, the rod penetration can be used for the size class > 2 cm and for the 0-30 cm layer only. From the testing of the revised manual, Cools (2005) found restrictions of the method for soil samples that were clayey in nature.

After drying, cloths could be very hard. According to the manual, cloths need to be manually crushed in the mortar before sieving. In the Flemish laboratory, such samples are usually milled directly. The determination of the coarse fragments is then based on the undisturbed samples with an exact volume of 100 cm^3. After drying, the weight of the mineral fragments > 2 mm is determined. The “Finish method” or the “Rod Penetration Method” has been added to the previous update of the manual but the description of the method was not detailed enough. The equation was only valid for a limited set of soils and should be validated and calibrated before using it on other soil types. The final version of the manual should include the combination of different methods to measure the BD and the coarse fragments in stony soils.

F) Lab calibration, QA/QC:

4th FSCC Inter-laboratory Comparison 2005-2006

Seven laboratories were found to report outliers and stragglers for more than 20 % of the analyses, based on the between-laboratory variability, and six laboratories based on the within-laboratory variability. Problem parameters are (1) the heavy metals and S extracted by Aqua Regia, (2) the exchangeable elements, (3) carbon content in samples with low organic carbon content and (4) the calcium carbonate determinations. Three years after the 3rd FSCC Inter-laboratory Comparison 2002-2003, more laboratories use the reference methods, have more experience with the reference methods, make more use of reference material and control charts

5th Interlaboratory Comparison 2007:

From 48 labs, nine laboratories were found to report outliers and stragglers for more than 20 % of the analyses, 5 based on the between laboratory variability, and 8 laboratories based on the within-laboratory variability (see also above for carbon). Compared to the 4th ring test, the CVs of all groups of analysis have improved or remained at a similar level.

QA/QC:

- Data integrity expert rules are established: 7 labs violated them. The rules will be refined, especially for peat (regarding pH), as an example.
- Tolerance levels (for ring test performance, and also intra-lab (within-run) repeatability) for a lower and higher concentration range will be introduced, considering quantification limits (when applying such limits post ring test to the labs, 75 % would meet these limits). For many soil properties, these limits would be still too broad (unpublished tolerance limits, developed by FSCC for ISO evaluation).
- FSCC reference samples are used.

G) Modifications of the methodology: national levels - *Example Sweden*

In Sweden the 770 Level I plots will be divided into core plots, which are the benchmark plots, and other plots. The core plots are studied more in detail, which will make up around 70-100 plots or 10-15% of the total amount. Some new plots have been defined. Where old plots are located in clear cut zones, new plots areas are allocated. The country will be studied with different intensity of plots, 16x16 km2, 16x 32 km2 and 32x32 km2, with the most intensive grid in the southern parts, and the least intensive grid in the northern part of Sweden (Lapland).

In the Swedish survey the depth 55-65 cm is sampled. Sweden intends to use this sample for the 40-80 cm sampling depth. The texture is assessed by the finger test method. With regard to WRB, 8 Reference Soil Groups are identified in the field; the qualifiers are added later.

3.4.3. Inventory-based trend assessment

Inventory stratification

Integrated evaluation assessments and pilot studies as to optimize trend assessment have stressed the importance of inventory stratification (especially Riek 1999; see also Wirth et al. 2004, Baritz et al. 2006d, Mellert et al. 2007). The bibliography for this report contains a list of integrated inventory studies using Level I data. The main stratification criteria for Level I developed by Riek (1999) are:

- sensitivity classes (sensitivity to pollutant input)
- humus forms
- soil chemical buffer zones acc. to Ulrich (1987).

For the development of a European baseline forest soil carbon map based on the Level I network, Baritz et al. (2009) have applied the concept of climate groups taken from the European soil regions map (BGR 2005). The map integrates aspects of biogeographic regions and natural vegetation zones in Europe thus may be quite suitable to stratify the Level I inventory.

Humus types

The humus form integrates the relationship between soil, vegetation and climate, and thus is crucial for stratifying storage of SOC in the forest floor (O and H horizons[24]) (see also Wolf and Riek 1998; Baritz et al 1999, Baritz 2003).

Humus form is already contained in the Forest Soil Condition Database. However, only the three main humus forms Mull, Moder and Mor are currently specified. In 2004, the FSEP decided to contact the European Humus Research Group in order to evaluate the possibility of refining the humus form.

According to the FSEP 2006 (13th panel), the humus classification of the European Humus Research Group (Englisch et al., 2005) will be adopted (second level of the classification). It distinguishes between Mor, Moder, Mull, Amphi for the terrestrial humus forms, and Anmoor, Peat (Histomor, Histomoder, Histomull, Histoamphi) for the semi-terrestrial humus forms.

Soil classification

In the Forest Soil Condition Database, the soil type is stated acc. to FAO (1990).

It is mandatory to classify the soil profile according to the most recent official version of the World Reference Base for Soil Resources. At the 13th FSEPM that was the version of 1998. At the World Congress of Soil Science in Philadelphia the new WRB version of 2006 has been introduced. After its publication, this will become the most recent official version. In the DAR-Q the applied version of WRB should be given.

- All qualifiers should be reported.
- Note that for soil classification only, the 0 cm line is at the contact between air and "soil".

WRB 1998 (and certainly the 2006 release) substantially refines the taxonomic description of the Level I soils. The ongoing evaluations for the European forest soil C baseline demonstrate that depending on the region, the soil type represents the effects of parent material, and acts as a predictor for soil C (Baritz et al. 2009). Therefore, the improved accuracy of the soil type will also improve the stratification and evaluation of the Level I data base (for example to derive default values for soil C).

Error types

It is well-known that the role of systematic errors in large inventories such as Level I and Level II is significant (Baritz et al. 2006c, 2006d). Therefore the FSEP, for example, has stressed the importance of quality control in the field. Recommendations for sample storage and integrity rules were developed and training courses were offered.

The following "internal" quality indicators were introduced:

QA in the field and in the lab	data sets collected acc. to the prescribed method (methods acc. to a fixed coding system will be introduced; DAR-Q, questionannaire = metadata)
QC in the field	– checks at national level – profile descriptions as QC at international level
QC in the lab	– ring tests – control charts

[24] H horizon: wet organic, peaty horizon (if H > 40 cm thickness; the soil type is a Histosol); the presence of an H horizon is a typical indicator for a hydromorphic soil (e.g. Gleysol);

O horizons (OL, OF, OH) of the forest floor develop under upland soil conditions (the top soil is not influenced by stagnic or gleyic soil water), so that non-hydromorphic and semi-hydromorphic soils develop (see also Ch. 2.2, this report).

There are also several “external” (user-oriented) indicators, such as

- # participants in ring tests,
- # problems solved,
- # countries which received support by the QA/QC working group.

The ring test results will be the crucial output.

With the proposed amendments to the ICP Forests submanual, the pool size estimate (SOC, litter) of the BioSoil project will be greatly improved. The soil carbon stocks for the initial Level I (1990-1995) can be re-calculated using the original C concentrations together with the measured bulk densities from the BioSoil project. However, due to some of the methodical changes, systematic deviations may be introduced. This needs to be carefully examined by each country. At this point, there is no strategy how this error can be quantified or even corrected at the European scale, or with what kind of evaluation strategy can this be neutralized.

Trend Assessment

Mellert et al. (2007) have conducted a preliminary assessment of the trend which can be expected for the German forest condition monitoring – based on existing literature available from forest ecosystem research and other assessments. They have concentrated on important Level I indicators for the state of soil aciditiy (pH), nitrogen stocks, exchangable bases, base saturation and soil carbon.

The main study inside the ICP Forests, which has looked at trend assessment, has been De Vries et al. (2000). The study focused on Level II, and has concentrated on detecting changes at the plot level rather than for a population (between-stratum). For the detection of change between-strata, the t-test for unpaired samples was used ($\alpha = 0.05$) – unpaired because the threshold for comparisons is higher. According to Mellert et al. (2007), plot-level comparisons for Level I are statistically not meaningful.

Mellert et al. (2007) also calculated the critical number of samples needed to statistically verify changes (within-stratum) based on the relationship between the change rate (% difference from the mean) and the variability (coefficient of variability). The minimum number of samples (Level I plots) for statistical comparisons between-strata is 9.

For the evaluations of the BioSoil database, some frame conditions have to be considered:

- Within-strata sample size can change between Level I (1990-1995) and BioSoil.
- Standard deviation can change (particularly for the O horizons of the forest floor).
- Comparison of means requires *homogeneous* variance which means that the local variability corresponds to the variability of the stratum. For Level I, the role of local variability cannot be assessed, the variability of the mean of a stratum is known; the relationship between both kinds of variability is unknown. *Homogenous* variance (of the resp. strata) can be generated via cluster analysis.

Mellert et al. (2007) provide an extensive literature review of studies which have monitored the above-mentioned indicators over various time intervals, e.g. Billet et al. (1990) for pH. Regarding soil C, they conclude that for some strata, and given that a time interval of ca. 20 years lies between the initial Level I and BioSoil, change can be detected for some strata. SOC sequestration will be highest for forest which can incorporate lots of N, and which perform accelerated growth. Increased litter production is thought to be the main driver for this.

3.4.4. Conclusions

Current work consisted in a closer look at the monitoring developments under ForestBiota (Level II) and BioSoil (Level I and II). With regard to the context covered in the MASCAREF project, the ForestBiota project will provide data about different dead wood sub-pools for typical forest types in Europe. The main achievement of the BioSoil project is the repetition of the Level I initial sampling. The manual on sampling and analysis has been improved beforehand. A test has shown that there are still some issues to be covered. It can be concluded that under BioSoil, comparability between the countries will be improved.

In order to detect changes from repeated sampling, the following aspects need to be considered:

- Stratification of the data base (for example climatic or biogeographic regions, combined with soil type or parent material group, and humus form)

For Level I, test of local variability for selected sites in each country (for a stratum): can a trend to over- or underestimate from the locahl sampling design be excluded (for example, if the type of analysis has changed, or if samples are treated differently)?

- Investigation of the effects of methodical changes between the sampling designs of the initial Level I and BioSoil. If possible, both systems need to be compared in a side study, and a correction factor developed and applied.

3.5. *Potential contributions under Forest Focus including cost estimates*

Working tasks:

- Integration of the outcomes under related to GHG reporting including validation, uncertainties and trend assessment
- Cost estimates

3.5.1. Review of the current discussion regarding integrated inventory concepts

COST Strategic Workshop 2008

From 11-13 March 2008, a strategic workshop was held in Istanbul, Turkey on "Forest ecosystems in a changing environment: identifying future monitoring and research needs". It assembled around 170 experts from 30 countries. The results are available under Fischer (ed.) (2008).

The discussion has focussed on a much broader scheme as dealt with in the area of greenhouse gas reporting. The fields to be covered by ecosystem research are: climate change, Ozone, pollutant deposition and biodiversity.

Interestingly, the monitoring activities analysed and presented in MASCAREF referring to ICP Forests and the continued EC monitoring programmes (Forest Focus, Life+) are also the core observation sites in the forest ecosystem research and observation programmes discussed on that workshop. Specifically, Level I and Level II (plus core sites) as well as NFI are the fundamental pillars in the so-called "multi-functional" monitoring.

It is believed that forests in Europe currently mitigate around 10 % of the total CO_2 emissions (Nabuurs et al. 2003). There are clear indications that soil currently plays an increasing role in acting as a sink for carbon. Carbon in the forest floor shows a similar trend, but less pronounced. Elevated CO_2 concentrations and N deposition may be closely involved as the main facilitators for that trend.

One of the important conclusions in the areas relevant for the range of issues covered here:

- "Linkages between the existing research and monitoring networks on the C and N cycles need to be established or strengthened".
- Both the above-ground as well as the below-ground processes need to be observed and investigated.

- "Models for carbon storage and reactions of forests to climate change need to be better calibrated to existing monitoring data".
- EU/ICP Forests Level I and II need to be linked with upscaling models to the EU scale, future management and climate scenarios.
- Particularly, "the assessment of carbon storage in forest soils is still a challenge and good estimation models are needed".
- There should be more overlap between process-based networks and their flux sites with the intensive monitoring plots.

In conclusion, the integration of NFI, Level I and II, including ecosystem research/monitoring sites (for example flux research networks) is needed in order to meet future monitoring needs, cause-and-effect research, and modelling.

National integrative concepts

Various studies under the Forest Focus national programmes have focused on integrated evaluation concepts. For example, regarding forest health monitoring, the development of critical loads (for S and N) is considered a key concept to study predict the effects of pollutant deposition on soils.

Under the EU Forest Focus regulation, various pilot projects have been launched which include studies about the sink/source behavior of various storage pools in forests (see also Table 3-11; a list of other national research projects see http://afoludata.jrc.ec.europa.eu/index.php/public_area/home). Freer-Smith et al. (2006) have conducted a detailed review of the Forest Focus regulation, and have provided an overview of national studies conducted in the context of soil carbon. Nevertheless, a systematic evaluation of the projects with the aim to extract important results to improve the existing monitoring and evaluation activities is still missing. For example, the Forest Focus pilot project: 'Monitoring changes in the carbon stocks of forest soils' includes tests of selected models: Yasso, RothC, ROMUL, Century, Forest-DNDC, SOILN) (www.metla.fi/hanke/843002) (Peltoniemi et al. 2007).

Table 3-11 Forest Focus pilot projects related to climate change questions (source: Freer-Smith et al. 2006)

country	project
DK	Litterfall monitoring
AT	SoilbioParams – effects on soil storage
EL	Effects of forest fires on carbon sequestration
FI	Monitoring changes in carbon stocks
FI	The role of understory and litterfall in carbon and nitrogen fluxes
IT	Biorefugia – response of tree species to climate change
IT	Carbon flux
D-BY	Soil respiration
D-BW	Carbon stocks – soil
D-BB	Simulation model carbon balance
D-BB	Regionalisation of soil change due to a lowering of the water table
D-BB	Fine root inventory on soil profile pit
D-NW	Carbon stocks monitoring
D-HE	Humus dynamic
D-HE	Litterfall and carbon cycles
D-HE	Carbon stocks – soil
D-NI	Carbon stocks – soil
D-NI	Carbon flux
NL	Predict changes in forest growth and carbon stocks

A prominent national example for integrated inventory-based research is the approach taken in Finland, where research has focused on the improvement of biomass estimation and uncertainties, and on gap filling for assessing C storage pools such as litter and soil. Forest stand and soil inventories were combined with the model YASSO, which largely depends on the input dynamics of litter into the decomposition system.

Accurate estimates of litter production and root turnover are of utmost importance in order to adequately model the carbon dynamics of the soil. Data for the dominant site factors as the driving forces for the C and N cycle need to be available, for example: factors affecting fine root turnover are root structure, root C/N relations, climate (frost, soil temperature, drought), and soil biology.

The following list presents some important research questions, which need further focus (sources: (1) COST 639 Memorandum of Understanding; (2) research seminar on "Carbon budget of Finnish forests 1920 – 2000", Helsinki, 2004):

- evaluation and testing of models which focus on the terrestrial carbon balance
- carbon fluxes:
  - comparison of model-based estimates with stand-scale measurements
  - development of forest carbon budgets: inventory and repeated assessment of pools compared to and verified against modelled data and flux measurements

improved biomass assessment is needed for:
  - element budgets of forest ecosystems
  - studies on nutrient cycling
  - NPP of forest ecosystems
  - biomass equations developed through bioenergy studies

- disaggregation of BEFs (age, site class, understory), biomass functions, uncertainty
- prediction of changes and amount of soil carbon; compare model based estimates with the measured soil carbon stock and stock change according to stand age (one of the limitations is the lack of data, e.g. for litter, but also roots

EU research (incl. Life +)

Future monitoring

EU-level forest monitoring should be maintained in the future in order to provide harmonized and reliable information about status of forests. After the ending of the Forest Focus regulation, funding is needed to continue the monitoring and coordination activities of Level I and II. During the period 2007-2013 the EU Life+ programme has included forest monitoring (Life+ is the Financial Instrument for the Environment).

The objectives for extending forest health monitoring under Life+ are to support:

- Global Forest Resource Assessment 2010
- UNFCCC, Kyoto protocol
- UNCBD
- MCPFE (Pan-European Criteria and Indicators for Sustainable Forest Management: lists over 30 parameters for monitoring biodiversity, forest health, carbon cycle etc. in forests)
- EU level programmes (e.g. Natura 2000, Water framework directive, EU soil strategy)

The follow-up EU-level Forest Monitoring System under the LIFE+ regulation is called the FutMon project. One of the highly relevant developments regarding monitoring is the establishment of joint NFI/Level I networks "FutMon large-scale plots". Intensive monitoring will be continued on 337 "basic plots", and "core plots" which are still to be elected.

It is foreseen to further extend the monitoring to

- element fluxes and nutrient cycling

- critical loads and levels
- water budgets and response to drought
- nutrient uptake and growth

The FutMon project has just started. Unfortunately, not all countries participate with the same intensity and coverage as under the ICP Forests. For example, Greece only participates with its Level II plots.

European research projects

(outside ICP Forests and Forest Focus, and besides forest ecosystem research covered on Ch. 5)

There is also a wide variety of European research projects which have used Level I and/or Level II data (CANIF, CNTER, NITREX, etc.). Some projects were already mentioned; some results, such as those from the RECOGNITION project, were made available through ICP Forests Technical Reports (e.g. 2004). With regard to carbon stored in forest vegetation and forest soils, the CarboInvent project has been mentioned (see Literature: Studies of the CarboInvent project related to organic carbon in forest soils). Some other projects were referred to earlier subchapter Forest Ecosystem Research, or can be viewed under http://afoludata.jrc.ec.europa.eu/index.php/public_area/home (especially national projects).

In the ATEAM[25] project, soil mapping and soil condition/monitoring data were applied in integrated soil-land use-climate-socio-economic modelling. The main aim was to assess the vulnerability of human sectors relying on ecosystem services with respect to global change. For example, the model projections tend towards a decline of the terrestrial carbon sink in Europe. A significant decrease in soil carbon was found in all scenarios. Another project with an integrated forest-agricultural soil biophysical as well as biomass component, linked with economic models, is the FP6 project INSEA (Integrated Sink Enhancement Assessment). These mentioned projects and others have suffered from the lack of statistical as well as geospatial data on forest resource assessments and forest management. Soil and forest inventory data must be better made available to applications in soil biophysical modeling (e.g. EPIC, DNDC, Roth-C, all models with multiple pools of soil and litter) as well as biogeochemical modeling (e.g. BiomeBGC; only with a litter pool and one SOM pool). Successful research on the effects of climate change on forests and the society cannot be imagined without such integrated inventory-modeling exercises.

3.5.2. Extended integrated monitoring concept

As an example, a conceptual proposal to integrate different monitoring intensity levels was drafted in the CarboInvent project (Figure 7, Baritz et al. 2006b). Similar approaches are also pointed out in the results of the COST strategic workshop on future monitoring and research needs (Fischer, ed. 2008). The results from the CarboInvent project can be obtained from the report for deliverable D.3.3 "Methodology to link forest ecosystem research with regional soil C inventories" → http://www.joanneum.at/carboinvent/soils.php).

The proposed system was drafted in the context of the preparations of the European soil thematic strategy, which requires such monitoring activities for all land uses. The main principle presented in Figure 3-7 is that high intensity measurement systems such as Level II is integrated/upscaled into the broader Level I. The latter is assumed to be sufficiently represented to allow regional assessments using existing map data such as for soils, but also RS data (remote sensing) on land cover/management, and also climate data. With respect to a monitoring approach based on different measurement intensity levels, see also De Vries et al. (2003).

Some first more detailed proposals of how to integrate Level I and II already exist, for example Schall and Seidling (2004). The main objective of their work was to upscale data on sulfur and lead

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[25] "Advanced Terrestrial Ecosystem Analysis and Modelling" (ATEAM, 2001-2004) (project N° EVK2-2000-00075)

in the organic layer, as well as nitrogen and sulfur in the soil solution. Another aspect of interest was relationships between foliar nitrogen and site and forest stand factors.

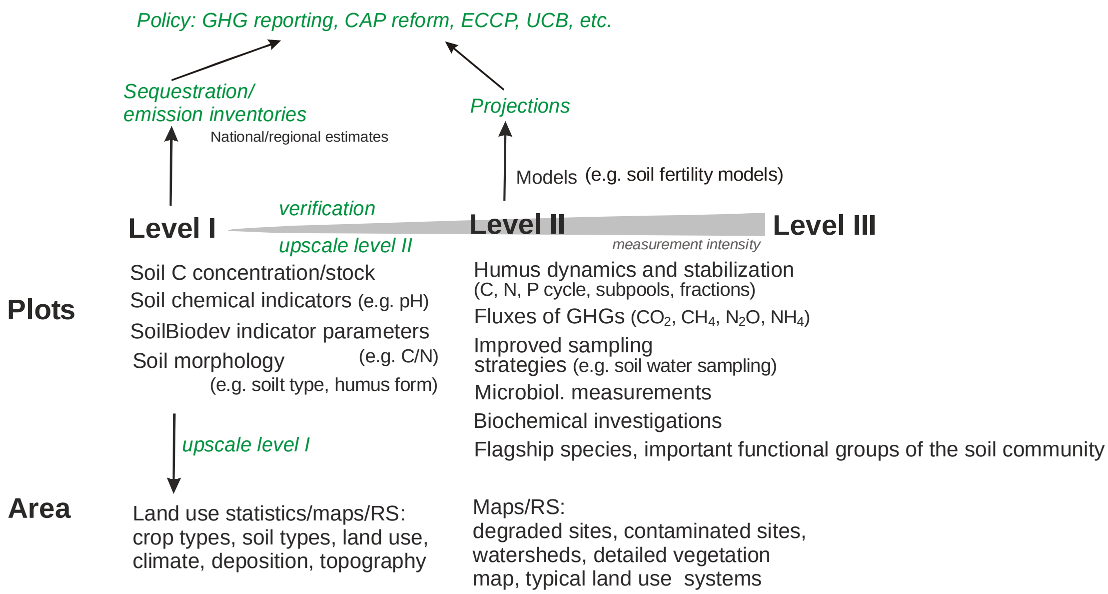


Figure 3-7 Measurements intensities in monitoring SOM (Baritz et al. 2004)

As for the needed Europe-wide integrated evaluations, JRC has also presented specific ideas and needs which are connected to its internal project and external cooperation activities (Bastrup-Birk (presentation during the ICP Forests Task Force Meeting, Tallin 2006):

- suitability map of European tree species: methods and results
- future climate scenarios
- development of a European biomass map
- development of forest growth model

In order to reach the set objectives (see also above), Bastrup-Birk (2006) has also given some examples for a possible work programme:

Example 1: Forest biomass estimation integrating Level I and II data

1. Calculation of forest biomass for Level II sites for the main European species using BEF (Biomass Expansion Functions).
2. Matching Level I and Level II plots with similar attributes to assign a biomass value to Level I plots (forest type, soil type, humus type, water availability, altitude, orientation, precipitation, radiation, temperature).

Example 2: Use of the model 3PG (simple process-based, stand-level model of forest growth; Landsberg and Waring 1997) to predict net primary production, and then to estimate stem, root and foliage biomass.

3.5.3. European forest soil (C) monitoring and the GHG inventory

The process-based reporting approach requires the repeated sampling of a soil inventory. Alternatively, a standard change rate can be derived from the two inventory (e.g. if only an insufficient amount of plots is available, of if the sampling dates do not correspond with the reporting schedule.

The data from the Level I and BioSoil inventories will be used by a large number of countries to demonstrate whether the soil C pool is growing or shrinking during the commitment period.

The Level I inventory has concentrated mainly on soil carbon, while the litter pool is omitted from the sampling. Only in a few countries, the L horizon is sample, which however only represents a small fraction of the whole litter layer (the larger one is fine woody debris).

Improvements needed to use Level I for soil C change estimates

It has been presented before that the Level I inventory suffers from a high level of systematic errors. In addition, some basic attributes important to soil carbon monitoring were missing in the available data. Therefore, the ICP Forests manual on soil sampling and analysis (Part IIIa) had been extended in 2006 (FSEP and FSCC 2006).

Table 3-12 presents the main limitations from the initial Level I inventory (1990-1995). From these limitations it can be concluded that very careful analysis of the soil carbon changes need to be done upon availability of the BioSoil data. The analysis of the Level I plots under MASCASREF has revealed that a filtering of the sites according to the quality and completeness of the observations is necessary. A similar exercise has been done by Wiedemann et al. (2001) and by Scheldemann (2002).

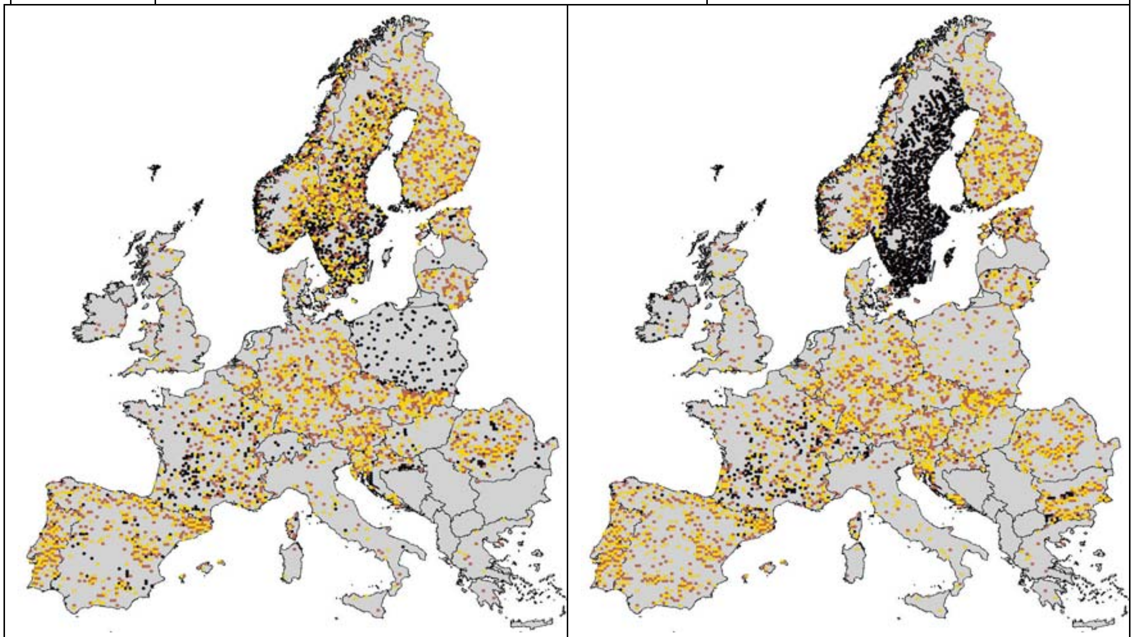
Figure 3-8 presents the results of several filtering exercises with the objective to identify a data set best suitable to predict regional soil carbon values. It was found that despite the limitations of the Level I data base (systematic differences between the countries; see also Baert et al. 1999), some very clear trends of site factors are reflected in the distribution of soil carbon stocks in the O layer as well as in the top soil carbon concentration (0-5/0-10 cm) and soil carbon stock (0-20/30 cm), r^2=0.42 for the O layer, and 0.40 for both mineral soil models.

If the data base would be further filtered (e.g. only plots where both soil and crown condition data are available at least since 1991; filters plots with older data; presumably, these are plots with less accurate coordinates, and mismatches of the tree species composition between soil plots and crown condition plots), the r^2 clearly improves (0.54 for the O layer, 0.44 for the mineral soil). It is assumed that regional models further improve the trends in the data base. These results support the main assumptions behind the Level I programme, that the main site factors at the European scale are reflected in the 16x16 km grid. On that basis it can be expected that – in combination with the BioSoil inventory – regional trends for soil carbon change can be detected.

Table 3-12 Proposed solutions to compensate limitations in the Level I inventory 1990-1995 with regard to the detection of soil carbon changes

Limitations	Description	Role of BioSoil
Wet soils	Unplausible soil type-C stock combinations: Histosols with low C stocks Histosols with C stocks only in the O layer Histosols with only O layer data (including weight of the O layer, no H horizon) Other soils having H horizons (and C stocks as high as Histosols) Other soils having soil C values for O layers (C as before)	Can be partly resolved with the availability of soil profile description: check soil nomenclature reported under BioSoil, and correct use soil profile descriptions: soils need to be clearly assigned either to hydromorphic, or semi-hydromorphic soil types
Data missing in certain depth classes	Unless soil profile descriptions become available, the reasons for missing values for certain depth classes remain unclear.	Shallow soils can be clearly recognized, and remain in the data base (limitation to sampling due to stones, rock or groundwater) Values below the analytical threshold need to be clearly marked. All other incomplete soils must be omitted from the evaluations
Bulk density and stones not reported	If these important soil physical parameters must be (e.g. in the case of bulk density) estimated from pedotransfer rules, a fairly large error is introduced.	Re-calcuate the soil carbon socks 1990-1995 using the soil physical parameters provided through the BioSoil inventory.
Inventory integration	reliably combine the soil grid with data on tree species composition (from the crown condition survey)	Use revised geo-coordinates from the BioSoil inventory, and harmonise with the crown condition survey data
Georeferencin	inaccurate plot coordinates; some deviations from those	

g	reported for the Level I crown condition plots	



Plots where data about the weight of the organic layer and the carbon concentration are available (in order to calculate C stocks for the O layer); Histosols excluded.	Plots where depth classes are complete (0-20 cm) incl. Regosols; Histosols are excluded; the Swedish plots are excluded due to methodical deviations in the mineral soil sampling.

Figure 3-8 Filtering of high-quality plots for soil carbon evaluations

(the black plots were filtered out of the evaluations for regional soil carbon modelling; the plots marked bright brown and dark brown represent two randomly selected sub-populations, one to the calculate regional soil carbon models, the other one to cross-validate the models, thus to estimate the model error)

Experiences from Level I –BioSoil evaluations

With regard to the reporting requirements, countries which have elected KP 3.4 need to demonstrate whether the carbon storage pools are sinks or sources; in case of a source, reporting has to be done with a higher tier, uncertainties to be quantified with country-specific data as well. The Level I and Level II data bases, combined with the BioSoil project, will be used in many case to fulfill that task. At the same time, theses data sets are being used to integrate the reporting approach between the pools, and to develop baseline and validation data for model applications (for those countries which choose to do so).

An example of repeated Level II assessments is provided in the Greek case study of the MASCAREF project. Another example is provided by a Flemish study (Cooles et al. 2008) to test the revised ICP Forests manual (FSEP and FSCC 2006). The first sampling was conducted in 1991-1992 (10 Level I plots) and 1993 (11 Level II plots), the repeated sampling in 2004 (and a third campaign purely for soil classification in 2007). Soil carbon changes were found in positive and negative directions. The authors conclude that the differences in bulk density and organic carbon analysis between the two inventory times probably prevent the elaboration of clear trends – at least with such small number of plots.

In a very recent study by Riek (2009; preliminary BioSoil evaluations for the MASCAREF project), soil carbon stocks were compared for a large number of plots: N=159 plots of the national forest soil condition inventory “BZE” (8x8 km), of that N=53 BioSoil plots (16x16 km). The whole set of BZE plots was initially sampled in 1991/1992, and repeated in 2006 plots. The BioSoil plots were additionally analysed acc. to the BioSoil requirements (Figure 3-9).

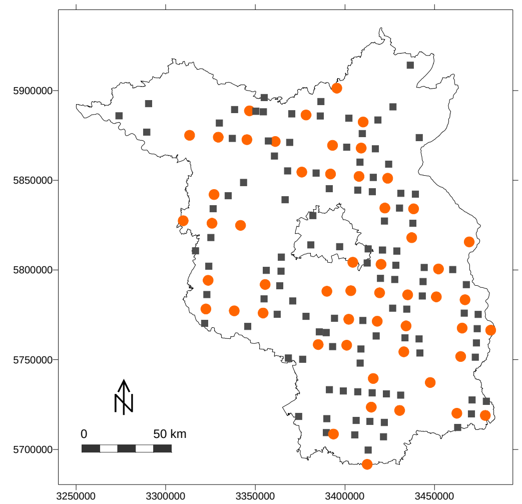


Figure 3-9 Distribution of plots in the Germany federal states of Brandenburg and Berlin (black: German forest soil condition inventory (BZE), red: EU/ICP Forests and BZE)

Prior to the evaluation, the plot data were very carefully checked for systematic errors (results not presented here):

- Comparative analysis comparing wet oxidation (initial inventory) and dry combustion (repeated assessment)
- Study on local within-site and within-pedon variability to check the sampling design
- Test for different approaches to stratify the population of plots into optimal units for the spatial C stock comparison

After some exploratory statistics, the data set was stratified into groups of soil types (mineral soil carbon) and groups of humus types (forest floor carbon). The results for the changes in soil organic carbon (stocks in the O layer and mineral soil 0-90 cm are presented in Figure 3-10.

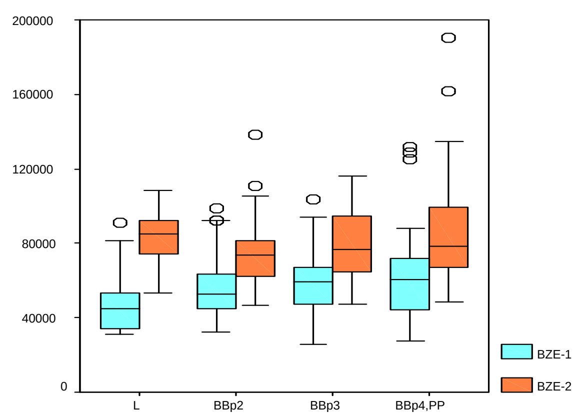


Figure 3-10 Comparison between the initial and repeated forest soil condition inventory (L:Luvisol, BBp2: weakly podzolic Cambisol, BBp3: moderately podzolic Cambisol, BBp4, PP: strongly podzolic Cambisol and Podzol, Intergades to Podzols)

Table 3-13 contains the descriptive statistics for the total C stocks, divided by groups of soil types. The mean differences were statistically significant based on the Wilcoxon test for independent means.

Table 3-13 Comparison of the total C stocks (O + 0-90 cm) for N=120 inventory plots

Layer	*BZE-1; C-stocks [t/ha]*			*BZE-2; C-stocks [t/ha]*			*difference (median)*	*annual change [t/ha]*
	arithm. mean	*SD*	*median*	*arithm. mean*	*SD*	*median*		
L	48.0	16.5	45.1	85.4	23.0	85.0	34.0	**2.664**
BBp2	55.7	17.3	52.8	76.1	21.6	73.7	20.9	**1.393**
BBp3	67.8	38.3	59.4	80.2	18.1	76.6	17.2	**1.147**
BBp4,PP	63.7	27.7	60.3	91.9	38.7	78.23	18.0	**1.200**
total mean	**59.5**	**27.0**	**53.6**	**82.4**	**26.8**	**75.6**	**22.0**	**1.468**

The results show a very strong increase on soil carbon stocks. The increase is by far higher than calculated for afforestation sites (Arrouays et al. 2002, Vesterdal and Raulund-Rasmussen 1998). For that reason, the role of systematic errors in the inventory was very carefully investigated again, and a hypothesis to be developed.

With such results, it appears strikingly important, the different inventories (Level I and Level II) are integrated with core sites (see above) and other ecosystem research sites, which allow full element budgets including litter turnover in the rooting zone. Validation exercises and the results from other similar studies are urgently needed. The evaluations of large-scale monitoring activities need to be as intensively discussed and coordinated as the sampling/analysis activities.

3.5.4. Monitoring cost

Inventory cost

The material presented here is based on the BioSoil test conducted by Cools (2005) for selected Flemish Level I plots. At the 12th FESP, the NFCs were asked to provide cost estimates for the Level I and Level II in the context of the BioSoil proposal. The results were compiled by DG ENV. The following results are cited from Cools (2005).

The test in Flanders showed that two to three plots could be sampled per day (excluding the soil profile description). In the test phase, the profile description on the Level I plots took one full day per profile. However, many countries will combine the sampling with the profile description during the survey. The FSCC estimates that a team of three technicians and one scientist is required to complete all the sampling and pedological characterisation work within one day (5 – 6 hours effective time spent on the plot). The estimation of the travel and maintenance costs of the four-wheel drive pick-up, was based on the kilometre allowance set by the Ministry of the Flemish Community (0.28 € per km). The average travel distance (based on 10 plots) from the Institute of Forestry and Game Management to the plots is 117 km one-way. In case one plot is sampled per day (including the profile description), there is an average cost of 65.5 €per plot. The cost of the sampling equipment is not yet included. The field technicians receive a daily allowance of 13 euro per lunch, which adds to 39 € for the team mentioned above. In addition, the daily income of the sampling team still has to be included.

Table 3-14 shows the estimated cost for a Level I plot (disturbed sample). Because of the increased sampling and measurement intensity for Level II, its cost would appear in triplicate (costs for Level I x 3). The costs for the core sample (volume-based sample) are identical for Level I and Level II (Table 3-15).

Table 3-14 Estimated cost of required laboratory analyses on <u>mixed</u> samples at the Level I plots (disturbed samples) [Euro €]

parameters	organic layer		mineral layers	
	L	*F+H*	*(M05, M51, M12,M24, M48)*	Total
<u>Physical soil parameters</u>				
Moisture content	**6.2**	**6.2**	**6.2**	
Particle size distribution (FAO, 1990a)			**45**	
3				
<u>Chemical soil parameters</u>				
pH(CaCl2) and pH(H2O)		**10**	**10**	
Organic carbon		**14.2**	**14.2**	
Total nitrogen		**20**	**20**	
Carbonates[1)]				
Aqua Regia extracted P, Ca, K, Mg, Mn	**120**	**120**	**120**	
Exchangeable Cations: Ca, Mg, K, Na, Al,		**50**	**50**	
Oxalate extractable Fe, Al		**24**	**24**	
	126.2	244.4	289.4 per layer	**1,818**

[1)] Calcareous soils were not included in this study.

Table 3-15 Estimated cost of required laboratory analyses on <u>undisturbed</u> samples at the Level I and Level II plots [Euro €]

Level	N° core samples	Cost of bulk density measurement	Total cost per plot
Level I and Level II	5 repetitions * 5 layers = 25	7.9	197.5

Because the method for bulk density and stones has been thoroughly investigated prior the BioSoil field work, the cost estimate for the physical measurements of the volume-based sample needs updating.

It was agreed that a separate sampling and analysis for genetic horizons is needed in the profile pit, in order to characterize the soil acc. to WRB. Based on the training courses (international: Austria, Belgium; national: Germany), it became clear that the type of laboratory analyses depends on the soil type, and the number of samples will depend on the number of genetic horizons. For most soil types the following analyses will be required: soil texture, soil organic carbon, soil reaction (pH) and exchangeable element (to determine the base saturation). In case of Podzols, the oxalate extractable Fe and Al is required too. A first rough estimation adds to 150 €per layer. In case of 6 layers or horizons, this comes to 900 € per profile.

Based on the data compiled during this test by FSCC, the description, sampling and analysis of one Level I plot would cost at least 3,100 €. The total sum mentioned corresponds roughly to the estimation made for the planning of the total BioSoil cost and the Commission’s contribution (see report of the first meeting of the JRC “BioSoil expert group”, Ispra, 13.-14. Dec 2004). Those cost not yet considered in the estimate by Cools (2005), such cost from the determination of bulk density with stony soils, the determination of the carbonate content with calcareous soils, labour cost, or the equipment cost, may be somewhat compensated by sites for which soil profile descriptions were already available, and for which no new profile pit needs to be dug. However, the complete FAO-based soil profile description and application of WRB requires profile properties and analyses for genetic horizons.

3.5.5. Conclusions

The current chapter has shown the achievements of Forest Focus and the specific needs to continue monitoring activities at fairly reasonable. Environmental policies (for example mitigation and adaptation to climate change, GHG reporting, planning of support measures in rural areas) require the prediction of change under changing climatic conditions, changed socio-economical frame conditions, etc. That is only possible, if data are available which fit into models, or where models are trained and modified to work with the existing data. Whenever such an exercise has been conducted, the lack of geo-referenced data, of data from repeated measurements, well-documented metadata, etc. became obvious. This situation will be majorly improved through Forest Focus.

However, there are also new challenges. The Brandenburg example about using the BioSoil data for trend detection has revealed the urgent need to integrate data from intensive monitoring and forest ecosystem research in order to explain/verify the results found. Level I is a large-scale survey, and cause-and-effect analysis is difficult without data coming from improved sampling designs proven to be free of systematic errors.

3.6. *General conclusions on using parameters from monitoring networks for assessing carbon sequestration in forests*

This work has focused on inventories related to forest ecosystem research and forest condition monitoring. Various activities exist in the member states and continent-wide Europe. Reporting on KP3.4 is expected to be based on the EU/ICP Forests Level I and BioSoil inventories. The BioSoil project (2006-2008) repeats the Level I (1990-1995) at about ¾ of the plots, and – with regard to the GHG reporting needs - concentrates on the soil and litter pools. The use of this data for terrestrial greenhouse gas emission inventories is facing some frame conditions which need to be considered:

- Litter needs to be defined: it is proposed to count the OF and OH horizons of the forest floor into the litter pool; fresh residues (OL) and fine woody debris (FWD) need to be excluded from the litter assessment due to the extremely high variability and lack of data.
- SOC changes need to be reliable. It requires that methodical improvements do not introduce systematic error. This needs to be carefully addressed when evaluating the BioSoil data, especially at the European level.
- SOC changes between 1990/1995 and 2006/2007 need to be extrapolated to 2008-2012. A validation at the end of the commitment period may be needed by sampling a set of representative Level I pots.
- SOC changes need to be verified on the basis of integrated modeling exercises (soil + climate + management/disturbance) and comparisons with flux data and with long-term measurements (forest ecosystem research).

While methodical improvements under BioSoil will improve (1) the reliability of the soil carbon estimates and (2) comparability between countries, differences between the initial samplings and those under Biosoil need careful consideration. Without links to long-term measurements, and intensive monitoring sites, the plausibility and validation of such results is difficult. It is hypothesized that the main challenge to utilize the wealth of soil monitoring data in Europe is the analysis and extraction of systematic errors and the plausibility of trends, and the identification of hot spots and outliers. Certainly, the uncertainty of the European sink/source estimate is enlarged compared to national level approaches.

Very few approaches have considered the aspect of verification, for example by integrating large scale inventories with measurement-intensive monitoring, or by comparing inventory-based changes with flux measurements such as those developed by the CarboEurope project.

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Annex I: Forest categories used under BioSoil - Revised scheme of European forest types for biodiversity assessment (Barbati et al. 2005)

Categories	*Types*
1. Boreal forest	1.1 Spruce taiga forest 1.2 Pine taiga forest 1.3 Boreal birch forest
2.Hemiboreal and nemoral Scots pine forest	2.1 Hemiboreal forest 2.2 Nemoral Pinus sylvestris forest
3. Alpine coniferous forest	3.1 Subalp. larch (*Larix decidua*)-stone pine (*P. cembra*) and dwarf pine (*P. uncinata*) 3.2 Subalp. and montane spruce (*Picea abies*) and montane mixed spruce-Silver fir (*Abies alba*)-forests 3.3 Scots pine (*Pinus silvestris*) and Black pine (*Pinus nigra*) forests
4. Atlantic and nemoral oakwoods, Atlantic ashwoods and dune forest	4.1 Atlantic and nemoral oakwoods 4.2 Atlantic ashwoods 4.3 Atlantic dune forests
5. Oak-hornbeam forest	5.1 Pedunculate oak (*Quercus robur*)–hornbeam (*Carpinus betulus*) forests 5.2 Sessil oak (*Quercus petraea*) – hornbeam (*Carpinus betulus*) forests
6. Beech forest	6.1 Lowland beech forests of S-Scandinavia and north central Europe 6.2 Atlantic and subatlantic lowland beech forests 6.3 Subatlantic submontane beech forests 6.4 Central European submontane beech forests 6.5 Carpathian submontane beech forests 6.6 Illyrian submontane beech forests 6.7 Moesian submontane beech forests
7. Montane beech forest	7.1 SW-Europ. mont. beech forests (Cantabrians–Pyrenees–Centr.Massif–SW-Alps) 7.2 Central European montane beech forests 7.3 Apennine-Corsican montane beech forests 7.4 Illyrian montane beech forests 7.5 Carpathian montane beech forests 7.6 Moesian montane beech forests 7.7 Crimean montane beech forests 7.7 Oriental beech and hornbeam-Oriental beech forests
8.Thermophilous deciduos forest	8.1 Downy oak (*Quercus pubescens*) forests 8.2 Supra-mediterranean oakwoods 8.3 Pyrenean oak (*Quercus pyrenaica*) forests 8.4 *Quercus faginea* and *Quercus canariensis* Iberian forests 8.5 Trojan oak (*Quercus trojana*) 8.6 Valonia oak (*Quercus ithaburensis spp. macrolepis*) forests 8.7 Chestnut forests (*Castanea sativa*) 8.8 Other deciduous woods
10. Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions	10.1 Mediterranean pine woodland 10.2 Mediterranean and Anatolian black pine woodland 10.3 Canarian pine woodland 10.4 Mediterranean and Anatolian Scots pine woodland 10.5 Alti-Mediterranean pine woodland 10.6 Mediterranean and Anatolian fir woodland 10.7 Juniperus woodland 10.8 Cupressus sempervirens woodland 10.9 Cedar woodland 10.10 Tetraclinis articulata stands 10.11 Mediterranean yew stands
11. Swamp forest	11.1 Boreal pine or spruce dominated mires 11.2 Alder dominated swamp and fen forest 11.3 Birch dominated swamp and fen forest
12. Floodplain forest	12.1 Riparian forest 12.2 Fluvial forest 12.3 Mediterranean and Macaronesian riparian forest
13. Native plantations	
14. Exotic plantations and woodlands	

4. Using National Forest Inventories for Harmonised GHG Reporting

Antoine Colin
IFN, France
E-mail: antoine.colin@ifn.fr

Sven Hans-Olof Petersson and **Göran Ståhl**
Swedish University of Agricultural Sciences, Sweden
E-mail: Hans.Petersson@srh.slu.se and Goran.Stahl@srh.slu.se

Abstract

This report assesses the potential of using data from European National Forest Inventories (NFIs) for the purpose of compiling annual reports to the UNFCCC and the KP. NFIs are conducted in most European countries today, and typically they are conducted based on statistical sampling principles. Thus, only a small fraction of the land is inventories, normally using sample plots on which different kinds of measurements and assessments are made. While the NFIs largely are installed for other purposes than greenhouse gas reporting, they can rather easily be modified to serve the purpose of providing data for emissions reporting as well. The objectives of this study were twofold. Firstly, an up-to-date assessment on the role of European NFIs was conducted based on a questionnaire. Secondly, critical factors for improving the utilisation of European NFIs were identified and further measures proposed. The study pointed out several possibilities and problems related to the use of NFI data for harmonised LULUCF sector reporting within EU and Europe. Issues on the positive side include: i) NFI data are available from almost all countries in Europe, or NFIs are currently being implemented; ii) The basic type of data provided by NFIs are suitable for a wide range of purposes connected with greenhouse gas reporting; iii) NFIs can be rather easily modified, and since reporting to the UNFCCC and its KP are major issues today, several NFIs currently modify their scope in order to provide better estimates related to greenhouse gases and iv) Between the European National Forest Inventories, collaboration is ongoing in order to improve the harmonisation across countries. On the negative side of using NFI data, the following items can be listed:i) NFI data are not available from all countries and all time periods, and thus geographical and temporal interpolation and extrapolation are needed in order to provide complete assessments, ii) Different definitions are used in different countries, and thus there is a major need to harmonise definitions and develop recalculation schemes in order to provide harmonised figures across Europe, iii) The accuracy of estimates of sparse events (like deforestation and burned areas) generally is low and iv) There are no guarantees that all countries will continue performing NFIs, although the trend lately has been that countries are installing such inventories.

4.1. *Introduction*

Mitigation and adaptation to climate change are issues of worldwide concern. Although the problems largely are due to emissions of carbon dioxide from exploitation of fossil fuels, many other societal sectors contribute to the emissions of greenhouse gases, or need to adapt to changing conditions. Land-use change and forestry play an important role in this context. Deforestation in the tropics is a major source of carbon dioxide to the atmosphere, while increased growth of boreal and temperate forests imply that these areas often are carbon sinks (IPCC 2000, Liski et al 2003).

Due to the importance of appropriate land-use strategies for mitigating greenhouse gas emissions the sector land use, land-use change, and forestry (LULUCF) is one of the current sectors from which the United Nation's Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol (KP) require annual reports regarding sources and sinks of greenhouse gases. This is the case although it is widely recognised that this sector poses substantial problems when the emissions or removals are to be estimated. For most other sectors, there is a straightforward link between activity data (e.g. amounts of oil used), emission factors (e.g. amount of carbon dioxide per unit oil), and the resulting emissions of greenhouse gases to the atmosphere. Problems involved with LULUCF sector emissions include insufficient data, non-annual data, poorly understood emission processes (e.g. emissions from soils), and different countries facing very different conditions, which imply that sharing of knowledge is not straightforward. While many different categories of land use are included in the LULUCF sector, forests normally are of prime importance.

In many countries nation-wide inventories of forests are conducted at regular intervals. Such inventories generally are known as National Forest Inventories (NFIs) and in most cases they are conducted based on statistical sampling principles (e.g. Ranneby et al. 1997, Tomppo 1993). Mostly, they have evolved for purposes other than greenhouse gas reporting and today they are conducted in most European countries (see COST E43; http://www.metla.fi/eu/cost/e43/). Cienciala et al (2008) show that NFIs are major sources of data for the reporting of greenhouse gas emissions and removals in a majority of European countries. Thus it is important to assess to what extent these inventories can be used to provide harmonised estimates of greenhouse gas emissions. This is especially relevant in Europe, where both the individual countries and the EU are Parties to the UNFCCC and the KP and thus are required to deliver annual emission reports. If definitions and other procedures are not harmonised between countries, this leads to inconsistent figures at the level of EU.

The European National Forest Inventories have different history (see COST E43; http://www.metla.fi/eu/cost/e43/). In the Nordic countries the activities started already in the 1920s. Over time, an increasing number of countries have initiated this type of inventory and today almost all countries in Europe have established an inventory of this kind. Lately, a major driver has been the need to report to the UNFCCC and the KP.

While the study by Cienciala et al (2008) pointed at several important features regarding the use of European NFIs for the greenhouse gas reporting, the countries in many cases had not decided upon definitions and procedures at the time when the study was conducted. Thus, it was judged that further studies of NFIs were needed in the scope of the MASCAREF project.

The objectives of this study were twofold. Firstly, an up-to-date assessment on the role of European NFIs was conducted based on a questionnaire. Secondly, critical factors for improving the utilisation of European NFIs were assessed and further measures proposed. The questionnaire also covered general country-specific issues and decisions related to the reporting, like core definitions and whether or not a country elected to report forest management under the KP.

The report is structured into two main parts, focussing on the two different objectives. It is based largely on a questionnaire, submitted in March 2008.

4.2. *State-of-the-art on the current use of European NFIs for greenhouse gas reporting*

4.2.1. Material and methods

Presentation of the questionnaire

The objective of the survey was to gather information on the current and potential contribution of European National Forest Inventories to the national reporting of greenhouse gas emissions within the LULUCF sector under the UNFCCC and its Kyoto Protocol.

A questionnaire was specifically elaborated for the purpose in January 2008 by the French IFN (M. Antoine Colin) with the support of the Swedish SLU (Dr. Hans Petersson) and the Austrian Umweltbundesamt[1] (Dr. Alexandra Freudenschuß). The questions were designed to provide an up-to-date assessment of relevant issues for LULUCF emission reporting in Europe, as identified by Cienciala et al. (2008).

The state-of-the-art assessment questionnaire on the role of NFIs in LULUCF reporting systems consisted of five distinct sets of questions, aiming at:

1. Providing a general view on the contribution of NFIs within the national UNFCCC reporting systems, regarding areas of land use categories and changes, and carbon stocks in the five ecosystem pools,
2. Specifying the forest definitions adopted within the national UNFCCC reporting systems,
3. Identifying the national systems developed for the detection of areas of land-use changes under the UNFCCC reporting and describing the use of NFI data,
4. Specifying the definitions used for the forest carbon pools and explaining the methodologies implemented in the estimation of carbon emissions and removals,
5. Presenting the systems developed to fulfil the KP requirements and the use of NFI data in these.

The questionnaire was distributed in February 2008 to the country representatives of workgroup 2 of the COST Action E43 (see COST E43; http://www.metla.fi/eu/cost/e43/), which includes experts technically responsible for compiling emission inventories for the LULUCF sector in the respective countries or members of the collaborating inventory teams. It was also distributed to the emission inventory experts from the organizations involved in the MASCAREF project.

The latest response the questionnaire was received in March 2008. The subsequent analyses were performed mainly through calculating the proportion of responses stating different alternatives. No statistical treatment was performed and the results should be regarded as describing the practices and decisions within the responding countries, only.

Presentation of the responding countries

The assessment of the current use of NFIs for greenhouse gas reporting in Europe in this report is based on the analysis of the responses provided by 24 European countries (Figure 4-1). Among this total, 21 countries belong to the community of EU27 countries. The nine partner countries involved in the MASCAREF project all responded to the questionnaire (Austria, Czech Republic, Germany, Greece, Italy, Lithuania, Netherlands, Romania, Slovakia and Sweden).

[1] The results on uses of biomass functions and expansion factors within European NFIs are presented in a separate MASCAREF report by Freudenschuß et al.

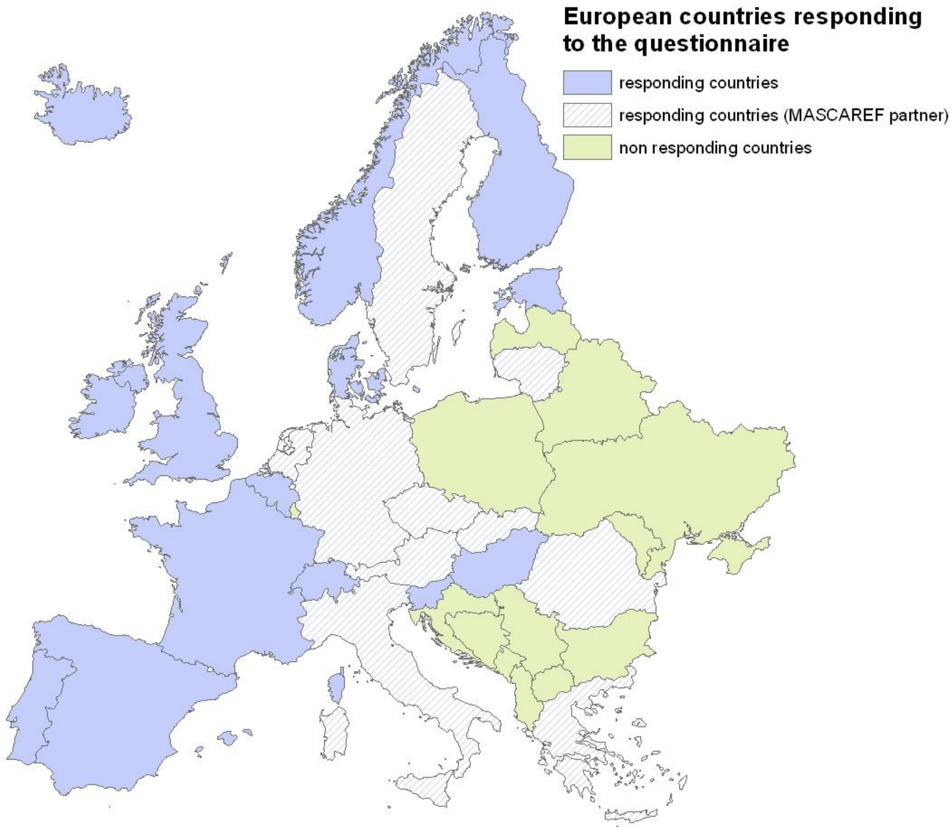


Figure 4-1 European countries responding to the questionnaire

FRA 2005 national reports (FAO 2005) provide figures on the forest area and the growing stock (in forests) within the 24 responding countries, and their share of EU27 and European countries (Table 4-1).

Table 4-1 Forest area and growing stock (in forests) of the 24 responding countries (and their share **within EU27 and European countries, respectively)**

Data	*European countries**		*EU27 countries*	
	24 responding countries	*Share of European countries*	*21 responding countries*	*Share of EU27 countries*
Forest area (x 10^6 ha)	150.2	*78.0%*	139.6	*89.7%*
Growing stock (x 10^9 m^3)	21.33	*80.0%*	20.02	*86.7%*

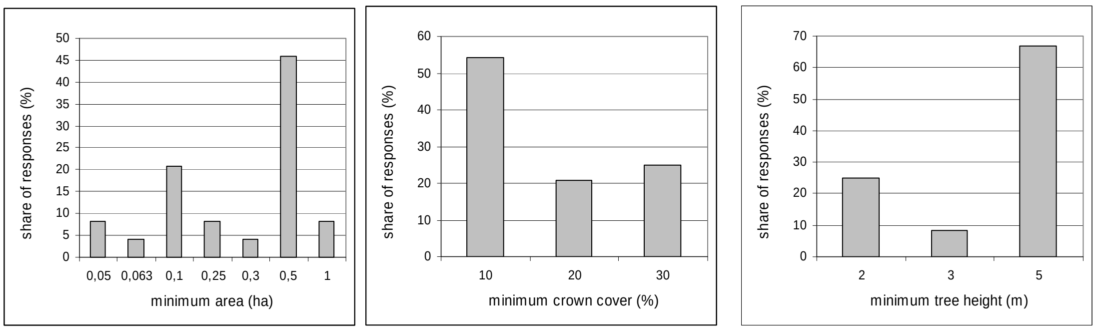
* Except the Russian Federation

According to the FAO definition (FAO 2005), the forest area of the 24 responding countries is 150.2 millions hectares and the growing stock is 21.33 billions m^3, which represent 78 % and 80 %, respectively, of the total forest area and growing stock at European level, excluding the Russian Federation. The shares of responding countries are even higher considering EU27, since nearly 90 % of the total forest area and 87 % of the total growing stock were included in this case (Table 4-1). Thus, from the point of geographical coverage the results of the questionnaire should provide a good description of current European conditions with regard to LULUCF sector reporting.

4.2.2. Forest definitions adopted in the national UNFCCC reporting systems

How are forests defined?

Since forest area is one of the key variables affecting the reported emissions, a broad definition of forest was intensively discussed and finally adopted by the Parties to the KP (Marrakech Accords, UNFCCC 2002). Predefined ranges of values for three key parameters were specified: the minimum area, the minimum crown cover, and the minimum tree height at maturity. Fgure 4-2 provides information on which thresholds have been selected within the responding countries.



Fgure 4-2 Adopted thresholds for the definition of forest within the 24 responding countries.

It is clear that the parameters that correspond to the FAO definition of forest have most frequently been adopted; this means a minimum area of 0.5 ha (46 % of the respondents), 10 % of minimum crown cover (54 %) and a minimum tree height of 5 m (67 % of the responses). However, they are applied simultaneously only by 29 % of the responding countries.

How are 'managed forests' defined?

According to the Good Practice Guidance for LULUCF (IPCC 2003), managed forests are subject to periodic or ongoing human interventions so that they include the full range of management practices from commercial timber production to stewardship for non-commercial purposes.

From the questionnaire responses, most countries (71 %) consider all their forests as managed. However, nature reserves are declared unmanaged by 8 % of the respondents (Figure 4-3) and the forests where leisure or aesthetics functions are predominant are reported unmanaged by 12.5 % and 4 %, respectively, of the responding countries.

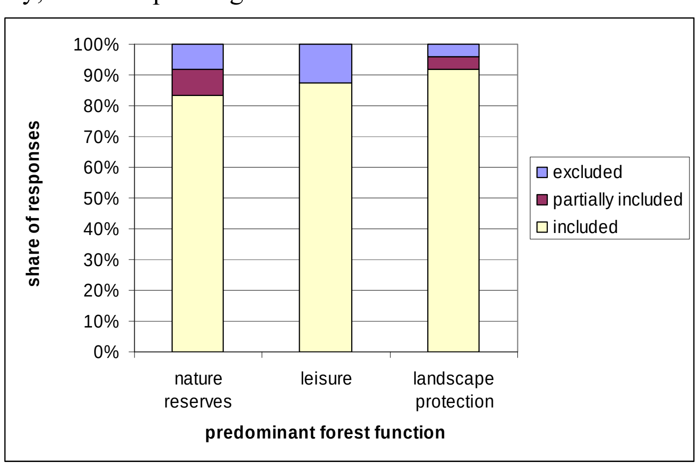


Figure 4-3 Share of responding countries where the definition of managed forest includes non-timber-production forests of different kinds

However, not all areas used for production of woody biomass are included in the managed forests category adopted for UNFCCC reporting. Almost half of the responding countries (46 %) state that plantations for bio-energy production do not always belong to the forest category. They are strictly defined as croplands in one third of the responding countries. Low productivity forests are excluded from the reporting in Estonia and they are partially excluded also in Finland and Great Britain.

Are un-stocked areas reported under the forest land category?

Except in Portugal, temporarily un-stocked forest areas, like clear-cuts or areas damaged by natural hazards such as wildfires or wind-throws are still considered forests unless evident signs of land use change are detected. This approach is in line with the forest definition approved in the Marrakech Accords.

The situation is much more diverse regarding to which IPCC category permanently un-stocked areas like forest roads, skidding tracks, and timber yards belong. In most countries, it depends on whether the minimum thresholds for the classification of the land under the forest land category are reached or not. However, tree nurseries are excluded from the forest land category in a majority of the responding countries (61 %).

4.2.3. Contribution of European NFIs to the estimation of areas of land-use changes

On the importance of detecting land use changes

GPG for LULUCF (IPCC 2003) defines six broad categories of lands for representing land areas within a country, *i.e.* forest land, cropland, grassland, settlements, wetland and other land. Countries are invited to provide their own definitions within the common IPCC framework.

Considering the methodological requirements in the GPG for LULUCF, carbon pool changes have to be reported separately (1) for land areas remaining in the given land category for 20 years prior to the current inventory year and (2) for land areas converted to the current land use category during the last 20 years.

The generic guidance to calculate the source or sink estimates for each one of the five ecosystem pools is to multiply the land use / land-use change area by a carbon stock coefficient or "emission factor". In that sense, it is a key issue for the national systems to be able to identify the land use transfers over a period of 20 years prior to the year the greenhouse gas inventory is performed.

Contribution of NFIs to the detection of land use changes

European NFIs to a varying extent contribute to national systems for detecting land-use changes (Figure 4-4). Since forest is a main concern of NFIs, NFI data are more often used to detect changes in the forest land category. About 46 % of the responding countries indicated that the NFI currently contributes to the estimation of land-use changes in this category. It obviously includes forests remaining forests, but also afforestation (from non-forest to forest) and deforestation (from forest to another land use category).

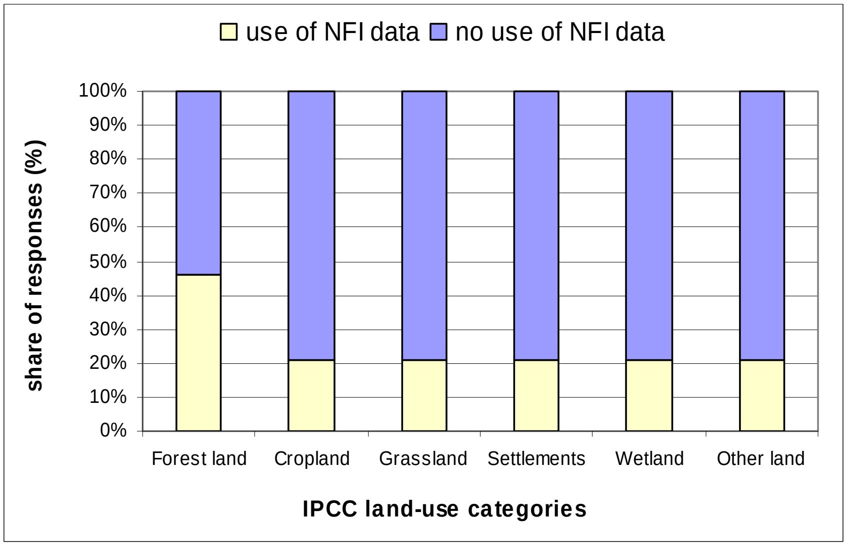


Figure 4-4 Contribution of NFI to the estimation of areas of land use changes under UNFCCC reporting

More generally, NFI data are being implemented to detect land-use changes for the six IPCC categories in about one fifth of the responding countries (21 %).

Methodologies for the detection of land use changes

Several methodologies are available to estimate land-use changes to and from forest. Common methods implemented include sampling (25 % of the respondents), land cover/use maps (21 %) and combinations of sampling and maps (17 %), see Figure 4-5. Other information sources such as aerial and satellite images, cadastral data, management plans or afforestation registries are also frequently used, alone or in combination with sampling and maps.

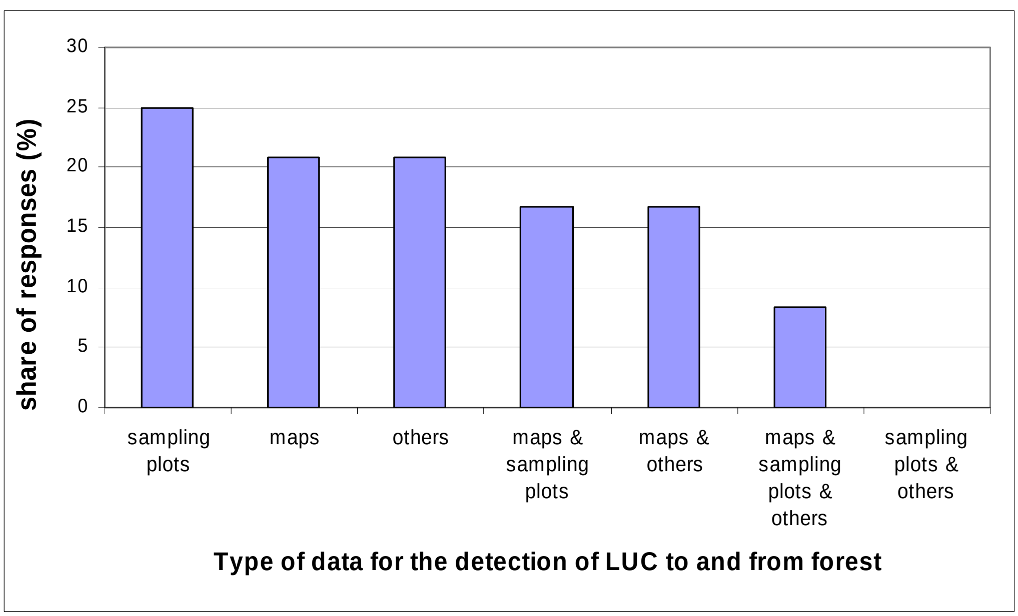


Figure 4-5 Sources of information implemented to detect the land use changes to and from forest over time (multiple answers are possible)

As presented above, about half (46 %) of the responding countries answered that at least one type of NFI data is being used in the system developed to detect land-use changes to and from forest. Among this group, NFI sampling plots are used in 82 % of the countries, NFI maps in 45 % and combinations of NFI sampling plots and NFI maps in 27 %. More broadly, 29 % answered that NFI data is the only source implemented in their national system for detecting land-use changes to and from forest.

GPG for LULUCF defines three methodological approaches for assessing the areas of the six broad IPCC land-use categories, depending on the type and accuracy of the information content. Approach 1 (GPG1) identifies the total area for each individual land-use category, but does not provide detailed information on changes of area between categories and is not spatially explicit other than at the national or regional level. Approach 2 (GPG2) introduces tracking of land-use changes between categories (for instance through the construction of a land-use matrix). Approach 3 (GPG3) extends Approach 2 by allowing land-use changes to be tracked on a spatial basis, either by geo-referenced sampling or by wall-to-wall mapping. Mixes of approaches may be used if required due to national circumstances.

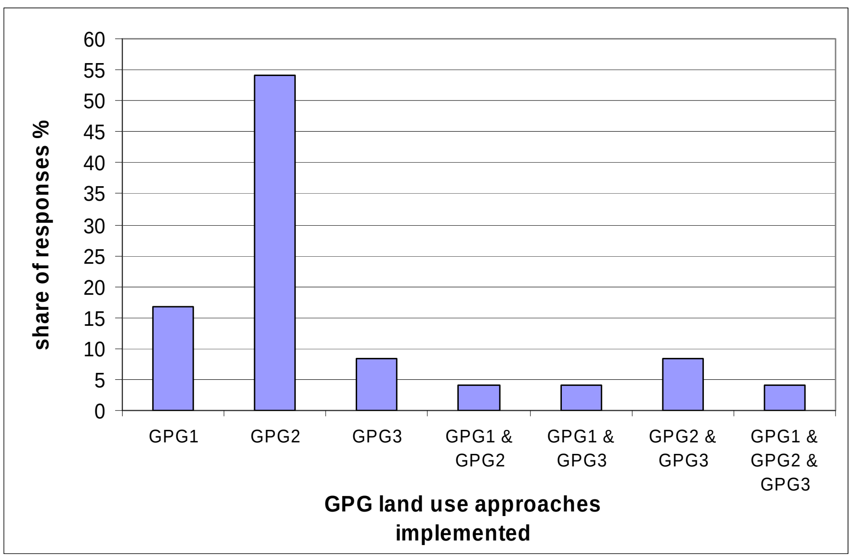


Figure 4-6 Application of the GPG for LULUCF approaches to estimate areas of different land- use categories.

The more advanced approaches provide area estimates of land-use changes. GPG2, GPG3 and the combination of GPG2 and GPG3 are being used in 70 % of the responding countries (Figure 4-6). On the other hand, the basic approach (GPG1) is used alone in 17 % of the responding countries. Those latter countries need to be encouraged to improve their reporting systems.

Availability of historical land-use data

The availability of historical data is vital when considering the calculation of stock changes in the different carbon pools associated with the land uses. According to the GPG of LULUCF, data are required 20 years before the year the inventory is performed. Consequently, land use information needs to be available from 1970 onwards.

Thirty percent of the responding countries can rely on land use data since 1970 (Table 4-2). However, the national systems should also be able to detect the previous land use of an area that has been converted. Eight percent of the respondents strictly fulfil the GPG recommendations, but

25 % have access to data since 1970 and are at least partially able to detect the land uses from the year the conversion has occurred.

Table 4-2 Oldest year of land use information implemented in the UNFCCC reporting system, and feasibility to trace the land uses from this year onwards

Oldest year used for the detection of land use changes	Share of responding countries	Possibility to detect the previous land use			
		Total	Yes	no	partially
Before 1970	13%	*100%*	33%	0%	67%
Year 1970	17%	*100%*	25%	25%	50%
From 1971 to 1989	50%	*100%*	33%	8%	59%
Year 1990 (baseline)	13%	*100%*	67%	33%	0%
After 1990	8%	*100%*	0%	100%	0%

Fifty percent of the European countries rely on land use information from between 1971 and 1989. A third of those countries answered that they are able to precisely identify and follow all land uses since the oldest year available, while for another 59 % extrapolations are performed.

Finally, almost every country (92 %) relies on historical information on land uses since 1990 (baseline year for emission reporting) and 86 % of the national systems are able to provide information (through direct measurements or modelling procedures) on the previous land use of the areas reported in the ongoing emission inventory.

4.2.4. Additional methodologies for the identification of land areas subject to Articles 3.3 and 3.4 activities of the Kyoto Protocol

According to the GPG for LULUCF, Parties are to report over the commitment period 2008-2012 emissions by sources and removals by sinks of CO_2 and other greenhouse gases resulting from LULUCF activities under Kyoto Protocol Article 3.3, namely afforestation (A), reforestation (R) and deforestation (D) that occurred since 1990. They are also to report any elected human-induced activities under Article 3.4, like forest management.

Additional requirements arising from the Kyoto Protocol reporting lead to the development of a set of supplementary estimations and methodologies for the accounting of emissions for LULUCF activities at the national level. GPG for LULUCF defines a methodological framework for the calculation of carbon stocks changes under Articles 3.3 and 3.4 of the Kyoto Protocol. The approaches currently implemented within the responding countries to the questionnaire are described in the following sections.

Definition of forest management

The first methodological step provided in the GPG for LULUCF is to properly define what forest management is. A broad definition was adopted in the Marrakech Accords: *Forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.*

From the questionnaire responses, managed forests and forests that are subject to forest management activities are strictly equal in most of the responding countries (83 %). In other words, all the managed forest areas defined in the UNFCCC reporting could be potentially reported under Kyoto Protocol Article 3.3 (obligatory) and Article 3.4 (if elected). In the remaining countries, the area of forests that are subject to forest management activities is smaller than the area of UNFCCC managed forests.

Identification of lands subject to activities under Articles 3.3 and 3.4 of the Kyoto Protocol

The second methodological step indicated in the GPG for LULUCF is to identify which lands are subject to Kyoto Protocol Article 3.3 (obligatory) and Article 3.4 (optional) activities by tracing the land use transfers of managed lands since 1990 onwards.

Article 3.3 of the Kyoto Protocol regards the reporting of greenhouse gas emissions by sources and removals by sinks in relation to the land-use changes induced by human activities since 1990 from and to the forest land category, namely afforestation (A), reforestation (R) and deforestation (D).

From the questionnaire responses, spontaneous re-growth without any regeneration efforts on abandoned managed lands is considered as afforestation by 82 % of the responding countries. In addition, while most of the countries do not make any distinction between afforestation and reforestation (92 % of the respondents), Ireland does and the concern is still under discussion in Slovakia. In most cases, a conversion from a forest to a forest road would not be reported as deforestation since forest roads in most countries are part of forest land, which is consistent with the basic FAO definition (cf. 2.1).

The minimum area to detect ARD activities varies largely among the 23 countries that answered to this question, from no minimum area (i.e. at least 0.05 hectare as prescribed by IPCC) to one hectare (Figure 4-7). These answers are all consistent with the Marrakech Accords definition of forest. The most common answer was 0.5 hectares.

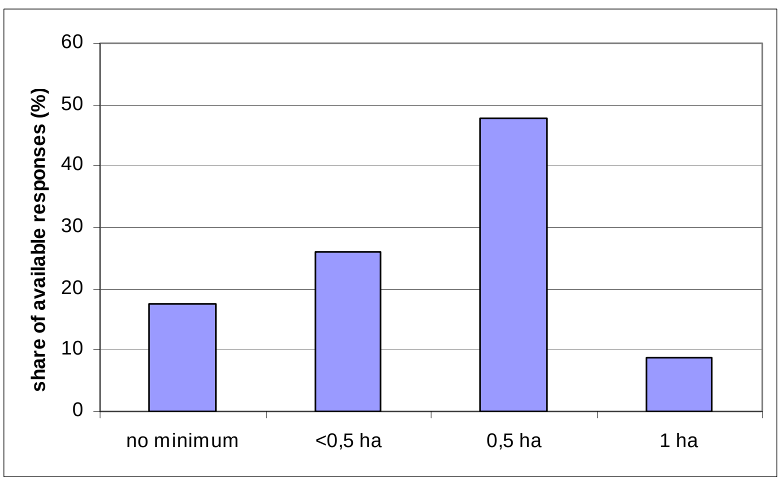


Figure 4-7 Minimum area for the detection of ARD activities

Article 3.4 of the Kyoto Protocol concerns the carbon sequestration in managed forests that remained managed from 1990 until the reporting year. Pragmatically, lands subject to Article 3.4 activities are the remaining managed areas once Article 3.3 activity areas have been estimated. Optional Article 3.4 of the Kyoto Protocol was elected by 71 % of the responding countries.

When calculating the emissions, it is important to estimate the area of the six broad IPCC land use categories in 1990 (baseline data). From the questionnaire responses, NFI data are being used in that perspective in almost half of the responding countries (46 %), directly or through extrapolation procedures. Moreover, a fifth (21 %) of the responding countries declared NFI is the only source of data being used in the system they developed to estimate the baseline data for the Kyoto Protocol reporting.

Once baseline data are estimated, the next step is to detect the areas where Article 3.3 (ARD) and Article 3.4 (forest management) activities have occurred since 1990.

NFIs are frequent sources of data for the land use transfer detection systems developed at the national level. Actually, 62.5 % of the responding countries answered that NFI data are currently used to achieve this objective, alone (37.5 %) or in combination with non-NFI data like maps on forest fires or afforestation, digital orthophotos, etc. The most frequently used NFI data are the ones gathered on the sampling plots (50 % of the responding countries) followed by the data extracted from maps, as presented in Figure 4-8.

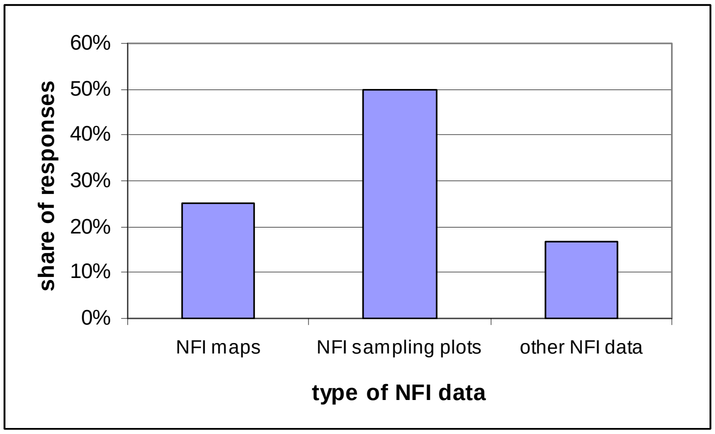


Figure 4-8 Type of NFI data implemented in the land use transfer detection systems developed for the Kyoto Protocol reporting

In addition, the Marrakech Accords prescribes that the geographical boundaries of areas encompassing units of land subject to afforestation, reforestation, deforestation and forest management are to be reported by the Parties. GPG for LULUCF defines two exclusive methods to achieve this objective. The first approach is to delineate areas that include multiple land units subject to Article 3.3 and 3.4 activities (e.g., areas are calculated and reported within administrative regions); the second approach implies that individual units of lands subject to 3.3. and 3.4 activities be individually identified.

From the questionnaire responses, the first approach is much more frequently applied, since it will be implemented in 77 % of the countries where a decision has been made in this regard (22 countries out of 24).

4.2.5. Contribution of European NFIs to the estimation of carbon stocks in the different pools of the ecosystem

GPG for LULUCF identifies five different pools within the ecosystem for which carbon stock changes should be reported under the UNFCCC and the Kyoto Protocol frameworks *i.e.* (1) aboveground biomass and (2) belowground biomass which are together defined as the living biomass pool, (3) dead wood and (4) litter which make up the dead organic matter pool, and (5) soil. IPCC also provides a generic definition of the five pools. The national definitions and the methodologies currently implemented to calculate the carbon stocks and changes in the five pools are presented and discussed in the following sections.

Living biomass pool, aboveground and below-ground biomass

According to the GPG for LULUCF, the aboveground biomass pool should include all living biomass above the soil *i.e.* stem, stump, branches, bark, seeds, and foliage. Belowground biomass corresponds to the roots of the whole aboveground vegetation until 2 mm diameter.

From the questionnaire responses, the living biomass pool includes both aboveground and belowground tree vegetation in most of the countries (Table 4-3). The only exception is Iceland where belowground biomass of trees is not reported so far since the required data are not yet available. NFI data are more frequently used in the carbon stock calculation of the aboveground biomass of trees (74 % of the countries) than for the belowground biomass.

Understorey vegetation is less frequently included in the living biomass pool. The aboveground biomass of understorey vegetation is reported by 25% of the countries, while only 8 % of the respondents also include the belowground biomass of understorey vegetation. Many of these countries implement NFI data in the calculations.

Table 4-3 Type of vegetation included in the reporting on living biomass pool and the use of NFI data

Type of vegetation	Carbon pools	Included in the accounting system (share of countries)	Estimate based on NFI data (share of countries where the information is relevant)
Trees	aboveground biomass	96%	74%
	belowground biomass	100%	42%
Understorey	aboveground biomass	25%	33%
	belowground biomass	8%	50%

Romania is the only country which includes both aboveground and belowground biomass of all vegetation. The possibility to exclude non-tree biomass (ground vegetation, shrubs, and herbaceous) from the living biomass is in line with the GPG for LULUCF, which states that non-tree biomass can be excluded when it is judged to be a small component.

Whereas tree biomass is reported in most countries, trees are defined in different ways. Minimum DBH varies from 0 (*i.e.* all the trees are included) to 12 cm (*i.e.* trees with a diameter > 12 cm at 1.3 m height are included). The most frequent answer is zero (29 %) while 20 % apply a minimum DBH of 5 cm and 20 % a minimum DBH of 7 cm (Figure 4-9).

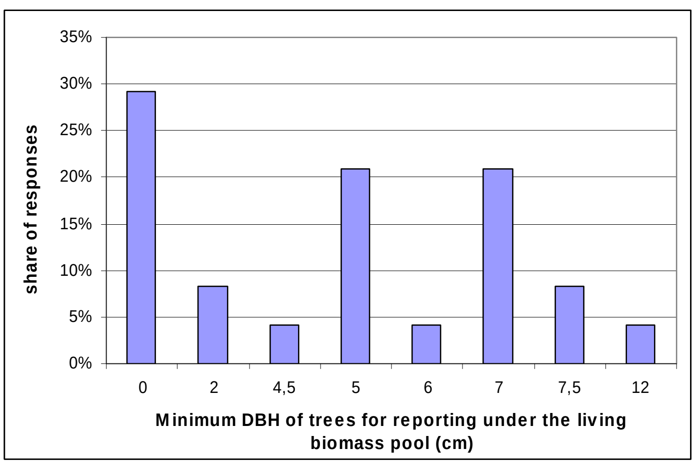


Figure 4-9 Minimum DBH of trees for their inclusion into the living biomass pool for the reporting

According to the GPG for LULUCF, two generic methods are available for estimating the annual carbon stock changes in the living biomass of forests remaining forests. The first one is the "default method", which relies on separate estimates of growth and drain. The drain comprises several components, such as commercial felling, fuel wood gathering, and mortality due to natural disturbances. The second method is the "stock change method". It consists of calculating the difference in the carbon stock for a given period of time from two successive inventories.

From the questionnaire responses, both methodologies are equally frequent within the European countries. According to the GPG for LULUCF, using default or stock change method is a matter of expert judgment, taking the national inventory systems and forest properties into account, since the level of statistical uncertainty of these two methodologies may dramatically vary from one country-specific situation to another.

In the group of countries where the default method is applied, NFI data sets are frequently used to estimate the carbon increment in aboveground biomass (Figure 4-10). A quarter of these countries only rely on NFI data for the provision of increment and removal estimates for both aboveground and belowground biomass pools. These figures are extracted from permanent plot sampling. On the other hand, less accurate data (IPCC default values) are used by 42 % of the countries, alone or in combination with other data sets and mainly for belowground biomass assessments.

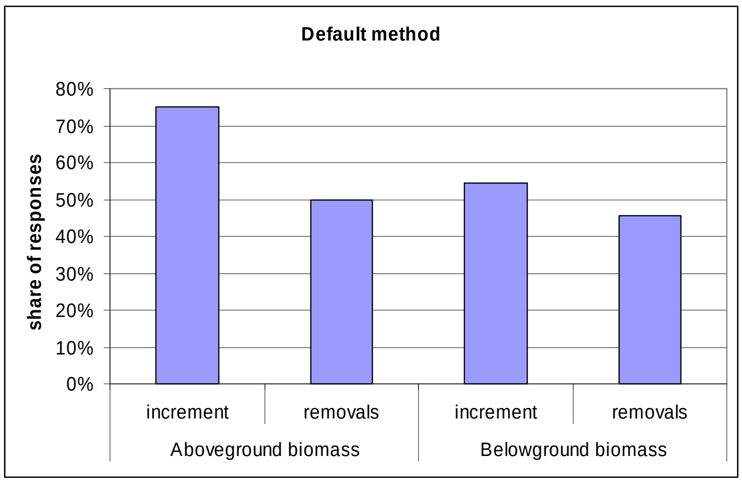


Figure 4-10 Contribution of NFIs to data provision for the IPCC default method for living biomass

When the stock change method is applied, most of the countries use NFI data for their carbon change estimates in the aboveground biomass pool (83 % of the respondents). This share is lower regarding the provision of belowground biomass estimates (42 %).

A significant number of countries only rely on NFI data when calculating the carbon changes in both aboveground and belowground biomass through the stock change method (42 %). Less accurate data (IPCC default values) are applied by 42 % of the responding countries, alone or in combination with other data and mainly for belowground biomass assessments.

Dead wood pool

GPG for LULUCF defines dead wood as the non-living woody biomass (dead wood lying on the surface, dead roots, and stumps are included) that is neither contained in the litter pool nor in the soil. Countries are, however, invited to provide their own definition of dead wood.

From the available responses, 30 % of the European countries consider that dead wood is not a source of greenhouse gases. Indeed, carbon stock changes in this pool are assumed to be zero and no report is done for this ecosystem pool in their inventory system. This approach is consistent with tier 1 methodology provided in IPCC guidelines. However, IPCC guidelines say that dead organic matter (including dead wood and litter) should be considered in future work on inventory methods since these pools are often significant carbon reservoirs.

Different minimum diameter thresholds are used when carbon stock changes in dead wood are reported, ranging from 0 to 15 cm. However, the most common min diameter is 10 cm (67 %); this corresponds to the FAO definition and is also consistent with the IPCC definition. Several countries (56 %) also include a minimum height/length threshold. A large proportion of countries do include lying dead wood (88 %) and stumps (62.5 %) in their inventories.

When it is relevant to make a carbon stock assessment, emissions are mainly estimated through the IPCC stock change method (81 % of the respondents). The stock change method implies to provide two carbon stock estimates for dead wood over a time period. The 19 % remaining countries responded that they are applying the second approach defined by IPCC, *i.e.* the default method, which relies on separate estimates for both inputs (natural mortality, disturbances) and outputs (decay rates and removals from forest management).

Changes in aboveground dead wood biomass are predominantly based on direct NFI data measurements or models built on NFI data sets, since 60 % of the responding countries answered that these data are being used in their inventory system, alone (50 %), or in combination with other data sets.

Litter pool

According to the GPG for LULUCF, the litter pool includes the biomass of the litter (mainly dead leaves and twigs) as well as the humic and fumic layers. However, Cienciala et al. (2008) reported that these two horizons are not included (or that this issue was still undecided) within the litter pool in 36 % of the countries, but instead in the mineral soil pool.

From the questionnaire responses, carbon changes in the litter pool are reported in 2/3 of the responding countries. In the others, litter is assumed to be a carbon neutral pool. When carbon changes in the litter are reported, modelling is the most frequently applied methodology (50 % of the respondents) as presented in Figure 4-11.

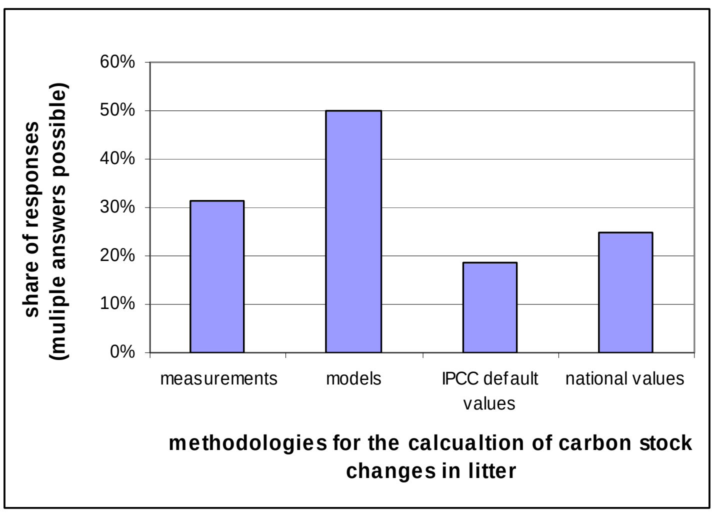


Figure 4-11 Methods for calculation of carbon stock changes in the litter pool (multiple answers possible)

The contribution of NFI data to the stock change calculations for the litter pool is relatively important since 44 % of the responding countries declared using them, alone (12.5 % of the countries only rely on NFI data for this calculation) or in combination with other data sources.

Soil pool

According to the GPG for LULUCF, soil organic matter refers to a complex of large and amorphous organic molecules and particles derived from the humification of aboveground and belowground litter, and incorporated into the soil, either as free particles or bound to mineral soil particles. It also includes organic acids, dead and living microorganisms, and the substances synthesized from their breakdown products.

IPCC considers it is *good practice* to separate mineral from organic forest soils for the reporting purpose. However, organic soils are often rare in European countries and the two types of soils are not reported separately in more than half (55 %) of the responding countries where an answer was available (22 responses out of 24).

Under the tier 1 approach of the GPG for LULUCF, it is assumed that the carbon stock in soil organic matter does not change when a forest remains a forest, regardless of changes in forest management, types, and disturbance regimes. From the questionnaire responses, this approach is applied in a third of the responding countries. In the remaining countries, modelling remains the more frequently implemented methodology to calculate carbon stock changes in soils (44 % of the respondents). However, the share of countries using IPCC default values is quite important (38 % as presented in Figure 4-12) since the amount and reliability of data on soils are sometimes limited due to the large variability of the carbon stocks within this pool.

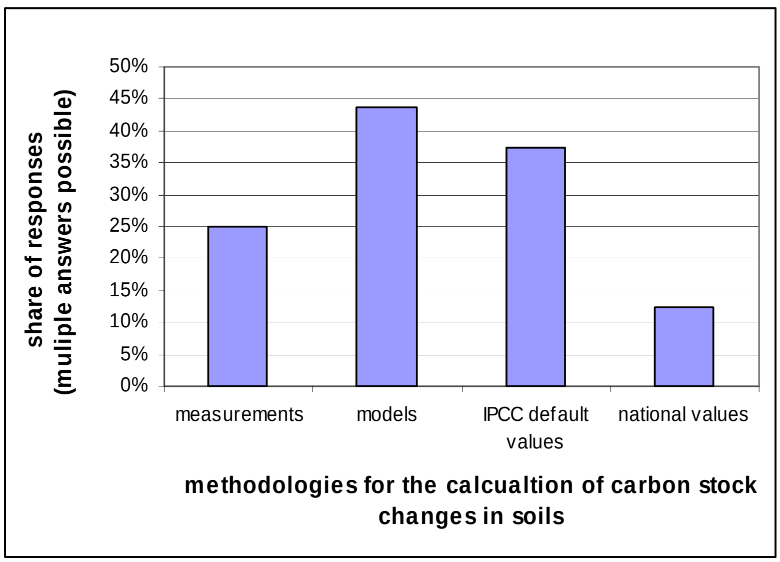


Figure 4-12 Methods for calculation of carbon stock changes in soils (multiple answers are possible)

The contribution of NFI data to the stock change calculations for soils is less than for litter. However, it is still important since 31 % of the responding countries declared using them, alone (19 % of the countries only rely on NFI data for this calculation) or in combination with other data sources.

4.3. *In-depth analysis of the role of NFIs for harmonised LULUCF sector reporting*

4.3.1. Requirements under the UNFCCC and the KP

Sound methodologies for monitoring carbon pools, and the matching of these carbon pools with land-use changes over time, are core elements in systems for reporting under the UNFCCC and the Kyoto Protocol (IPCC, 2003). Reporting under the UNFCCC requires data from managed land from the base year (1990) and onwards, while reporting under the Kyoto Protocol, which is activity based, mainly requires data for the commitment period (2008-2012), although land-use data from 1990 onwards are needed to assess what areas are subject to afforestattion, reforestation, and deforestation (Article 3.3) or any of the management activities under Article 3.4. If only the activity Forest Management (FM) is elected, the KP reporting only requires high quality data of carbon pools during the commitment period, since gross-net accounting is prescribed under Article 3.3 and 3.4 FM. Gross-net accounting refers to an accounting system based on current changes in carbon stocks, crediting removals by sinks and debiting emissions by sources, while a net-net accounting system relates emissions/removals to a baseline value (normally 1990). The activities Cropland management, Grassland management and Revegetation (Article 3.4) are net-net accounted and motivate high data quality also for the baseline.

Under both the UNFCCC and the KP, CO_2 emissions from liming and biomass burning also have to be reported. In addition, this is the case also for some non-CO_2 gases, as N_2O-emissions from forest fertilization, N_2O-emissions from mineralization connected to land use conversion to Cropland, and N_2O and CH_4-emissions from biomass burning.

For UNFCCC reporting, consistent data are desired for all reporting years; however, for many Parties the quality of data has improved over time. This might partly be explained by the fact that the KP was decided upon in 1997 (Kyoto Protocol, 1997) and that NFIs and other data providers gradually have adapted to the new requirements.

4.3.2. General use of NFI data for the reporting

Only Finland, Slovenia and Sweden state that they could base their entire LULUCF sector reporting on NFI-data in the future. This requires monitoring systems that can match carbon pools to land use and land-use changes over time, and also that changes can be tracked back to the base year. Forestry historically has been important for Finnish and Swedish economies and it is not surprising that these two countries have comprehensive NFIs. Slovenia is an example of a country that recently has developed its NFI. In several other countries, like Ireland, Italy and Iceland, the acquisition of data for reporting to the UNFCCC and the KP also has been a major driver for developing new NFIs.

Twenty out of twenty-four responding countries argue that they would be able to use NFI data for monitoring land use, land-use transfers, and carbon pools for Forest land, at this stage or in a near future. This is very promising since NFIs usually contribute with high quality carbon pool data from forests and since the largest managed carbon stocks usually are found on Forest land. Twenty-five percent of the respondents were positive towards estimating carbon pools using NFI data for a majority of IPCC's six different land-use categories. Thus, several NFIs also include data for other categories than forest.

4.3.3. Key issues related to the use of NFI data for harmonised reporting

In this section, key issues regarding the contribution of NFIs to harmonised LULUCF sector reporting at the EU level are identified and discussed. The treatment follows the same structure as the presentation of the questionnaire results in Chapter 2. It covers the areas:

1. Data for estimating areas of land-use categories and land-use change
2. Data for assessing changes in the carbon pools
3. Data for estimating emissions of non-CO_2 gases

4. Miscellaneous

Data for estimating areas of land-use categories and land-use change

Regarding areas of land-use categories and transfers, two main approaches were identified in the questionnaire. The first one could be categorized as a sample based approach, complemented with maps or aerial photos (or other remote sensing techniques as satellite images). Nearly two thirds of the countries used this approach. The sampling within this approach usually was conducted by the NFI. The second approach, applied by one third of the countries, was based on maps, sometimes combined with cadastre data.

Forty-six percent of the responding countries in the questionnaire build their 1990-baseline on NFI data. This is made by direct estimates or by interpolation and extrapolation of NFI data, often combined with other data sources. One third of the countries consider it possible to "trace managed land from the base year", 54% partly and 12% not possible at al. This is not very good, since tracing land use transfers is a fundamental issue of both the UNFCCC and the KP reporting. It implies a high risk of incorrectly accumulated ARD areas from 1990 onwards.

While NFI data are important for land-use estimation it is clear that other sources of data need to be used in a majority of countries. This is due to the fact that NFIs normally concentrate on forest areas, while other land-use areas are covered by other surveys. However, in some cases the NFIs on a sample basis cover the entire land area and in such cases – especially if permanent sample plots are used – the inventories provide excellent data for constructing the land-use change matrices required under the GPG for LULUCF.

One possibility to improve the usability of NFIs in this regard would be to assess the conditions in the past on plots that have only recently been established within NFI (or other) inventory systems. If permanent plots have been established in a country post-1990, then the conditions at year 1990 onwards could either be assessed in the field on the plots (with a fair degree of accuracy) or aerial photos - or other remote sensing material - could be used to assess land-use changes since 1990. This type of remote sensing based assessments also could be used to complement NFIs that only cover forest areas.

Assessment of historical land use on NFI plots would make them more useful in several countries. It would also provide a direct link – if permanent plots are used – between land-use and carbon pool related measurements on forested plots. For non-forest plots some type of model assumption regarding the carbon pools would be needed.

While NFIs nowadays almost always are conducted as sample surveys, the identification of land areas – as required under the Kyoto Protocol – need to be carried out at the level of larger regions. Still, since permanent plots are used in many countries, transparent systems can be developed where conditions on individual sample plots can be checked by review teams in connection with in-depth reviews.

In the context of following land-use transfers, definitions of the land-use categories are important – especially the definition of forest land. FAO (2005) defines forest as land with a minimum area of 0.5 ha, with a minimum crown cover of 10% and a minimum tree height of 5 m – at maturity *in situ*. Even if only one third of the responding countries use the FAO definition, still the FAO area, crown cover and tree height thresholds are frequently used within national definitions (area 46%, crown cover 54% and tree height 71%). A problem is that the current FAO definition arose in 1998 while the UNFCCC and KP definitions should be applied from 1990.

Following the activities within COST E43 (http://www.metla.fi/eu/cost/e43/) the trend within European NFIs is to either make direct assessments of 'FAO forests', or develop recalculation schemes, so that the FAO definition of forest can be used for reporting at the national level without complication.

Sparse events (like deforestation and burned areas) often pose problems in sample based surveys. As a consequence, results from NFIs often are not very accurate with regard to such estimates, unless a very large number of plots is used.

Data for assessing changes in the carbon pools

Regarding carbon stock change estimates, the most important pool for most countries in Europe is the living biomass pool. NFI data are well suited for assessing this pool since the inventories target forests (and often also other tree-covered areas) and since biomass can be rather straightforwardly estimated using either biomass functions or biomass expansion factors (Somogyi et al. 2007). Whether the stock change or the default method is used is a matter of national circumstances. Often the stock change method can be easily applied if a country has a large number of permanent plots that cover the entire country at regular intervals. Otherwise the default method might be more appropriate to use. In the latter case, a very important issue is how the drains due to harvesting are estimated. When consumption statistics are used (which is a non-NFI issue) care most be taken so that systematic errors are avoided. With permanent plot data, or certain inventories of harvesting, direct assessment of drain can be conducted. At least over longer periods of time, drain estimates based on permanent sample plots should provide reliable estimates at the national level (e.g Ståhl et al. 2004).

Further, the questionnaire pointed at several harmonisation issues regarding the definition of aboveground and belowground biomass. One rather important issue would be to use the same threshold diameter regarding what trees are included in the estimates. It is proposed that a 0 cm threshold be applied, either through direct measurements or by using recalculation schemes in order to convert from the threshold actually used in the inventory to the 0 cm threshold. Based on Swedish data, a sensitivity analysis was conducted that showed that about 15% of the carbon stock is excluded if a 10 cm threshold is used, compared to 0 cm threshold. Regarding non-tree vegetation, about 60% of responding countries stated that there is a potential to include also seedlings and understorey vegetation in the reporting.

For the belowground biomass pool it is obvious that no direct measurements can be conducted during practical inventories. However, allometric relationships between aboveground and belowground biomass can be used or biomass function be applied that directly predict the belowground biomass from aboveground tree characteristics (e.g. Petersson & Ståhl 2006). Thus, the NFIs provide important data also for the belowground biomass.

Changes in soil organic carbon are difficult to assess in large-scale surveys like NFIs. Consequently only a small proportion of NFIs are used for repeated measurements of the soil carbon pool. On the other hand, the inventories provide basic data that can be applied in models that can be used to estimate changes in soil carbon (e.g. Liski et al 2002). The soil organic carbon pool is probably the largest pool and it is alarming that only 54% of the responding countries intend to monitor this pool by either measurements or models. The remaining countries seem to rely on default values or have not yet decided a methodology. Two thirds of the countries are able to distinguish basic soil types from NFI data and about half of the countries are able to separate mineral from organic soils.

Dead wood increasingly is being incorporated in NFIs, mainly for purposes of assessing biodiversity; a majority of countries have such data in their NFIs. These data can be utilised also for estimating changes in the dead wood carbon pool, at least with regard to aboveground dead wood. Belowground dead wood poses several problems, although methods utilising stump decomposition functions are applied on NFI permanent plot data in some countries. The questionnaire also pointed at several needs for harmonising the basic definitions of dead wood between countries. Among countries that have decided upon a definition of minimum threshold of dead wood, about 50% have chosen a 10 cm diameter threshold, and about 40% a minimum length of 130 cm; 84% percent include both standing and lying trees, and 64% also stumps in their definition of dead wood.

From a harmonisation perspective, the litter pool is comparable with the dead wood pool, although the litter pool offers even more harmonisation problems. Some countries will probably use the option not to report removals from the litter pool, by proving that the pool does not constitute a net source. About half of the countries answered that they could separate litter from the soil organic carbon pool. Among countries that report this pool, measurements, modeling and default values are used. One promising thing is that about 60% state that there is a potential to at least partly apply NFI data for this pool.

Some conclusions regarding the use of NFIs for assessing the different carbon pools are:

1. NFIs are excellent tools for estimating carbon pool changes in living biomass in forests
2. Dead wood is increasingly incorporated in NFIs and this pool can be assessed based on NFI data in a majority of countries
3. Litter and soil organic carbon poses substantial harmonisation problems. NFI data seem to be used only to a limited extent to follow changes in these pools, although basic NFI data can be applied in model-based predictions.
4. There is a need to further harmonise the definitions of the carbon pools used by the different European countries, and develop procedures so that countries can report using 'reference' definitions.

Data for estimating non-CO_2 emissions

NFIs may also be used for monitoring non-CO_2 emissions. N_2O emissions from drainage of soils today are optional but might become mandatory to report in the future. In this context, NFIs can contribute with basic data on areas of drained land and may also provide information on soil type, current draining ability of ditches, etc. For some European countries N_2O emissions from drainage of soils are important in the LULUCF-reporting. This is the case since large areas are drained and since the GWP of N_2O is set to 310 (one emitted N_2O-unit is assumed equivalent to an emission of 310 CO_2 units).

Nitrous emissions from N fertilization of forest land are quite uncommon in European countries and usually the sampling intensity of NFIs is too low to properly monitor uncommon events. To improve the accuracy of estimating N_2O emissions from N fertilization of forest land, production statistics of traded quantities of fertilizers might be a better alternative than using NFI data. However, with the current reporting system it is desirable that such emissions could be reported separately for, e.g., land under Forest management and under AR.

Nitrous emissions from disturbance associated with land-use conversion to Cropland are reported under the LULUCF sector. It might be straightforward to monitor such emissions in connection with conversions from Forest land to Cropland using NFI data. Historically, conversions from Forest land to Cropland have been rare, but recently prices of crops have increased and this type of conversions should not be neglected in future monitoring.

Especially in the Mediterranean area, fires are common and there is a potential of monitoring fires using NFI data. According to GPG for LULUCF emissions should be reported separately per gas (N_2O, CH_4 and CO_2) and per wildfires and controlled burnings, respectively. NFIs might not only provide information on areas burned but also on emitted amounts per area. The emitted amounts require at least information on *i*) type of fire (for example, temperature and oxygen-supply might influence the amount and proportion of different emitted gases), *ii*) living woody biomass stock before and after fire, and iii) dead wood and litter stocks before and after fire. There is a higher potential of monitoring wildfires than controlled burnings by NFIs, because wildfires probably are spatially more randomly distributed than controlled burnings. Controlled burnings are usually made to improve regeneration of trees or for biodiversity reasons (in northern Europe), and since the intention is to make them controlled their location and situation before and under fire is known. This may be one reason for not using NFI-data for monitoring controlled burnings.

Miscellaneous

In addition to what has been treated above there are several issues related to NFI data that affect their usefulness for the reporting. One very important issue is the availability of data, since inventories in different countries have been conducted at different time intervals. While the UNFCCC and KP require annual reporting, there is a clear need for interpolation and extrapolation procedures to be developed when NFI data are used. At the moment, different countries use different approaches for this, and development work is needed in order to establish harmonised routines.

Further, definitions used within NFIs often change over time, and thus there is a need for countries to establish national recalculation methods that make data temporally comparable.

Uncertainty assessment is another undertaking that is required according to the GPG for LULUCF. While the GPG proposes two basic methods for this purpose, sample based NFI fit poorly into both. Instead, procedures based on statistical sampling theory should be developed.

4.4. *Discussion and Conclusion*

This study has pointed as several possibilities and problems related to the use of NFI data for harmonised LULUCF sector reporting within EU and Europe. Several issues can be listed on the positive side:

- NFI data are available from almost all countries in Europe, or NFIs are currently being planned
- The basic type of data provided by NFIs are suitable for a wide range of purposes connected with greenhouse gas reporting
- NFIs can be rather easily modified, and since reporting to the UNFCCC and its KP are major issues today, several NFIs currently modify their scope and design in order to provide better estimates related to greenhouse gases.
- Between the European National Forest Inventories, collaboration is ongoing in order to improve the harmonisation across countries.

On the negative side of using NFI data, the following items can be listed:

- NFI data are not available from all countries and all time periods, and thus geographical and temporal interpolation and extrapolation is needed in order to provide complete assessments.
- Different definitions are used in different countries, and thus there is a major need to harmonise definitions and develop recalculation schemes in order to provide harmonised figures across Europe.
- The accuracy of estimates of sparse events (like deforestation and burned areas) generally is low.
- There are no guarantees that all countries will continue performing NFIs, although the trend lately has been that countries are installing such inventories.

Continued collaboration between the European NFIs is a key concern if the reporting at EU level should be based on country-level NFI data. This type of harmonisation has been ongoing for a long time on a bilateral basis, while since 2003 it has been formalised under the umbrella of the European National Forest Inventory Network (ENFIN). Almost all EU countries (and several other countries as well) are members of ENFIN – which has the major objective of making information from NFIs comparable and available at the European level. Since 2004, the concrete work has been conducted within the project COST Action E43 (http://www.metla.fi/eu/cost/e43/). Within this project, one of the workgroups has focussed specifically on the use of NFIs for greenhouse gas reporting.

Regarding the suitability of NFIs for different hypothetical post-Kyoto agreements, there are several options currently being discussed. Negotiations of such an agreement may cover issues like gross-net or net-net accounting, holistic or activity based systems, and possibly connections between data quality and rules for the accounting. NFIs usually provide high-quality carbon pool data. If a net-net accounting approach is chosen, then the accuracy of estimates of carbon pools at the baseline could be improved by using average data from several years. Such averaging could also improve estimates using the gross-net approach. A similar solution to improve data quality and to avoid undesired variation between years would be to report for longer periods rather than on an annual basis.

The IPCC has developed new guidelines (2006) intended but not yet adopted for future reporting. Compared to current reporting, the LULUCF sector and the agriculture sector are suggested to be reported together. The reporting of Harvested Wood Products and emissions from some non-CO_2 gases are suggested mandatory.

In conclusion, our study shows that NFIs play a major role in the LULUCF sector reporting in Europe. Since NFIs are established mainly for other purposes than greenhouse gas reporting, but can rather easily be adapted to cover this topic as well, NFIs offer a cost-efficient alternative to initiating new inventories. However, use of NFI data for this purpose poses several problems. Although harmonisation efforts are ongoing there are still several needs to make data and information comparable, and to fill in geographical and temporal data gaps.

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5. Enhancing the Capacity of European National Forest Inventories to Support the LULUCF/AFOLU Sector Reporting

Göran Ståhl and **Sven Hans-Olof Petersson**Swedish University of Agricultural Sciences, Sweden
E-mail: Hans.Petersson@srh.slu.se and Goran.Stahl@srh.slu.se

Abstract

Reliable reporting and accounting of greenhouse gas emissions and removals are becoming increasingly important in the global ambitions to mitigate climate change. This concerns several sectors, including the land use, land-use change, and forestry (LULUCF) sector of the UN Convention on Climate Change (UNFCCC; IPCC 2000) and its Kyoto Protocol (KP). In the future this sector will be merged with the current agriculture sector to form the agriculture, forestry, and land use (AFOLU) sector (IPCC 2007). Within both the current LULUCF sector and the future AFOLU sector data requirements are substantial in relation to what is generally available in the countries that are parties to the convention. In many cases data from National Forest Inventories provide a significant portion of the data required for the forestry sector. Sometimes these inventories also provide data on land use changes. Due to this, National Forest Inventories are attracting increased interest from the climate change community although these inventories mainly have been developed for purposes other than greenhouse gas reporting.

5.1. *Introduction*

Trees are the most dynamic components of the terrestrial ecosystem with regard to greenhouse gas emissions and removals. Tree growth implies major carbon sequestration whereas harvesting and disturbances, such as fires, result in carbon dioxide emissions. National Forest Inventories generally provide reliable data on tree volumes and biomass and thus they can be used to estimate changes in tree carbon stocks over time. This includes both aboveground and belowground biomass. Moreover, mainly due to the interest from the point of view of biodiversity monitoring, dead wood is mostly included in the assessments. Changes in dead wood stocks also are important in greenhouse gas reporting. Litter and soils sometimes are sampled although in most cases the precision of those assessments are low in National Forest Inventories.

National Forest Inventories are conducted in slightly different ways in different countries. Normally they are sample-based, i.e. only a very small portion of forests are actually measured. However, by applying sampling theory one can show that often rather modest sample sizes yield high precision for several important parameters, such as total volume or biomass within larger regions or countries. Some countries still apply approaches where the entire forests are partitioned into stands, which then are surveyed periodically with quick methods (due to the huge costs that would otherwise arise). However, a clear trend is that almost all countries adopt sample-based national forest inventories, due to their superiority from the perspective of quality control and costs. Another trend is that countries move from systems that survey countries region by region, to systems that cover a certain fraction of the entire country every year. The latter approach is superior from the point of view of providing annual estimates of the kind required under UNFCCC and KP.

In a study by Colin et al. (2008) it was shown that most European countries utilize National Forest Inventories for monitoring changes in tree carbon stocks and for the reporting of this component to the UNFCCC and the KP. Most countries also utilize national forest inventory data for reporting the dead wood component. To a lesser degree, the data are used for litter and soils, and land use transfers. However, a conclusion was that National Forest Inventories are very important for the reporting and accounting within the LULUCF/AFOLU sector and thus further study on how National Forest Inventories may be developed for enhancing the quality of the reporting are motivated.

The objective of this study was to analyze European National Forest Inventories from the point of view of their usefulness for the reporting, and to propose changes that could be implemented in order to enhance the quality of the reported figures. The likely costs associated with such changes are also crudely assessed.

5.2. *Review of current NFIs in relation to reporting requirements*

In this section we review to what extent European national forest inventories are currently used for LULUCF sector reporting, creating a basis for suggesting improvements. The presentation is made for the major reporting subject areas within the LULUCF sector, as described by Bird (2008) and Colin et al. (2008). We present advantages and disadvantages of using NFIs for the reporting, forming a basis for the subsequent chapter (3) where it is proposed how the disadvantages can be reduced by adequate NFI improvements.

The review largely is based on the findings from the study by Colin et al. (2008), which was conducted within the framework of the MASCAREF project as a questionnaire submitted to European countries. The responding countries are shown in Figure 5-1.

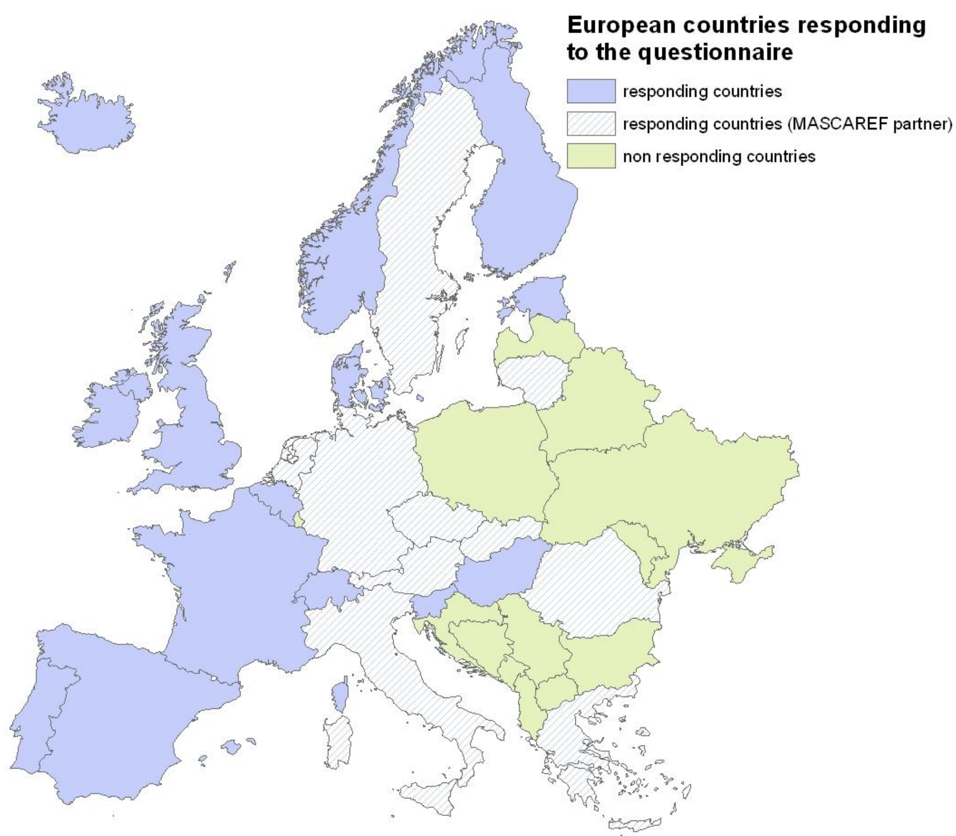

Figure 5-1 European countries included in the questionnaire (from Colin et al. 2008)

The forest area of the responding countries is 78% of Europe's forests (excluding Russia) and 90% of the forests within EU-27. Non-respondents (some of which did not receive the questionnaire) are mainly located in east Europe. In some of these countries national forest inventories are not conducted on a regular basis, although in several countries (like Russia) planning for such inventories is ongoing.

5.2.1. Coverage of NFIs

The spatiotemporal coverage of NFIs and thus data availability is an important issue. At the level of EU, the only large countries that lack a regular NFI today appear to be Poland and Greece. In all other countries NFIs are conducted with certain intervals. While the UNFCCC and KP require annual reporting, there is a clear need for interpolation and extrapolation procedures to be developed when NFI data are used. At the moment, different countries use different approaches for this, and development work is needed in order to establish harmonised routines.

Overall, the coverage and number of plots installed by European National Forest Inventories is overwhelming. Large amounts of money are spent on providing decision support information to (mainly) national stakeholders. The EU as well as the international society at large (e.g. through the work of FAO) can benefit from this, since regional compilations can be produced from the information provided by the countries.

5.2.2. Data provision by NFIs

In this section, we review what type of data is provided by NFIs, in relation to the reporting needs. We first explore land-use categories and land-use transfers and then study the different carbon pools and non-CO_2 gases.

Land-use categories and land-use changes

The Good Practice Guidance (GPG) for LULUCF (IPCC 2003) defines six categories of lands: forest land, cropland, grassland, settlements, wetland, and other land. Considering the methodological requirements, carbon pool changes have to be reported separately for land areas remaining in the given land category and for land areas converted to the current land use category during the last 20 years.

European NFIs to a varying extent contribute to national systems for detecting land-use changes. Since forest is a main concern for NFIs, NFI data are more often used to detect changes in the forest category. About 46 % of the responding countries indicate that the NFI currently contributes to the estimation of land-use changes in this category. It obviously includes forests remaining forests, but also afforestation (from non-forest to forest) and deforestation (from forest to another land use category). However, NFIs are used for general land-use and land-use transfer data in only about 20% of the countries (Figure 5-2).

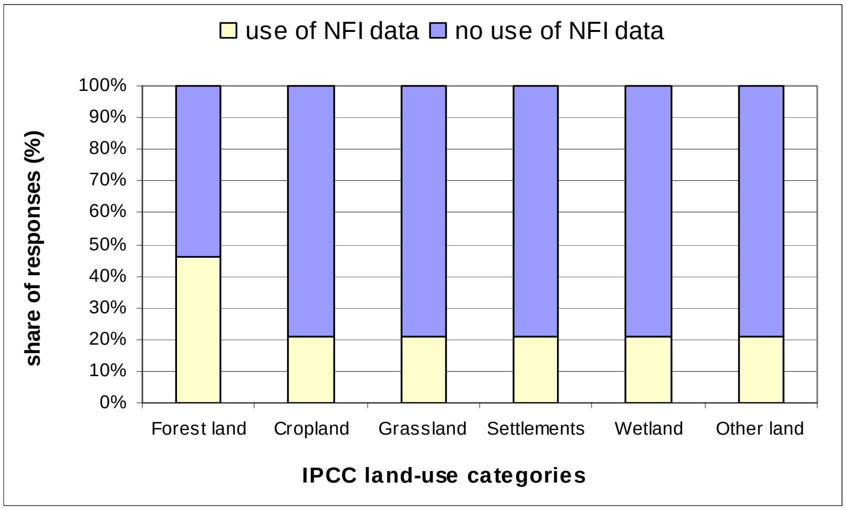

Figure 5-2 Contribution of NFI to the estimation of areas of land use changes under UNFCCC reporting (from Colin et al. 2008)

One straightforward, but expensive, approach to improve the usability of NFIs from the point of view of estimating all types of land-use categories and land-use transfers would be to expand the geographical scope of the inventories to cover the entire land area of countries. In such expansions permanent plots, and most likely two-phase approaches combining remote sensing and field survey, should be applied. However, such expansions in many cases would be very expensive. An alternative solution would be to link the NFIs with inventories providing land use and land use change statistics. This is described in more detail later on.

Historical land-use data

Historical land-use data are important since the state up to twenty years before the base year (normally 1990) sometimes is required. In Table 2-1, a summary of the availability of such information is provided.

Table 5-1 Oldest year of land use information implemented in the UNFCCC reporting system, and feasibility to trace land use from this year onwards (from Colin et al. 2008)

Oldest year used for the detection of land use changes	Share of responding countries	Possibility to detect the previous land use			
		Total	Yes	no	partially
Before 1970	13%	*100%*	33%	0%	67%
Year 1970	17%	*100%*	25%	25%	50%
From 1971 to 1989	50%	*100%*	33%	8%	59%
Year 1990 (baseline)	13%	*100%*	67%	33%	0%
After 1990	8%	*100%*	0%	100%	0%

Almost all countries (92 %) have access to historical information on land uses since 1990 and 86 % of the national systems are able to provide information (through direct measurements or modelling procedures) on the previous land use of the areas reported in the ongoing emission inventory.

From the point of view of improving national forest inventories in this regard, NFIs that have been started up recently (or for other reasons lack historical land-use data) could combine field assessments of past land use with historical remote sensing data to produce records of historical land use for their permanent plots. In this way, even newly established NFIs would generally be able to gain access to the historical data needed for classifying different areas to either classes with stable or changing land use. Alternatively, in many cases the historical land use (at least when nothing has changed) could be assessed directly during the field inventory and thus only in the uncertain cases there would be a need to consult old imagery. The latter type of approach could be applied as a means to reduce costs.

Identification of lands subject to activities under Articles 3.3 and 3.4 of the Kyoto Protocol

About one fifth (21 %) of the responding countries declared that NFIs are the only source of data being used in the system they developed to estimate the baseline data for the Kyoto Protocol reporting. Once baseline data are estimated, the next step is to detect the areas where Article 3.3 (ARD) and Article 3.4 (forest management) activities have occurred since 1990. NFIs are frequent sources of data for the land use transfer detection; 62.5 % of the countries answered that NFI data are currently used to achieve this objective, alone (37.5 %) or in combination with non-NFI data like maps on forest fires or afforestation, digital orthophotos, etc. The most frequently used NFI data are the ones gathered on the sampling plots (50 % of the responding countries) followed by the data extracted from maps.

In addition, the Marrakech Accords prescribes that the geographical boundaries of areas encompassing units of land subject to afforestation, reforestation, deforestation and forest management are to be reported by the Parties. GPG for LULUCF defines two methods to achieve this objective. The first approach is to delineate areas that include multiple land units subject to Article 3.3 and 3.4 activities (e.g., areas are calculated and reported within administrative regions); the second approach implies that individual units of lands subject to 3.3. and 3.4 activities be individually identified. From the questionnaire responses, the first approach is much more frequently applied, since it will be implemented in 77 % of the countries where a decision has been made in this regard (22 countries out of 24).

With permanent NFI plots, identification of ARD and forest management is straightforward. However, from a data uncertainty point of view it is very demanding to assess sparse events (like deforestation) with adequate accuracy in sample based surveys.

Regarding identification of areas, the first approach of the GPG has to be adopted when sample surveys are conducted. With permanent plots quality control can still easily be implemented through checks of some sub-sample of the plots by independent control teams; the permanent plots with known locations allows for transparency of the system.

Data on above- and belowground biomass

NFI data are frequently used in assessing aboveground biomass of trees (74 % of the countries). Understorey vegetation is less frequently included in the living biomass pool; aboveground biomass of understorey vegetation is reported by 25% of the countries, while only 8 % of the countries also include the belowground biomass of understorey vegetation. Many of these countries implement NFI data in the calculations (Table 5-2).

In most cases understorey vegetation constitute only a tiny fraction of living biomass, and thus it is doubtful if inclusion of non-tree biomass should be recommended for NFIs from the point of view of GHG reporting. However, for both above- and belowground biomass there is room for improvements regarding the use of NFI data. Especially for belowground biomass, a major reason for not using NFI data is the lack of adequate functions (or other conversion factors) relating measurable tree quantities to belowground biomass (cf. Somogyi et al. 2007 and Zianis et al. 2005).

Table 5-2 Type of vegetation included in the reporting on living biomass pool and the use of NFI data (from Colin et al. 2008)

Type of vegetation	Carbon pools	Included in the accounting system (share of countries)	Estimate based on NFI data (share of countries where the information is relevant)
Trees	aboveground biomass	96%	74%
	belowground biomass	100%	42%
Understorey	aboveground biomass	25%	33%
	belowground biomass	8%	50%

Whereas tree biomass is reported in most countries, trees are defined in different ways. Minimum DBH varies from 0 (*i.e.* all the trees are included) to 12 cm (*i.e.* trees with a diameter > 12 cm at 1.3 m height are included). The most frequent answer was zero (29 %) while 20 % apply a minimum DBH of 5 cm and 20 % a minimum DBH of 7 cm (Figure 5-3).

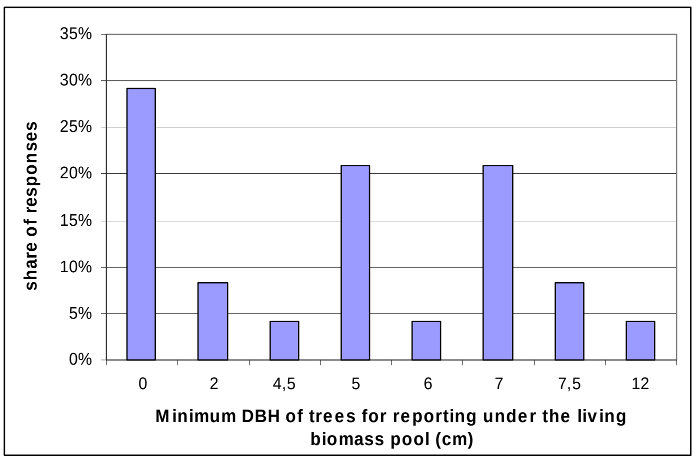

Figure 5-3 Minimum DBH of trees for their inclusion into the living biomass pool for the reporting (from Colin et al. 2008)

Figure 5-3 points at the importance of further harmonisation of NFIs. Even if the differences mainly involve small trees, there are examples of countries where quite substantial biomass changes have occurred among small trees.

Dead wood

Carbon stock changes in this pool are assumed to be zero by 30% of the countries and thus the pool is not reported (consistent with GPG Tier 1 methodology). Further, substantial differences in the definition of the dead wood pool were observed. The most common minimum diameter is 10 cm (67 %); this corresponds to the FAO (2005) definition and is also consistent with the IPCC definition.

Changes in aboveground dead wood biomass are predominantly based on direct NFI data measurements or models built on NFI data sets, since 60 % of the responding countries answered that these data are being used in their inventory system, alone (50 %), or in combination with other data sets.

Clearly there is room for improvement of NFIs regarding the inclusion of dead wood for the GHG reporting. Issues to consider include definitions (harmonisation), inclusion of deadwood into the inventory systems, and development of conversion factors that account for degree of decomposition. One important issue that deserve to be highlighted is how dead root systems are dealt with. In many cases it is unclear whether or not they are included in the mean time as the changes in carbon in dead root systems may be substantial if harvests increase or decrease over time.

Litter pool

Just like in the case of dead wood, substantial differences in definitions of litter were observed (see also Cienciala et al. 2008).

From the questionnaire responses, carbon changes in the litter pool are reported in 2/3 of the responding countries. In the others, litter is assumed to be a carbon neutral pool. When carbon changes in the litter are reported, modelling is the most frequently applied methodology (50 % of the respondents) as presented in Figure 3-24.

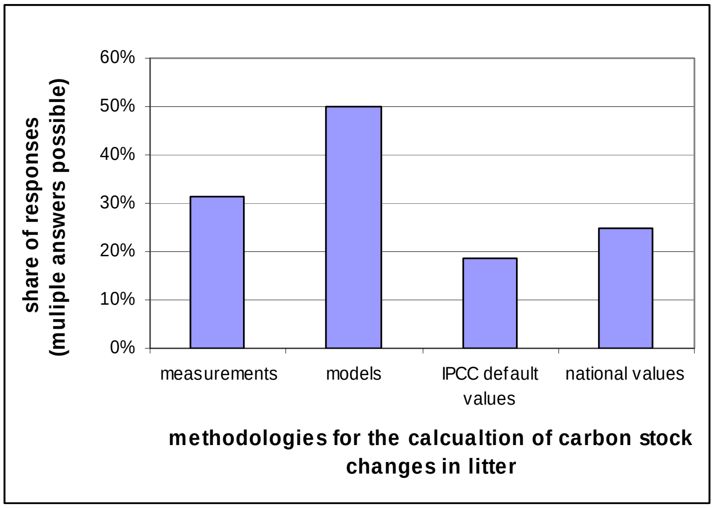

Figure 5-4 Methods for calculation of carbon stock changes in the litter pool (multiple answers possible; from Colin et al. 2008)

NFI data frequently are used for the litter pool calculations; 44% of the countries declared using them, alone (12.5 %) or in combination with other data sources.

The assessment of GHG emissions from litter apparently could be better in NFIs. However, due to the methodological problems involved it is unclear if direct measurement of this pool should be conducted or if variables that support model based assessments instead should be recommended. We judge that direct measurements should only be conducted at all NFI plots if there is reason to believe that major changes occur and if the available budget is sufficient for making the required measurements with high accuracy. There is an obvious risk for varying extent of systematic errors between different time points; if this occurs the estimated changes would have very poor accuracy.

Soil organic carbon

For this pool, the share of countries that use IPCC default values is quite large (38 %; Figure 5-5). Otherwise countries rely either on modelling, repeated measurements, or national default values.

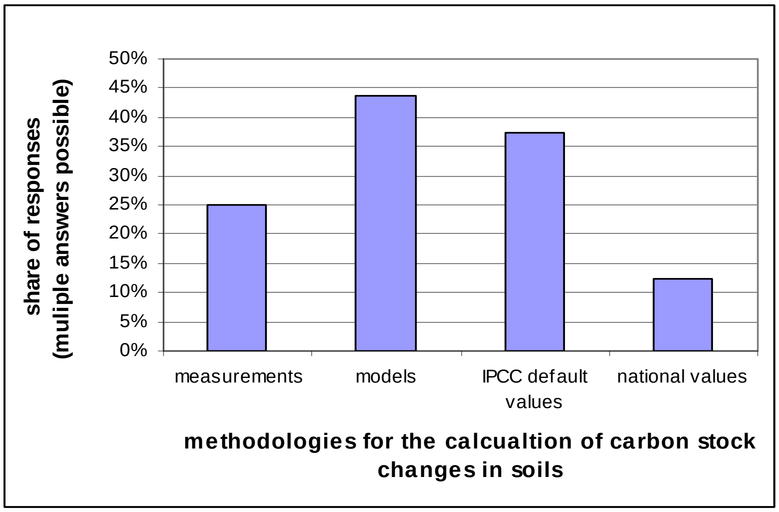

Figure 5-5 Methods for calculation of carbon stock changes in soils (multiple answers are possible; from Colin et al. 2008)

The contribution of NFI data to the stock change calculations for soils is less than for litter. However, it is still important since 31 % of the responding countries use them, alone (19 % of the countries only rely on NFI data for this calculation) or in combination with other data sources.

Many countries probably would gain precision in moving from IPCC default values in the reporting to model based assessments. In this context, NFIs could provide valuable input to the model used. Just like for the litter pool, it is important that very careful measurements of soil organic carbon are performed (if they are performed), since there is an obvious risk that change estimates based on repeated measurements will include an unknown systematic error component.

Non-CO_2 gases

Many non-CO_2 gases are optional to report today, but may become mandatory in the future. N_2O emission from drained soils is one example, nitrous emissions from fertilisation another. In this context, NFIs can contribute with basic data on areas of drained or fertilised land and may also provide information on soil type. However, when these activities only cover small areas problems arise to assess them with sample based inventories. Issues like fertilisation also are difficult to detect and thus require other data sources, or information from land owners or managers.

Especially in the Mediterranean area, fires are common and there is a potential of monitoring fires using NFI data. According to GPG for LULUCF emissions should be reported separately per gas (N_2O, CH_4 and CO_2) and per wildfires and controlled burnings. NFIs might not only provide information on areas burned but also on emitted amounts per area. The emitted amounts require at least information on *i*) type of fire (for example, temperature and oxygen-supply might influence the amount and proportion of different emitted gases), *ii*) living woody biomass stock before and after fire, and iii) dead wood and litter stocks before and after fire.

5.2.3. Definitions adopted

Definitions are important for coherent reporting. Below, we illustrate this with two important definitions from a LULUCF GHG reporting perspective – forest area and forest management. Forest area is one of the key variables affecting the reported emissions; a broad definition of forest was intensively discussed and finally adopted by the parties to the KP (Marrakech Accords, UNFCCC 2002). Predefined ranges of values for three key parameters were specified: the minimum area, the minimum crown cover, and the minimum tree height at maturity. Figure 3-46 provides information on which thresholds have been selected within the responding countries.

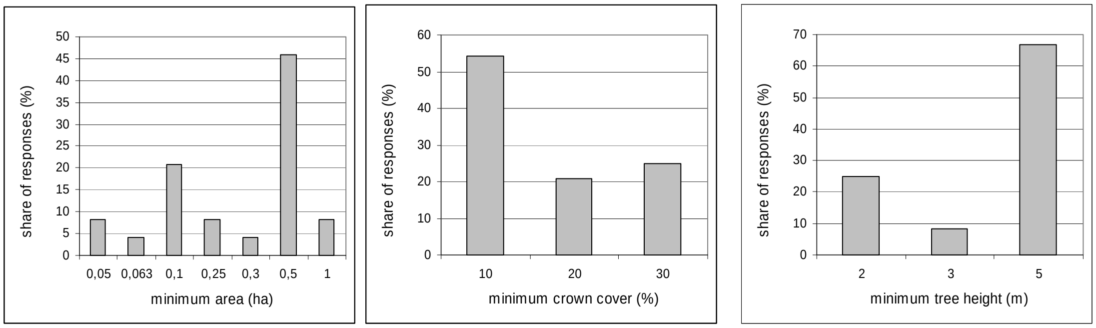

Figure 5-6 Adopted thresholds for the definition of forest within the 24 responding countries (from Colin et al 2008)

It is clear that the parameters that correspond to the FAO definition of forest have most frequently been adopted; this means a minimum area of 0.5 ha (46 % of the countries), 10 % of minimum crown cover (54 %) and a minimum tree height of 5 m (67 % of the responses). However, they are applied simultaneously only by 29 % of the responding countries.

Another important definition concerns 'managed forests'. From the questionnaire responses, most countries (71 %) consider all their forests as managed. However, nature reserves are declared unmanaged by 8 % of the respondents (Figure 5-7) and the forests where leisure or aesthetics functions are predominant are reported unmanaged by 12.5 % and 4 %, respectively, of the responding countries.

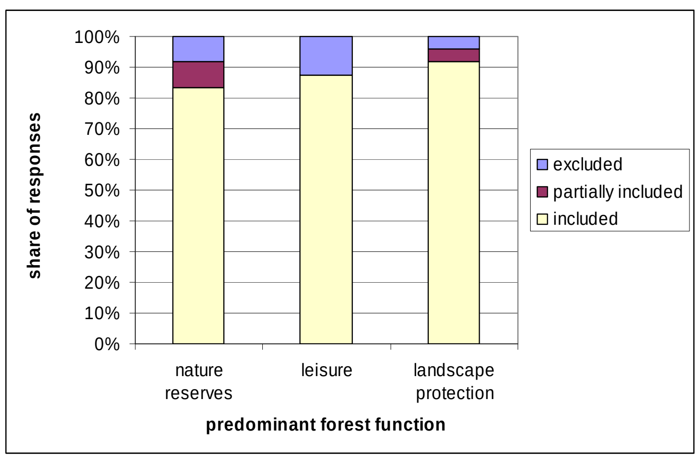

Figure 5-7 Share of responding countries where the definition of managed forest includes non-timber-production forests of different kinds (from Colin et al. 2008).

Although there are many similarities between countries, it appears that harmonisation is still an important issue. NFIs can contribute to this through reporting according to agreed-upon comparable reference definitions.

5.3. *Propositions for improved LULUCF/AFOLU sector reporting based on NFI data*

National Forest Inventories continuously are developed to meet new requirements. Thus there are good possibilities to revise current practices in order to make the inventories better adapted for LULUCF/AFOLU sector reporting. In this chapter we propose changes that would be relevant for a majority of NFIs to apply. The propositions are based mainly on the findings by Colin et al (2008), Freudenschuss & Weiss (2008), work within COST E43, and a synthesis within the scope of the MASCAREF project.

In a previous study within the MASCAREF project (Colin et al. 2008) advantages and disadvantages of using national forest inventories (NFIs) for the reporting were identified. Issues on the positive side include:

- NFI data are available from almost all countries in Europe, or NFIs are currently being implemented.
- The basic types of data provided by NFIs are suitable for a wide range of purposes connected with LULUCF/AFOLU sector greenhouse gas reporting.
- NFIs can be rather easily modified, and since reporting to the UNFCCC and its KP are major issues today, several NFIs currently modify their scope in order to provide better estimates related to greenhouse gas emissions and removals.
- Uncertainty assessment of reported figures generally is fairly straightforward following standard sampling theory.
- Between the European NFIs, collaboration is ongoing in order to improve the harmonisation of reported figures across countries.

On the negative side, the following main items were identified:

- NFI data are not available from all countries and all time periods, and thus geographical and temporal interpolation and extrapolation are needed in order to provide complete assessments.
- Although basic data related to forest area and biomass are available in all NFIs, the coverage of other land use categories and land use transfers, as well as non-biomass carbon pools, could be improved upon.
- Different definitions are used in different countries, and thus there is a need to harmonise definitions and develop recalculation schemes (so called ‘bridges’) in order to provide harmonised figures across Europe.
- The accuracy of estimates of sparse events (like deforestation and burned areas) generally is low.
- There are no guarantees that all countries will continue performing NFIs, although the trend lately has been that countries are installing such inventories.

We identify the following main possibilities for improvement of NFIs to enhance their capacity for LULUCF/AFOLU sector reporting. The propositions follow the same structure as the NFI-related problems identified above.

5.3.1. NFI data availability

Although NFI data are available from most European countries (or NFIs are being planned, also in Russia which comprises a large portion of European forests) some countries do not conduct NFIs on a regular basis. Some large countries of this kind are located in east Europe and it is unclear whether or not NFIs will be installed in these in a near future.

However, at the level of EU almost all countries conduct NFIs at a regular basis. For those (few) countries where NFIs currently are not carried out, like Poland and Greece, the measurements within the ICP Forests level I plot networks could be expanded and utilised as substitutes. Current activities within the EU/Life+ FutMon project include studies on how to merge the plot networks of NFIs and ICP Forests level I, as there are obvious synergies resulting from doing so.

Another issue related to data availability concerns temporal coverage. In many countries NFIs are only conducted at certain intervals and thus harmonised procedures for interpolating and extrapolating data become important. Currently there is a lack of such procedures and thus there is a need for methodological development. However, there is a limit to how long interpolations and extrapolations are meaningful, and in some countries shorter intervals between inventories would be appropriate.

With regard to data availability, our propositions are to ensure that adequate data are provided through appropriately merging the ICP Forest level I network with NFIs, and to develop harmonised procedures for data interpolation and extrapolation.

5.3.2. Additional variables

Many NFIs could be improved from a land-use category and land-use transfer estimation point of view by developing a full coverage of terrestrial areas. Currently, only about 20% of the European NFIs can be applied for estimating all types of land- use categories and transfers. Many NFIs only cover forests and this, naturally, implies limitations in relation to estimating areas of land-use categories and land-use changes. In many cases, like in Ireland and Switzerland, two-phase approaches involving air photo interpretation and field survey could be applied to limit the inventory costs if the spatial coverage were increased. The sample plots ideally should be permanent to permit efficient estimation of changes.

An alternative to expanding the NFIs for land-use transfer assessment is to seek collaboration with the landscape level inventories (incl. the EU LUCAS survey) that are emerging in many countries. Whereas these inventories generally are appropriate for following land-use changes their capacities to monitor carbon pool changes are mostly limited. However, by ensuring linkages (same core set of variables) in both types of inventories co-utilisation of data would be facilitated and thus data on land-use changes from landscape inventories could be matched with data on the related carbon pool changes from NFIs. In most cases this would be the most straightforward, at least from a cost point of view, organisational approach and thus only in those countries where no landscape level inventory is ongoing should the NFIs aim for increased spatial coverage.

The biomass carbon pools

In a MASCAREF study by Freudenschuss and Weiss (2007), 24 European countries were asked about their usage of biomass expansion factors (BEFs) and biomass functions (BFs) in connection with NFIs. It was found that more than 50 % of the responding countries use NFI data and locally derived BEFs or BFs. Including those countries that plan to use NFI data for this purpose in the future there is a clear majority that use NFI data.

Figure 5-8 and Figure 5-9 show the frequency distribution of the use of BFs, BEFs, both (BEFs and BFs) or other approaches for above- and belowground biomass estimates based on local studies, international literature or the IPCC GPG (default values). The first two bars (green-blue colour) represent BEFs or BFs used in combination with the default method (increment and removal); the third bar (yellow) shows the percentage of countries that use BEFs or BFs in combination with the stock change method. Thus, some countries use BEFs or BFs from local studies but also international BEFs or BFs and/or IPCC default values e.g. for other tree species the cross sum of the bars goes beyond 100%.

The results show that most countries (83%) apply BEFs or BFs which are based on local studies. About 17% (12.5% default and 4% stock change method) of the countries use local biomass functions whereas the majority (37.5%) uses local BEFs (12.5% increment/removal, 25% stock change method) and 25% use BEFs as well as BFs (12.5% for each method). Barely other methods than the application of BEF or BF are used to estimate living aboveground biomass (e.g. France).

BEFs or BFs from international sources are used in about 29% of the countries. 20% uses both, local and international BEFs or BFs, whereas two countries (NO and NL) rely only on international BFs (in total 8%, 4% for each method). However, BEFs derived from international literature are used more frequently (in total 16%; 8% for each method) than international BF. One country applies both, BEFs and BFs, from international sources.

IPCC default values are applied in 33% (about 17% for each method) but only one country (4%) uses no other international or local factors or functions.

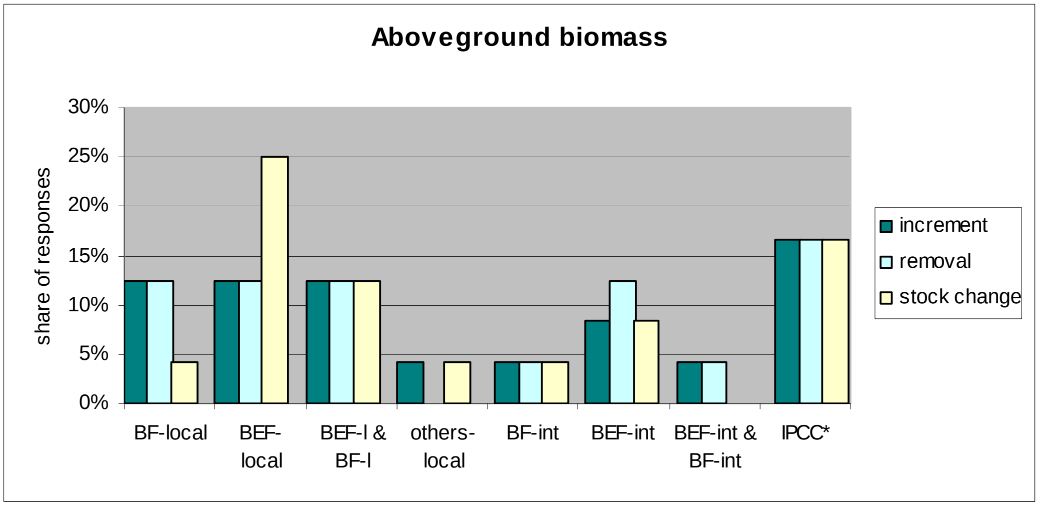

Figure 5-8 Use of BEF and BF from local studies (l), international literature (int) and IPCC default values for living aboveground biomass of the responding countries (from Freudenschuss and Weiss 2008)

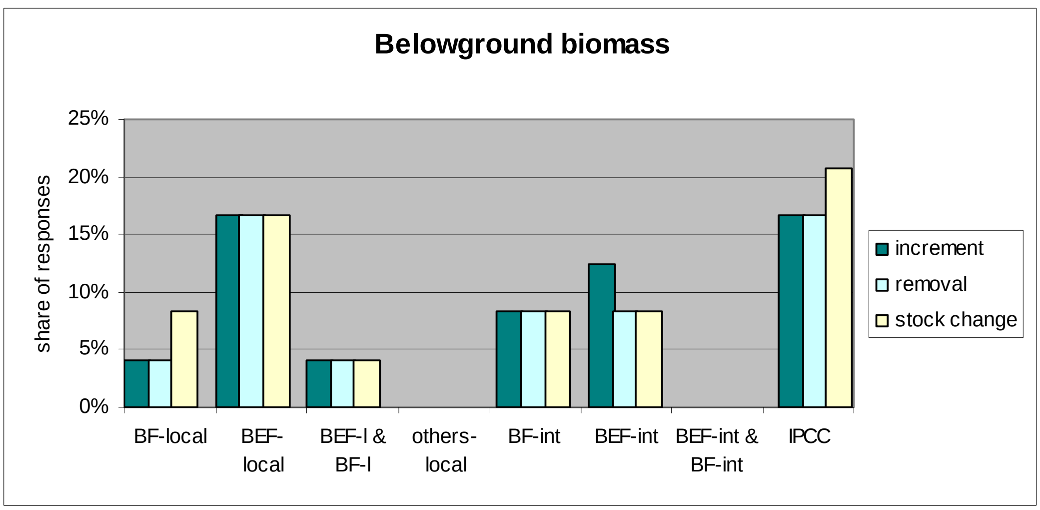

Figure 5-9 Use of BEF and BF from local studies (l), international literature (int.) and IPCC default values for living belowground biomass of the responding countries (from Freudenschuss and Weiss 2008)

Regarding aboveground biomass, most countries appear to cover this pool with adequate accuracy, although the ‘classical’ problem of utilising compatible biomass functions and biomass expansion factors obviously still is posing challenges. The underlying problem is that biomass functions are very expensive to develop/improve due to the huge workloads involved in felling and weighing trees, including their stump-root systems. Regional – rather than country-by-country approaches – to develop improved biomass functions would be a cost-effective (but probably difficult-to-organize) alternative. For belowground biomass, this problem is even more pronounced as rather few countries currently appear to have access to local BFs or BEFs for this biomass pool. In some cases newly functional relationships of this kind have been developed for application in NFIs, see Petersson and Ståhl (2006).

We propose that continued work with developing biomass functions and biomass expansion factors are necessary in order to ensure high quality reporting based on NFI (or other) forest data. This holds for both the above- and belowground biomass components.

The non-biomass carbon pools

Changes in soil organic carbon are difficult to assess in large-scale surveys like NFIs. Consequently only a small proportion of NFIs are used for repeated measurements of the soil carbon pool. On the other hand, the inventories provide basic data that can be applied in models that can be used to estimate changes in soil carbon (e.g. Liski et al 2002). Dead wood increasingly is being incorporated in NFIs, mainly for purposes of assessing biodiversity; a majority of countries already have such data in their NFIs. These data can be utilised also for estimating changes in the dead wood carbon pool, at least with regard to aboveground dead wood. Belowground dead wood poses several problems, although methods utilising stump decomposition functions are being developed in some countries.

In many countries there is clearly an option to improve the capacities of the NFIs by expanding the measurements related to dead wood, litter, and soils, although this involves several methodological challenges. Dead wood increasingly is being included in NFIs, mainly due to the importance of this substrate as an indirect biodiversity indicator. Thus, as dead wood also is important from the LULUCF/AFOLU sector reporting, it is likely that it will gradually be included in all NFIs. Dead wood requires other conversion factors than biomass, and in most countries there is a clear potential to improve those factors.

Litter includes both fine woody debris and the upper organic soil layer. Less than 50% of the NFIs cover these fractions today and there is room for improvement. However, the methodological challenges are substantial. The situation is similar for soil organic carbon. It is unclear whether or not increased measurements of litter and soils in NFIs should be recommended. An alternative is to further improve model- based assessments of these pools, as it is known from several studies that small measurement errors on large pools may cause substantial bias in change estimates. However, to support the model-based assessment appropriate data on independent variables in the model must be collected and for many NFIs this would imply slightly increased ambitions in the data collections.

Further, models for the litter and soils must be fed with calibration data and their performance must be checked at least from a limited set of sites where careful measurements are conducted. In some cases – when the NFIs already conduct soil surveys – it might be appropriate to co-organize careful control measurements of this kind in connection with the NFIs.

5.3.3. Further harmonisation of the reporting

Countries currently use slightly different definitions of the variables relevant for the LULUCF/AFOLU sector reporting. Harmonisation of NFIs has lately been initiated in several projects and processes, e.g. COST Action E43 of the European Union. Continued harmonization is important. However, the definitions of the different carbon pools are not extremely important for the overall reported figures since different boundaries between them will not alter the overall changes. On the other hand, for comparing results between countries during the process of quality control these definitions do matter. Based on Swedish data, a sensitivity analysis was conducted that showed that about 15% of the carbon stock is excluded if a 10 cm diameter threshold was used for aboveground biomass, compared to a 0 cm threshold.

Further, different definitions of forest, forest management, afforestation, deforestation, etc. may in some cases imply major differences in reported figures. Again based on Swedish data, 23% of the carbon stocks were found on areas with some type of logging restriction. Whether or not such areas are classified as managed, and thus reported, then becomes an important issue.

In harmonization, reference definitions and procedures to convert from national definitions to reference definitions are important. The latter kind of procedures are sometimes called bridging procedures, as they are used to move to the mainland of a reference definition. A harmonisation bridge can take different forms, from mere recalculations based on existing data to advanced statistical functions to convert from existing definitions to reference definitions. Sometimes it involves a combination of different methods. In general, each party to an agreement must construct its own bridges, at least as long as each party acquires basic data differently.

In conclusion, further harmonization is important, and to some extent this is likely to be a self-regulated process due to the interests of the NFIs to improve information comparability. However, the process is moving slowly and it is likely that several years of work remain before substantial improvements in data harmonization are reached. The processes not only move towards harmonisation, but also towards an increased degree of standardization between countries since the NFIs appear to adopt the agreed-upon reference definitions during revisions.

5.3.4. Estimation accuracy for sparse features

For most activities and carbon pools low-intensity sample based surveys are fully sufficient for providing fair accuracies for the reporting. However, those few activities where major emissions or removals occur on small land areas pose substantial problems for the reporting, especially when sample based surveys are applied. For the LULUCF/AFOLU sector reporting this is the case mainly for deforestation and removals of biomass through cutting or fire. Biomass removals in many cases are assessed using non-NFI statistics (industrial consumption statistics etc.) and thus deforestation (which is especially important due to the KP) and burning are left as examples of such features.

If reporting is based fully on NFI data it should be ascertained that reasonable accuracy is obtained for sparse features. If it is not, there are examples of add-on methods to NFIs that could be applied to improve the accuracy in this context. For example, clear-cut areas can be identified using difference images in satellite remote sensing and targeted field inventories be implemented to assess the carbon pool changes.

However, improvement of NFIs to enhance the precision of estimates related to sparse features is notoriously difficult. Thus in this context we only propose that analyses be made so that sparse events do not cause huge uncertainties to the overall reported figures.

5.3.5. Long-term secured NFIs

From the point of view of EU level reporting there are no guarantees that countries will maintain their NFIs at current ambition levels. To maintain the usefulness of NFIs some agreement probably should be aimed at, through which all countries would ensure a certain minimum level of forest information for the reporting to the UNFCCC/KP and similar international processes (incl. EU's own forest-related directives). Such an agreement could specify what information should be delivered, at what time intervals, the spatio-temporal resolution, and the minimum accuracy levels. Countries could then seek the most cost-effective solutions to providing this information, building on those existing forest and landscape level inventories that already are conducted for supporting the country-level decision making processes.

As an example of an activity along the above lines, the EU Joint Research Centre is responsible for a current project to establish a forest information system at the EU level, building largely on available data from the NFIs.

In some countries NFIs have only recently been started. For example, this is the case in many eastern European countries. The success of these inventories at least to some extent depends on what support is received from other NFIs and supportive bodies at the EU level. Supportive actions could be initiated by the JRC or through active collaboration within the European National Forest Inventory Network (ENFIN).

5.3.6. Summary of propositions and cost estimates

In summary, our main propositions for improved NFI-based LULUCF/AFOLU sector reporting are:

1. Ensure adequate spatial and temporal coverage of forest data through merging NFI networks with the ICP Forests level I network. This process is already ongoing within the EU Life+ FutMon project.
2. Expand the spatial scope of NFIs in those countries where landscape level inventories are not ongoing, so that also non-forest areas are included whereby land-use transfers can be assessed.

If landscape inventories are ongoing, a core set of variables should be shared with NFIs so that data on carbon pool changes can be linked with data on land-use transfers.

3. In many NFIs it might be worthwhile to invest in more measurements related to deadwood, litter, and soil organic carbon. However, especially for litter and soils, these measurements should probably be targeted on providing input to model-based assessments rather than changes by repeated measurements.
4. Further improvements on the conversions from tree volume based measurements to above- and belowground biomass stocks are recommended.
5. Continued harmonisation along the lines established in COST Action E43 is recommended. This includes both the further elaboration of reference definitions and the development of bridging procedures to transit from national to reference definitions.
6. An EU level agreement regarding forest information provision would be appropriate, in order to secure the union's need for certain information without compromising the needs of the individual countries to maintain tailored information systems that support national policy needs. Special support also could be targeted to those countries (mainly in Eastern Europe) with limited experiences from usage of NFI data.

The costs connected associated with the above propositions are difficult to assess. Regarding (a) this work is ongoing and should be covered by already allocated funds. A likely outcome is that the merger in many countries will lead to better efficiency through avoiding duplicated work. However, it is likely that some (few) countries would need to increase their inventory intensities in order to provide meaningful data. The overall effects are difficult to assess but a crude judgment is that no additional costs would be incurred.

Regarding (b) two-phase approaches involving remote sensing should most likely be applied. If the LUCAS inventory will continue to cover the entire EU, landscape level data would be supplied through this inventory. Further, in many countries other landscape level inventories also are conducted. We assess that expanding the spatial scope of NFIs would only be motivated in very few countries, perhaps 15% of the EU countries. We assess the resulting annual costs at appr. 1.5 MEuro.

Regarding (c) only about 50% of the NFIs currently cover those pools with appropriate methodology. Increased efforts thus would involve a large number of countries, although with fairly limited costs in each case. We assess the total costs to amount to 2 MEuro annually.

Regarding (d) the work would mainly be conducted within research projects. All major regions and tree species would need to be covered, unless good conversion functions and factors already exist. A crude estimate, partly based on the study by Freudenschuss and Weiss (2008), is that about 20 projects would be needed, each comprising 0.3 MEuro. The resulting total cost would be 6 MEuro.

Harmonisation according to proposition (e) would need to continue for several years. A crude estimate is that within 6-7 years most of the core variables would be available in harmonised form. The annual cost might amount to about 3 MEuro, and thus the total costs to about 20 MEuro. This is based on an assumption that one person year per country would be spent on this type of work. The overall annual costs would amount to about 7.5 MEuro.

The most important measure to secure proper usage of NFI data across European countries in the long run probably is to support continued collaboration and harmonization of the output information from the inventories. Preferably, the JRC could have a close linkage to such continued work.

5.4. *Discussion*

Only Finland, Slovenia and Sweden state that they could base their entire LULUCF sector reporting on NFI data in the future. This requires monitoring systems that can match carbon pools to land use and land-use changes over time, and also that changes can be traced back to the base year. Forestry historically has been important for Finnish and Swedish economies and it is not surprising that these two countries have comprehensive NFIs. Slovenia is an example of a country that recently has developed its NFI. In several other countries, the acquisition of data for reporting to the UNFCCC and the KP also has been a major driver for developing new NFIs. In yet other countries newly developed NFIs are planned to serve multiple purposes, including carbon reporting. In a case example from Romania, Bouriaud and Marin (2009) show that the new NFI is likely to substantially improve the quality of the greenhouse gas reporting from Romanian forests. The work of the Romanian NFI may serve as an example for other (mainly eastern) European countries that are currently planning to use NFI data for the LULUCF/AFOLU sector reporting.

For most countries, NFI data will be one out of several data sources for completing the LULUCF/AFOLU sector reporting and clever combinations of different data sources should be sought in order to produce high quality data at low costs.

Uncertainty assessment is another undertaking that is required according to the GPG for LULUCF. While the GPG proposes two basic methods for this purpose, sample based NFI fit poorly into both. Instead, procedures based on statistical sampling theory should be developed and applied. In this work, it is important to combine sampling errors with the model errors from biomass functions and similar model relationships that are applied.

Continued collaboration between the European NFIs is a key concern if the reporting at EU level should be based on country-level NFI data. This type of harmonisation has been ongoing for a long time on a bilateral basis, while since 2003 it has been formalised under the umbrella of the European National Forest Inventory Network (ENFIN). Almost all EU countries (and several other countries as well) are members of ENFIN – which has the major objective of making information from NFIs comparable and available at the European level. Between 2004 and 2009, the concrete work was conducted within the project COST Action E43 (http://www.metla.fi/eu/cost/e43/). One important result from COST E43 is a book that comprehensively describes the European NFIs (Tomppo et al. 2009). In this book all types of details regarding NFIs can be found, for example when they started and how they have evolved over time.

Regarding the suitability of NFIs for different hypothetical post-Kyoto agreements, there are several options currently being discussed. Negotiations of such an agreement may cover issues like gross-net or net-net accounting, holistic or activity based systems, and possibly connections between data quality and rules for the accounting. NFIs usually provide high-quality carbon pool data. If a net-net accounting approach would be chosen, then the accuracy of estimates of carbon pools at the baseline could be improved by using average data from several years. Such averaging could also improve estimates using the gross-net approach. A similar solution to improve data quality and to avoid undesired variation between years would be to report for longer periods rather than on an annual basis.

The IPCC has developed new reporting Guidelines (2006) intended for future reporting. Compared to the current reporting, the LULUCF sector and the agriculture sector are suggested to be merged. The reporting of Harvested Wood Products and emissions from some non-CO_2 gases becomes mandatory.

In conclusion, our study shows that NFIs play a major role in the LULUCF sector reporting in Europe, and there are several interesting ways to enhance NFIs in order to improve their usefulness for GHG reporting. One very important key is to make sure that the harmonisation process among European NFIs continues.

5.5. *Conclusions*

Reliable reporting and accounting of greenhouse gas emissions and removals are becoming increasingly important in the global ambitions to mitigate climate change. This concerns several sectors, including the land use, land-use change, and forestry (LULUCF) sector of the UN Convention on Climate Change and its Kyoto Protocol. In many cases data from National Forest Inventories provide a significant portion of the information required for this sector. Thus, National Forest Inventories are attracting increased interest from the climate change community although the inventories mainly have been developed for purposes other than greenhouse gas reporting. National Forest Inventories are conducted in slightly different ways in different countries. However, normally they are sample-based, i.e. only a small portion of the forests is actually measured. By applying sampling theory it can be shown that by applying only relatively modest sample sizes high precision can still be achieved for several important parameter estimates, such as total volume, biomass, or deadwood within larger regions or countries. Further, the inventories are conducted at regular intervals in most European countries, apart from some small countries and some countries in east Europe. A comprehensive coverage of the history, scope and design of European NFIs is provided in Tomppo et al. (2009).National Forest Inventories continuously are developed to meet new requirements. Thus there are good possibilities to revise current practices in order to make them better adapted to suit the needs for LULUCF sector reporting (or AFOLU sector reporting, as the LULUCF sector is likely to be merged with the Agriculture sector in the future). Within the EU, this is important as the union has agreed upon a burden-sharing mechanism within which Kyoto Protocol emission reduction targets are shared between the EU-15 countries. Thus, figures within and between sectors need to be comparable across countries. The objective of this study was to review European National Forest Inventories from the point of view of their usefulness for the reporting (based on previous reports within the MASCAREF project), and, especially, to propose changes that could be implemented in National Forest Inventories in order to enhance their usefulness for the reporting. The likely costs associated with such changes were also broadly assessed. In a previous study within the MASCAREF project advantages and disadvantages of using National Forest Inventories (NFIs) for the reporting were identified. Issues on the positive side include: i) NFI data are available from almost all countries in Europe, or NFIs are currently being introduced; ii) The basic types of data provided by NFIs are suitable for a wide range of purposes connected with LULUCF/AFOLU sector greenhouse gas reporting; iii) NFIs can be rather easily modified, and since reporting to the UNFCCC and its KP are major issues today, several NFIs currently modify their scope in order to provide better estimates related to greenhouse gas emissions and removals, iv) Uncertainty assessment of reported figures generally is fairly straightforward following sampling theory and v) Between the European NFIs, collaboration is ongoing in order to improve the harmonisation of reported figures across countries. On the negative side, the following main items were identified: i) NFI data are not available from all countries and all time periods, and thus geographical and temporal interpolation and extrapolation are needed in order to provide complete assessments, ii) Although basic data related to forest area and aboveground biomass are available in all NFIs, the coverage of other land use categories, land use transfers, as well as belowground and non-biomass carbon pools, could be improved upon; iii)Different definitions are used in different countries, and thus there is a need to harmonise definitions and develop recalculation schemes (so called ‘bridges’) in order to provide harmonised figures across Europe, iii) The accuracy of estimates of sparse events (like carbon emissions from deforestation and burned areas) generally is low and iv) There are no guarantees that all countries will continue performing NFIs, although the trend lately has been that countries are introducing such inventories.

Based on the identified drawbacks of NFIs, we propose the following main possibilities for improving NFIs to enhance their capacity for LULUCF/AFOLU sector reporting:

<u>NFI data availability:</u> Although NFI data are available from most European countries (or NFIs are being planned, e.g. in Russia where a large portion of European forests is located) some countries do not conduct NFIs on a regular basis. Some large countries of this kind are located in east Europe and it is unclear whether or not NFIs will be installed in these in a near future.

However, within EU almost all countries conduct sample based NFIs on a regular basis. For those (few) countries where NFIs currently are not carried out, the measurements within the ICP Forests level I plot networks could be expanded and utilised as substitutes. Current activities within the EU/Life+ FutMon project include studies on how to merge the plot networks of NFIs and ICP Forests level I, as there should be obvious synergies from doing so.

Another issue related to data availability concerns temporal coverage. In many countries NFIs are only conducted at certain intervals and thus harmonised procedures for interpolating and extrapolating data become important. Currently there is a lack of such procedures and thus there is a need for methodological development. However, there is a limit as to how long interpolations and extrapolations are meaningful, and in some countries shorter intervals between inventories would be appropriate. With regard to data availability, our concrete propositions are to ensure that adequate data are provided through appropriately merging the ICP Forest level I network with NFIs, and to develop harmonised procedures for data interpolation and extrapolation.

Additional variables: Many NFIs could be improved upon from a land-use category and land-use transfer estimation point of view by developing a full coverage of terrestrial areas. Currently, only about 20% of the European NFIs can be applied for estimating all types of land-use categories and transfers. Many NFIs only cover forests and this, naturally, implies limitations in relation to estimating areas of all land-use categories and land-use changes. In many cases, like in Ireland and Switzerland, two-phase approaches involving air photo interpretation and field survey could be applied to limit the inventory costs if the spatial coverage were increased. The sample plots ideally should be permanent to permit efficient estimation of changes.

An alternative to expanding the NFIs for land-use transfer assessment is to seek collaboration with the landscape level inventories (incl. the EU LUCAS survey) that are emerging in many countries. Whereas these inventories generally are appropriate for following land-use changes their capacities for monitoring carbon pool changes are mostly limited. However, by ensuring linkages (same core set of variables) in both types of inventories co-utilisation of data would be facilitated and thus data on land-use changes from landscape inventories could be matched with data on the related carbon pool changes from NFIs. In most cases this would be the most straightforward, at least from a cost point of view, organisational approach and thus only in those countries where no landscape level inventory is ongoing should the NFIs aim for increased spatial coverage.

Further, in many countries there is clearly an option to improve the capacities of the NFIs by expanding the measurements and functional relationships related to belowground biomass, dead wood, litter, and soils, although this involves several methodological challenges. Regarding the aboveground biomass pool, most countries cover it with adequate accuracy, although the ‘classical’ problem of utilising compatible biomass functions and biomass expansion factors still is posing challenges. The underlying problem is that biomass functions are expensive to develop/improve due to the huge workloads involved in felling and weighing trees, including their stump-root systems. Regional – rather than country-by-country approaches – to develop improved biomass functions would be a cost-effective (but probably difficult-to-organize) alternative. Especially for the belowground biomass component, inappropriate biomass functions currently appear to limit the use of NFI data. Dead wood increasingly is being included in NFIs, mainly due to the importance of this substrate as an indirect biodiversity indicator. Thus, as dead wood also is important for the LULUCF/AFOLU sector reporting, it is likely that it will gradually be included in all NFIs. Dead wood requires other carbon conversion factors than biomass, and in most countries there is a clear potential to improve those conversion factors. Litter includes both fine woody debris and the upper organic soil layer. Less than 50% of the NFIs cover these fractions today and there is room for improvement. However, the methodological challenges are substantial. The situation is similar for soil organic carbon. It in unclear whether or not increased measurements of litter and soils in NFIs should be recommended. An alternative is to further improve model- based assessments of these pools, as it is known from several studies that small measurement errors on large pools may cause substantial bias in change estimates. However, to support the model-based assessment appropriate data on independent variables in the models must be collected and for many NFIs this would imply increased ambitions in the data collection. Further, models for the litter and soils must be fed with calibration data and their performance must be checked at least from a limited set of sites where careful measurements are conducted. In some cases – when the

NFIs already conduct soil surveys – it might be appropriate to co-organize careful control measurements of this kind in connection with the NFIs. Thus, from the point of view of increased scope of NFIs in some (few) cases increased spatial coverage with permanent plots could be worthwhile to consider. In many cases closer collaboration with landscape level inventories would instead be appropriate. Further, by systematically screening the need for input data from litter and soil models, slight increases in the NFI variable lists most likely would be useful. For both aboveground, and, especially, belowground biomass improved biomass expansion factors or biomass functions are needed in many cases. Lastly, dead wood should be included in all NFIs and conversion factors depending on the degree of decomposition be developed.

Further harmonisation of the reporting: Countries currently use slightly different definitions of the variables relevant for the LULUCF/AFOLU sector reporting. Harmonisation of NFIs has lately been initiated in several projects and processes, e.g. COST Action E43 of the European Union. Continued harmonization is important, although the definitions of the different carbon pools are not extremely important for the overall reported figures since different boundaries between them will not alter the overall changes. On the other hand, for comparing results between countries during the process of quality control these definitions do matter. Further, different definitions of forest, forest management, afforestation, deforestation, etc. may in some cases imply major differences in reported figures. Thus, further harmonisation is important, and to some extent this is likely to be a self-regulated process due to the interests of the NFIs in improving information comparability. However, the process is moving slowly and it is likely that several years of work remain before substantial improvements are reached. The processes not only move towards harmonisation, but also towards an increased degree of standardization between countries since the NFIs appear to adopt the agreed-upon reference definitions during revisions.

Estimation accuracy for sparse features: For most activities and carbon pools low-intensity sample based surveys are fully sufficient for providing fair accuracies in the reporting. However, those few activities where major emissions or removals occur on small land areas pose substantial problems, especially when sample based surveys are applied. For the LULUCF/AFOLU sector reporting this is the case mainly for deforestation and removals of biomass through cutting or fire. Biomass removals in many cases are assessed using non-NFI statistics (industrial consumption statistics etc.) and thus deforestation (which is especially important due to the KP) and burning are left as main examples of such features. If reporting is based fully on NFI data it should be ascertained that reasonable accuracy is obtained for sparse features. If it is not, there are examples of add-on methods to NFIs that could be applied to improve the accuracy in this context. For example, clear-cut areas can be identified using difference images in satellite remote sensing and targeted field inventories be implemented to assess the related carbon pool changes (and check so that the change was really deforestation and not only a cutting as part of normal forestry practices). However, improvement of NFIs to enhance the precision of estimates related to sparse features is notoriously difficult. Thus in this context we only propose that analyses be made so that sparse events do not cause huge uncertainties to the overall reported figures.

Long-term secured NFIs: From the point of view of EU level reporting there are no guarantees that countries will maintain their NFIs at current ambition levels. To maintain and ascertain the usefulness of NFIs some agreement probably should be aimed for, through which all EU countries would ensure a certain minimum level of forest information for the reporting to the UNFCCC/KP and similar international processes (incl. EU's own forest-related directives). Such an agreement could specify what information should be delivered, at what time intervals, the geographic resolution, and the minimum accuracy levels. Countries could then seek the most cost-effective solutions for providing this information, building on those existing forest and landscape level inventories that already are conducted for supporting the country-level decision making processes. As an example of an activity along the above lines, the EU Joint Research Centre is responsible for a current pilot project to establish a forest information system at the EU level, building largely on available data from the NFIs. In several European countries (especially in the eastern part) NFIs have only recently started and the full potential of the data for the reporting has not yet been utilised. It is important that those countries are given appropriate support, e.g. by activities organised by the JRC or by the European National Forest Inventory Network (ENFIN).

Summary of propositions, and cost estimates: In summary, our main propositions for improved NFI-based LULUCF/AFOLU sector reporting are: a) Ensure adequate spatial and temporal coverage of forest data through merging NFI networks with the ICP Forests level I network. This process is already ongoing within the EU/Life+ FutMon project; b) Expand the spatial scope of NFIs in those countries where landscape level inventories are not ongoing, so that also non-forest areas are included whereby land-use transfers can be assessed. If landscape inventories are ongoing, a core set of variables should be shared with NFIs so that data on carbon pool changes can be linked with data on land-use transfers; c) In many NFIs it might be worthwhile to invest in more measurements related to deadwood, litter, and soil organic carbon. However, especially for litter and soils, these measurements should probably be targeted on providing input to model-based assessments rather than changes by repeated measurements, d) Further improvements on the conversions from tree based measurements to above- and belowground biomass stocks are recommended. Regional collaboration in developing biomass expansion factors and biomass functions should be sought, e) Continued harmonisation along the lines established in COST Action E43 is recommended. This includes both the further elaboration of reference definitions and the development of bridging procedures to pass from national to reference definitions, f) An EU level agreement regarding forest information provision would be appropriate, in order to secure the union's need for certain information without compromising the needs of the individual countries to maintain tailored information systems that support national policy needs. Special support also could be targeted to those countries with limited experiences from usage of NFI data.

The costs associated with the above propositions are difficult to assess. Regarding (a) this work is ongoing and should be covered by already allocated funds. A likely outcome is that the merger in many countries will lead to better efficiency through avoiding duplicate work. However, it is likely that some (few) countries would need to increase their inventory intensities in order to provide meaningful data. The overall effects are difficult to assess but a crude judgment is that no overall additional costs would be incurred. Some countries are likely to save money whereas others would face the opposite situation.

Regarding (b) two-phase approaches involving remote sensing should most likely be applied. If the LUCAS inventory will continue to cover the entire EU, landscape level data would be supplied through this inventory. Further, in many countries other landscape level inventories also are conducted. We assess that expanding the spatial scope of NFIs would only be motivated in few countries, perhaps 15% of the EU countries. We assess the resulting total annual costs at about 1.5 MEuro occurring only for a limited number of countries.

Regarding (c) only about 50% of the NFIs currently cover those pools with fair methodology. Increased efforts thus would involve a large number of countries, although with fairly limited costs in each case. We assess the total costs to amount to about 2 MEuro annually.

Regarding (d) the work would mainly be conducted within research projects. All major regions and tree species would need to be covered, unless good conversion functions and factors already exist. A crude estimate is that about 20 projects could be prioritized, each comprising about 0.3 MEuro. The resulting total cost would be about 6 MEuro.

Harmonisation according to proposition (e) would need to continue for several years. A crude estimate is that within 6-7 years most of the core variables and definitions would be available in harmonised form. The annual cost might amount to about 3 MEuro, and thus the total costs to about 20 MEuro. This is based on an assumption that about one person year per country would be spent on this type of work. Based on the above assumptions, the overall annual costs would amount to about 7.5 MEuro, each year within a period of 6-7 years. If all activities cannot be supported we judge that the most important activity would be to provide a foundation for continued collaboration (incl. harmonization) among the European NFIs, and ensure that harmonized UNFCCC/KP reporting is a high-priority target for the collaboration. The JRC could be an active partner in such collaborative work.

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6. Current status of use of Biomass Expansion Factors and Biomass Functions

Alexandra Freudenschuß and **Peter Weiss**
Umweltbundesamt, Austria
E-mail: alexandra.freudenschuss@umweltbundesamt.at and peter.weiss@umweltbundesamt.at

Abstract

The assessment of changes in forest biomass has become an inevitable need for the fulfilment of national reporting obligations to the Convention on Climate Change (UNFCCC, 1992) and its Kyoto Protocol (UN, 1997). Thus reliable, accurate and transparent methods of estimates for forest biomass are required. In general, national forest inventories (NFIs) provide highly accurate estimates in volume of growing stock, forest area and other data on forest resources, which build an essential basis for the estimates on total tree C-pools and their changes. However, NFIs were originally not designed to estimate total tree biomass thus the application of suitable biomass expansion factors (BEF) or biomass functions (BF) is necessary to expand timber-oriented measurements to total (aboveground and belowground) tree biomass. The aim of the paper is to give an overview of the current use of BEFs and BFs in 24 countries.

6.1. *Introduction*

In brief, the difference of these two major approaches is that BEF are used to convert or expand an available tree or stand parameter like stem wood volume/biomass to total tree biomass whereas BF predict tree biomass as a function of measured tree data like dbh, tree height etc. Somogyi et al. (2007) give a comprehensive overview on the different approaches and advice on how to proceed when selecting BEF or BF. In case appropriate tree-level BF are available their use should be given preference over the use of BEF, since the applicability of BEF to the applied volumes or converted biomass estimates needs a thorough evaluation to avoid highly biased biomass estimates. Furthermore BF principally better reflect the dynamic component of biomass development over tree size (age) then the static nature of a BEF. However, situations may exist where no BF for certain conditions under consideration exist, but BEF.

The IPCC-GPG (2003) provide some default values for BEF according to different climatic zones, forest types and the two major approaches of estimations for C-stocks (stock change method, default method – increment and drain data). However, countries are encouraged to develop and apply country specific BEF or BF. Studies carried out within COST E21 and CARBOINVENT (Löwe et al., 2000; Zianis et al. 2005) focused their work on the compilation of available biomass expansion factors and biomass and stem volume equations.

The aim of the present working paper is to screen the current use of biomass expansion factors and biomass functions within European National Forest Inventories in order to fulfil national reporting requirement. The core element of work is the summary table presented in the Annex which also provides input for the MASCAREF project.

6.2. *Material and methods*

The results of this working paper are based on the responses of a specific questionnaire which was elaborated in early 2008 by the French IFN (A. Colin) with the support of the Swedish SLU (H. Petersson) and the Austrian Umweltbundesamt (P. Weiss, A. Freudenschuß). The questions were designed to provide an up-to-date assessment of the more relevant issues for LULUCF emission reporting in Europe identified by Cienciala et al. (2008). General views on the questionnaire and detailed results of the country responses are given in the project report to Chapter 4.

Part 4 of the questionnaire is related to the estimation of living aboveground and belowground biomass. Country representatives were asked to provide information on the applied method (stock change or default method), the origin of used BEF or BF (local studies, international literature, IPCC default) and their availability for different species (genius species). From 24 responding countries 20 have BEF or BF available from local studies but only about half of them also provided information on tree species.

Therefore, the National Inventory Reports (NIRs) of the submission 2007 from the 24 responding countries had been screened for relevant information related to the use of BEF and BF for estimations on carbon stock changes in living tree biomass, additionally to the information given in the questionnaire responses. For some reasons in some countries the information gained from the questionnaire did not correspond with the information given in the NIRs. This might partly be due to recently undertaken improvements of national reporting procedure (e.g. in Portugal) or other reasons which could not be clarified within this work package and would require some further research. The results of both research work is summarised in the table in the Annex of this working paper.

6.3. *Results*

6.3.1. Summary of the country responses to the questionnaire

Based on the questionnaire results both methodologies, default or stock change method, are used equally among the responding countries to estimate changes in living biomass (aboveground and belowground biomass).

Figure 6-1 Use of BEF and BF from local studies (l), international literature (int) and IPCC default values for living aboveground biomass of the responding countries shows the frequency distribution of the use of BFs, BEFs, both (BEFs and BFs) or other approaches for aboveground biomass estimates based on local studies, international literature or the IPCC GPG (default values). The first two bars (green-blue colour) represent BEFs or BFs used in combination with the default method (increment and removal); the third bar (yellow) shows the percentage of countries that use BEFs or BFs in combination with the stock change method. Thus, some countries use BEFs or BFs from local studies but also international BEFs or BFs and/or IPCC default values e.g. for other tree species the cross sum of the bars goes beyond 100%.

The results show that most countries (83%) apply BEFs or BFs which are based on local studies. About 17% (12.5% default and 4% stock change method) of the countries use local biomass functions whereas the majority (37.5%) uses local BEFs (12.5% increment/removal, 25% stock change method) and 25% use BEFs as well as BFs (12.5% for each method). Barely other methods than the application of BEF or BF are used to estimate living aboveground biomass (e.g. France).

BEFs or BFs from international sources are used in about 29% of the countries. 20% uses both, local and international BEFs or BFs, whereas two countries (NO and NL) rely only on international BFs (in total 8%, 4% for each method). However, BEFs derived from international literature are used more frequently (in total 16%; 8% for each method) than international BF. One country applies both, BEFs and BFs, from international sources.

IPCC default values are applied in 33% (about 17% for each method) but only one country (4%) uses no other international or local factors or functions.

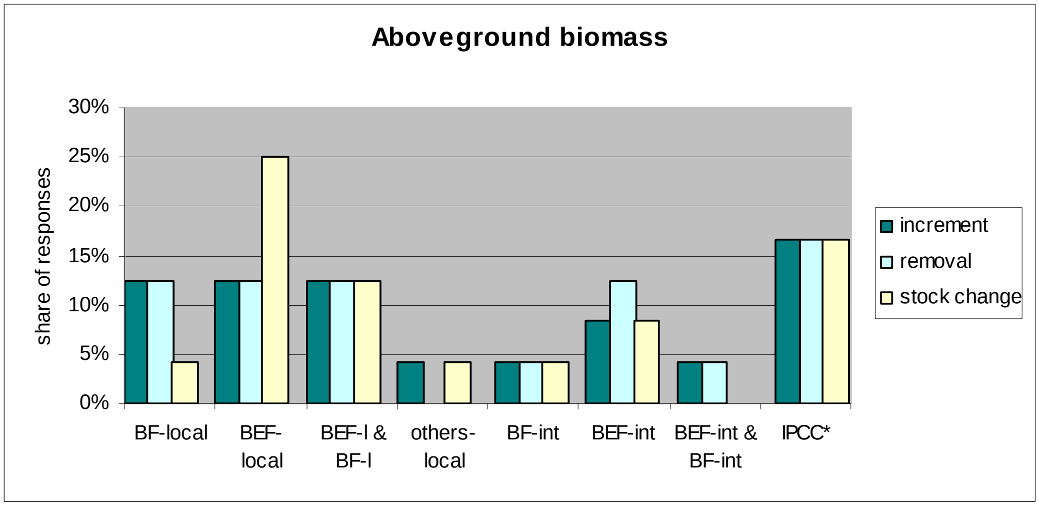

Figure 6-1 **Use of BEF and BF from local studies (l), international literature (int) and IPCC default values for living aboveground biomass of the responding countries**

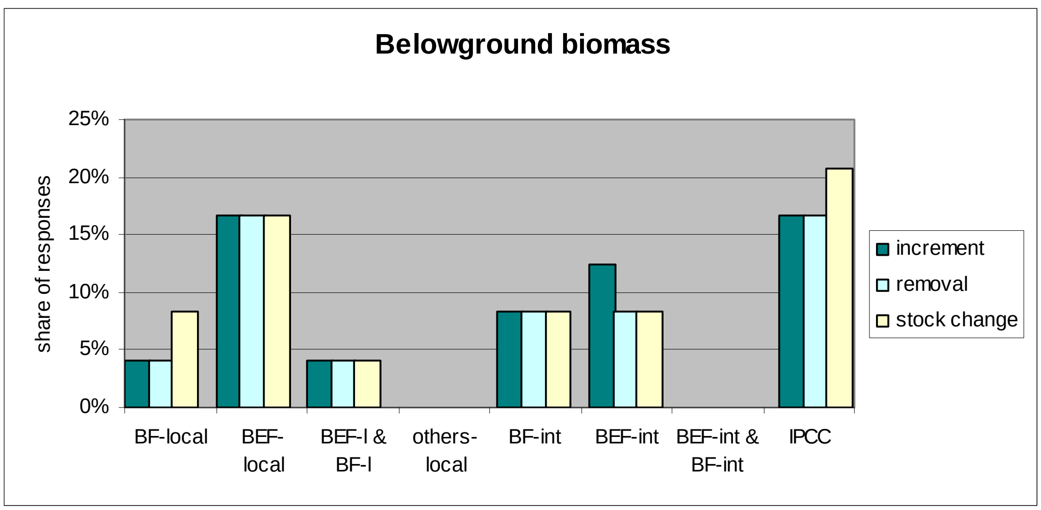

Figure 6-2 **Use of BEF and BF from local studies (l), international literature (int.) and IPCC default values for living belowground biomass of the responding countries**

Figure 6-2 is equally structured as Figure 6-1 but belongs to belowground biomass. The percentage of countries that use BEFs or BFs from local studies is considerably lower than those for aboveground biomass. Local BFs are used in 17% of the countries (4% default, 12.5% stock change method) whereas local BEF are used more frequently (33 %). A combination of BEFs and BF are used in 8% (4% for each method). The IPCC default values are applied by about 38% (17% default and 21 % stock change method) of the countries.

Overall, the obtained results on the use of BEF and BF are in general consistent with the results identified by Cienciala et al. (2008).

National BEF or BF together with NFI data are used in 54% of the responding countries to estimate living aboveground biomass, 17% use NFI data but apply no national BEF/BF (international BEF/BF, IPCC default BEF or other methods instead) and the remaining 29% have national BEF/BF but use no NFI data (but have potential to use NFI data).

Less than half of the countries indicated the types of tree species for which the BEF or BF from local studies are available, thus the NIRs were additionally screened for further information. In this regard additional information on the related tree compartments to which the BEF and BF refer as well as the required input parameters was extracted if they were described clearly otherwise cells were left blank. This detailed information is included in the table in Annex 6-1.

As for application and a detailed comparison of the various BEF and BF in use a thorough research of the underlying definitions (e.g. stem wood, volume) is vital and recommended the related literature to the BEF and BF is complied (references to the Annex 8-1).

6.3.2. Discussion of the results

More than two thirds of the responding nations use NFI input data when extrapolating to total tree C stocks. A large percentage of the remaining nations would have the potential to use NFI input data for these estimates, but do not use their NFIs so far. This finding indicates that the majority of the European nations have or use country specific NFI input data to extrapolate to or estimate total C stocks. More than a half uses their NFI data together with national BEFs or BFs, which let expect overall country specific biomass estimates. The potential for country specific estimates would be even higher if the facts are taken into consideration that 1) most of the 29 % that use national BEF/BF but do not use NFI data as input parameters would have the potential to do so, 2) BF or BEF exist from countries that may be used in neighbouring countries with similar ecological conditions which use IPCC default values so far.

With respect to the distinction between BEFs or BFs the responses or survey gave evidence that a majority of countries use BEFs. This finding may be, however, misleading since we know countries that use local valid BFs to derive country specific BEFs that are used then for the estimates. Stem volume is the most frequent input parameter for the expansion to aboveground biomass with BEFs. So, aggregated or intermediate NFI results on stem wood are frequently used to expand to the other biomass compartments. However, the documentation in the NIRs does often not allow a clear picture of what is expanded to what for the following reasons. 1) While parameter like dbh are clearly defined, stem wood is not always and includes different tree parts in individual countries, 2) different terms are used, the meaning of which is not clear ("round wood", "stem wood", "volume" etc.), 3) sometimes information in the NIRs is lacking, 4) what is included in "aboveground" and "belowground" biomass (as estimated parameters) varies from country to country.

On the other hand, as indicated above, NFIs are available in most countries. The availability of NFI data would allow very likely a more frequent use of BFs on basis of clearly defined single tree parameters like dbh. This would circumvent problems related with the expansion of "stem wood", as intermediate product (in its various definitions). But even here, a clear definition and documentation of what are the results of the BFs is needed (see also the following chapter on recommendations).

Both, the IPCC default method (increment minus drain) and the stock change method are equally often used by the countries (each by 12 countries). Also here, a critical evaluation would be necessary if both approaches lead to comparable final results. This is very much dependent on the methods of the surveys and what the individually used input statistics on "increment", "drain", "harvest" and "stock" include and exclude.

More generally speaking the outcomes of the questionnaire as well as the compilation in the table may indicate similarities between approaches of different countries by using same acronyms which may be misleading. In fact, when studying the individual NIRs a large variety of approaches in the individual countries becomes evident. The reasons for that are differences in the general approaches (e.g. default method vs. stock change method), different input data, different definitions for the input data, different methods for the biomass estimates (BEFs vs. BFs), different outcomes of the used BEFs or BFs.

The need for a clear definition and documentation of used terms and parameters to allow a comparison of the approaches, input parameters and output parameters becomes evident one more time and would be the recommended first step for harmonisation.

6.4. *Recommendations for the use of BEF/BF*

General considerations for the selection of BEF or BF primarily concern the following points:

- Tree species: BEF and BF vary with tree species. Therefore, it is necessary to select these tools with respect to the fit of tree species under consideration. If no BEF or BF for selected tree species are available a survey through literature may help to identify tree species which have a similar tree architecture and for which BEF or BF are available.
- Eco region: Biomass distribution of one species varies between eco regions. A BF for boreal conditions may not fit for the same species in temperate conditions. Therefore, the BEF and BF must fit to the eco regions under consideration. In case they are not available, it may be checked if BEF and BF from other eco regions fit or if available BEF and BF for other tree species leads to more appropriate estimates.
- Stand characteristics: Biomass distribution differs between stand characteristics (eg. coppice stand vs. seed forest). The stand characteristics of the source data for the BEF and BF need to be checked.
- Tree characteristics: Biomass distribution varies with the tree characteristics (eg. free standing trees vs. trees in stand, dominating vs. suppressed, defoliated vs. non-defoliated). Therefore, the fit of used BEF and BF to the average tree characteristics under consideration needs to be checked.
- Data deficiencies and methodological inconsistencies: BEF and BF based on data deficiencies and methodological inconsistencies may lead to wrong or biased estimates. Therefore, the underlying data and methods need to be checked before the application of these tools. In any case, but particularly when data and methods for BEF and BF are not properly described, a check of the plausibility of results from the selected BEF and BF with the help of input data from well known model sites and with the use of other BEF and BF is required.
- Compartments that are included in the applied BEF and BF and their definitions need to be clarified before these tools are used.

Further specific considerations for the selection of BEF concern the

- Tree size or tree dimensions: BEF vary with tree size. Therefore, if available, different BEF reflecting these different sizes of a tree or stand should be used.
- Tree compartment to be expanded or converted: It is crucial to clarify *from what* will be expanded/converted *to what* and if the available BEF are suited for this expansion/conversion. This requests also a careful survey through the original literature of the BEF and the underlying definitions (eg. for stem wood, tree biomass, density etc).
- Tree level vs. stand level BEF: It needs to be clarified it the used BEF represent stand level BEF (leading to "per ha" results) or tree level BEF (leading to "per tree" results).

Zianis et al. (2005) and Muukkonen and Mäkipää (2006) compiled a numerous amount of BF for tree species in Europe, and this data base is also regularly updated and can be visited at the METLA homepage. In any case, a careful survey through the original literature and the underlying conditions of these BF is necessary.

Hence, further specific considerations for the selections of BF are:

- Tree dimensions: For example, BF may have been developed on basis of data for certain DBH classes and may therefore only be valid for these DBH classes. Their use for other DBH classes may lead to biased or even unrealistic figures for these DBH classes (usually for the lower or upper DBH classes).
- Social status of the tree: The biomass distribution of trees varies with their social status. Therefore, a function developed on basis of data for dominating trees may lead to biased biomass estimates for suppressed or the average social tree status (Ledermann and Gschwantner, 2006).

Stock change vs. default method:

Estimates on basis of the IPCC GPG carbon stock change method may directly use the estimates on basis of the BEF and/or BF while the IPCC GPG default method (increment minus drain) needs a different approach to estimate the carbon stock change. Similarly to the stock change approach, drain biomass can be directly estimated with the use of the BEF and BE. For increment, a two step approach is necessary because the increment of green or root biomass is not parallel to the DBH increment and the same DBH increment for two different tree age classes is related with two different biomass increments. Therefore, increment of tree biomass needs to be estimated as the difference between the biomass estimated on basis of DBH2 and the biomass estimated on basis of DBH1 (and in a same manner for the further tree parameters eventually to be included in the equations). As an example here, DBH2 and DBH1 reflect the endpoints of the DBH increment between two NFI periods.

Uncertainty issues:

If representative BEF and BE are not available – and this is very likely the more frequent case - the biomass estimates should be carried out with the use of several BEF and/or BF which are relatively nearer to the conditions under consideration. The variation of the results which were obtained with these various BEF and/or BF needs to be reflected in the uncertainty budget of the estimates. Representativeness should be interpreted in a strict manner with respect to uncertainty. Frequently both, existing BEF and BF, were not developed on basis of a representative data set.

6.5. *Conclusions and Perspective*

The present contribution compiled the individual approaches to estimate total tree biomasses and the involvement of NFIs for these estimates in European countries. The paper compiles responses of 24 European nations to a related questionnaire and supplementary information on basis of the NIRs of these nations. More than 50 % of the responding nations carry out biomass estimates that include NFI data and locally derived BEFs or BFs. Including those that have NFI data for this purpose principally available but do not use them and those that use NFI data and would have a potential to substitute their used default values for expansion, a large percentage of countries would have the potential to carry out their estimates with more appropriate parameters for their local conditions.

BEFs are more often used than BFs and stem wood (in its various understandings and as a result of NFIs or harvest statistics) is the most frequently used input parameter for the expansion to total tree biomass.

The answers to the questionnaire as well as the survey through the NIR indicate – although a sufficiently clear documentation of the methods is often lacking – a large variety of methods in the individual countries. Even the meaning of input parameters and result parameters with same names vary from country to county which becomes evident with the description of these parameters in the individual NIRs or when studying the underlying equations. Differences in the general approaches (eg default method vs. stock change method and BEFs vs. BFs) add to the variety.

As a perspective: The availability of NFIs in most countries as well as a large amount of locally available BEFs or BFs for a large number of tree species that could be eventually also used in other countries with similar ecological conditions are promising with regard to a possible harmonisation. To be clear from the start, a hand book of definitions of all potentially used input and output parameters and a questionnaire with regard to the use of these defined parameters within the estimates in the individual countries is recommended.

6.6. *References*

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Annex 6-1 Compilation and overview of the use of BEF and BF (Table A1: Compilation of BEF and BF used within 24 European countries; information given in italics is derived from the NIRs, submission 2007)

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
AT - Austria	BF	l	x	x		AG	Norway spruce	*branches, needles*	*dbh, height, crown ratio*	(1)	yes	
	BF	l	x	x		AG	fir		*dbh, crown ratio*			
	BF	l	x	x		AG	pine		*dbh, height, crown ratio*			
	BF	l	x	x		AG	larch	*branches*	*dbh, height, crown ratio*			
	BF	l	x	x		AG	beech		*dbh, crown ratio*			
	BF	l	x	x		AG	oak					
	BF	l	x	x		AG	hornbeam					
	BF	l	x	x		AG	ash					
	BF	l	x	x		AG	poplar					
	BF	l	x	x		AG	other hardwood deci.species					
	BF	l	x	x		AG	other weed tree species					
	BF	l	x	x		BG	all	*roots*	*dbh*			yes
	BF	int	x	x		BG	all					
BE- Belgium	BEF	l/int			x	AG	*spruce*	*total AG BM*	*total SW volume*	*(2);(3)*	yes	
	BEF	l/int			x	AG	*pine*					
	BEF	l/int			x	AG	*Douglas fir*					
	BEF	l/int			x	AG	*larch*					
	BEF	l/int			x	AG	*other resinous*					
	BEF	l/int			x	AG	*beech*	*total AG BM incl. foliage*				
	BEF	l/int			x	AG	*oak*					
	BEF	l/int			x	AG	*"nobles" species [a]*					

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BEF	l/int			x	AG	*poplar*					
	BEF	l/int			x	AG	*other deciduous*					
	BEF	l/int			x	BG	*spruce*	*total BG*	*total AG BM*			yes
	BEF	l/int			x	BG	*pine*					
	BEF	l/int			x	BG	*Douglas fir*					
	BEF	l/int			x	BG	*larch*					
	BEF	l/int			x	BG	*other resinous*					
	BEF	l/int			x	BG	*beech*					
	BEF	l/int			x	BG	*oak*					
	BEF	l/int			x	BG	*"nobles" species* [a]					
	BEF	l/int			x	BG	*poplar*					
	BEF	l/int			x	BG	*other deciduous*					
CH-Switzer-land	BEF	l	x	x		AG/*BG*	*decid. (5 regions, 3 altitudes)*	*total AG+BG biomass*	*round wood over bark*	(4);(5);(6)	yes	yes
	BEF	l	x	x		AG/*BG*	*conif. (5 regions, 3 altitudes)*					
	BF	*l*	*x*	*x*		*AG*	*to all trees measured at NFI II*	*branches, twigs, foliage and bark*				
	BEF	l	x	x		BG						
	BF	*l*	*x*	*x*		*BG*		*coarse roots*		*(4)*		
CZ-Czech R.	BEF	l	x	x		AG		total AG BM	*volume increment + factor V_{ub} to V_{ob}*		no - pot.	
	BEF	int	x	x		AG						
	BEF	IPCC	x	x		AG						
	BF	l	x	x		AG						
	BF	int	x	x		AG						
	BF	IPCC	x	x		AG						
	BEF	int	x			BG		roots				no - pot.

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BEF	IPCC	x	x		BG						
DE-Ger-many	BEF[b]	l			x	AG		*branches, needles (evergreen)*	*volume of standing timber (Dbh, D_7, height)*	*(7)*	yes	
	BEF	l			x	BG		roots		*(8)*		yes
	BEF	*IPCC*				*BG*				*NIR 2006*		
DK- Den-mark	BEF	l	x	x		AG	Norway spruce			(9)	yes	
	BEF	l	x	x		AG	oak					
	BEF	l	x	x		AG	beech					
	BEF	int	x	x		AG/BG	*conifers*	*total BM (incl. BG)*	*stem volume*	(10)		
	BEF	int	x	x		AG/BG	*broadleaves*		*AG BM*	(11); (12)		
	BEF	l	x	x		BG	Norway spruce			(9)		no
	BEF	l	x	x		BG	oak					
	BEF	l	x	x		BG	beech					
	BEF	int	x	x		BG	Norway spruce, oak, beech		*conif: stem volume , D* *deci: AG BM*	(10); (11); (12)		
EE-Estonia	BEF	IPCC	x	x		AG					yes	
	BF	IPCC	x	x		AG						
	others	IPCC	x	x		AG						
	BEF	*int*	*x*	*x*		*AG/BG*	*Pine, Spruce, Birch, Asp, Alder, Others*	*total BM*	*volume*	*NIR 2007; (17)*		
	BEF	IPCC	x	x		BG						yes
	BF	IPCC	x	x		BG						
	others	IPCC	x	x		BG						

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
ES-Spain	BEFD[c]	l			x	AG	*Alnus glutinosa*	*total AG BM*	*Volume*	*(13)*	yes	
	BEFD[c]	l			x	AG	*Betula spp.*					
	BEFD[c]	l			x	AG	*Castanea sativa*					
	BEFD[c]	l			x	AG	*Eucalyptus spp.*					
	BEFD[c]	l			x	AG	*Fagus sylvatica*					
	BEFD[c]	l			x	AG	*Fraxinus spp.*					
	BEFD[c]	l			x	AG	*Quercus canariensis*					
	BEFD[c]	l			x	AG	*Quercus faginea*					
	BEFD[c]	l			x	AG	*Quercus ilex*					
	BEFD[c]	l			x	AG	*Quercus petraea*					
	BEFD[c]	l			x	AG	*Quercus pubescens*					
	BEFD[c]	l			x	AG	*Ulmus spp.*					
	BEFD[c]	l			x	AG	*Abies alba*					
	BEFD[c]	l			x	AG	*Pinus halepensis*					
	BEFD[c]	l			x	AG	*Pinus nigra*					
	BEFD[c]	l			x	AG	*Pinus pinaster*					
	BEFD[c]	l			x	AG	*Pinus pinea*					
	BEFD[c]	l			x	AG	*Pinus radiata*					
	BEFD[c]	l			x	AG	*Pinus sylvestris*					
	BEFD[c]	l			x	AG	*Pinus uncinata*					
	BEFD[c]	*IPCC*			*x*	*AG*	*other species*			*NIR 2007*		
	BF	IPCC			x	AG						
	BEF	IPCC			x	BG						no
	BF	IPCC			x	BG						

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
FI-Finland	BEF	l	x	x		AG/BG	Pinus silvestris	*total tree biomass*	*stem volume*	(16); (17)	yes	
	BEF	l	x	x		AG/BG	Picea abies					
	BEF	l	x	x		AG/BG	Betula spp					
	BEF	l	x	x		AG/BG	other broadleaves					
	BEF	*l*	*x*	*x*		*AG/BG*	*spruce*			*NIR 2007; (16)*		
	BEF	l	x	x		BG	Pinus silvestris			(16); (17)		yes
	BEF	l	x	x		BG	Picea abies					
	BEF	l	x	x		BG	Betula spp					
	BEF	l	x	x		BG	other broadleaves					
FR-France	others	l	x			AG	Sessile oak			(14)	yes	
	others	l	x			AG	douglas fir					
	others	l	x			AG	Norway spruce					
	others	l	x			AG	beech					
	others	l	x			AG	Scots pine					
	others	l	x			AG	Maritime pine					
	others	l	x			AG	Silver fir					
	BEF	int		x		AG			*stem volume*			
	BEF	int	x	x		BG	decid.+ conif.			(15)		yes
GB – Great Britain	BEF	l			x	AG	Sitka spruce			(31)	no - pot.	
	BEF	l			x	AG	beech					
	BF	l			x	AG	Sitka spruce					
	BF	l			x	AG	beech					
	others	l			x	AG	Sitka spruce					
	others	l			x	AG	beech					

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BEF	l			x	BG	Sitka spruce			NIR 2007		no
	BEF	l			x	BG	beech					
	BF	l			x	BG	Sitka spruce					
	BF	l			x	BG	beech					
GR-Greece	BF	l	x	x		AG				NFI	yes	
	BEF	IPCC		x		AG						
	BEF	*IPCC*	*x*			*AG*			*volume*	*NIR 2007*		
	BEF	*IPCC*	*x*	*x*		*BG*						no
HU-Hungary	BEF	l			x	AG			volume (diameter, height)		yes	
	BEF	IPCC			x	AG						
	BEF	IPCC			x	BG						no
IE-Ireland	BEF	l			x	AG/*BG*		whole tree volume	standing stem wood volume		no-pot.	
	BEF	l			x	BG						no–pot.
IS-Iceland	BF	l	x	x		AG	birch (Betula pubenscens)			(19)	no-pot.	
	BF	l	x	x		AG	rowan (Sorbus aucuparia)					
	BF	l	x	x		AG	feltleaf willow (Salix alaxensis)					
	BF	l	x	x		AG	dark-leafed willow (Salix myrsinifolia)					
	BF	l	x	x		AG	black cottonwood (Populus trichocarpa)					
	BF	l	x	x		AG	Sitka spruce (Picea sitchensis)					
	BF	l	x	x		AG	Engelmann spruce (Picea engelmannii)					
	BF	l	x	x		AG	white spruce (Picea glauca)					
	BF	l	x	x		AG	Norway spruce (Picea abies)					

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BF	l	x	x		AG	lodgepole pine (Pinus contorta)					
	BF	l	x	x		AG	Siberian larch (Larix sibirica)					
	BEF	l	x	x		BG	birch (Betula pubenscens)					no - pot.
	BEF	l	x	x		BG	rowan (Sorbus aucuparia)					
	BEF	l	x	x		BG	feltleaf willow (Salix alaxensis)					
	BEF	l	x	x		BG	dark-leafed willow (Salix myrsinifolia)					
	BEF	l	x	x		BG	black cottonwood (Populus trichocarpa)					
	BEF	l	x	x		BG	Sitka spruce (Picea sitchensis)					
	BEF	l	x	x		BG	Engelmann spruce (Picea engelmannii)					
	BEF	l	x	x		BG	white spruce (Picea glauca)					
	BEF	l	x	x		BG	Norway spruce (Picea abies)					
	BEF	l	x	x		BG	lodgepole pine (Pinus contorta)					
	BEF	l	x	x		BG	Siberian larch (Larix sibirica)					
IT-Italy	BEF	l			x	AG	*Norway spruce*	AG tree BM	*growing stock volume;*	(18)	yes	
	BEF	l			x	AG	*Silver fir*					
	BEF	l			x	AG	*larches*					
	BEF	l			x	AG	*mountain pines*					
	BEF	l			x	AG	*mediterranean pines*					
	BEF	l			x	AG	*other conifers (diff. forest typologies -NIR)*					
	BEF	l			x	AG	*European beech (diff. forest typologies -NIR)*					
	BEF	l			x	AG	*Turkey oak (diff. forest typologies -NIR)*					

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BEF	l			x	AG	*other oaks (diff. forest typologies -NIR)*					
	BEF	l			x	AG	*other broadleaves (diff. forest typologies -NIR)*					
	BEF	l			x	AG	*sweet chestnut*					
	BEF	l			x	AG	*hornbeams*					
	BEF	l			x	AG	*evergreen oaks*					
	BEF	l			x	AG	*eucalyptus coppices*					
	BEF	l			x	AG	*poplars stands*					
	BEF	l			x	AG	*other plantations*					
	BEF	l			x	AG	*rupicolous forest*					
	BEF	l			x	AG	*riparian forest*					
	BEF	l			x	AG	*shrublands*					
	BEF	l			x	BG	*Norway spruce*	*BG BM*	*volume of growing stock*			no
	BEF	l			x	BG	*Silver fir*					
	BEF	l			x	BG	*larches*					
	BEF	l			x	BG	*mountain pines*					
	BEF	l			x	BG	*mediterranean pines*					
	BEF	l			x	BG	*other conifers (diff. forest typologies -NIR)*					
	BEF	l			x	BG	*European beech (diff. forest typologies -NIR)*					
	BEF	l			x	BG	*Turkey oak (diff. forest typologies -NIR)*					
	BEF	l			x	BG	*other oaks (diff. forest typologies*					

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
							-NIR)					
	BEF	l			x	BG	*other broadleaves (diff. forest typologies -NIR)*					
	BEF	l			x	BG	*sweet chestnut*					
	BEF	l			x	BG	*hornbeams*					
	BEF	l			x	BG	*evergreen oaks*					
	BEF	l			x	BG	*eucalyptus coppices*					
	BEF	l			x	BG	*poplars stands*					
	BEF	l			x	BG	*other plantations*					
	BEF	l			x	BG	*rupicolous forest*					
	BEF	l			x	BG	*riparian forest*					
	BEF	l			x	BG	*shrublands*					
	BEF	int			x	BG						
	BEF	IPCC			x	BG						
LT- Lithuania	BEF	l			x	AG	Pinus silvestris			(20)	no-pot.	
	BEF	l			x	AG	Picea abies					
	BEF	l			x	AG	Betula spp. (B. pendula and B. pubescens)					
	BEF	l			x	AG	Populus tremula					
	BEF	l			x	AG	Alnus spp. (A. glutinosa and A. incana)					
	BEF	l			x	AG	Quercus robur					
	BEF	l			x	AG	Fraxinus excelsior					
	BF	l			x	AG	Pinus silvestris					
	BF	l			x	AG	Picea abies					
	BF	l			x	AG	Betula spp. (B. pendula and B.					

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
							pubescens)					
	BF	l			x	AG	Populus tremula					
	BF	l			x	AG	Alnus spp. (A. glutinosa and A. incana)					
	BF	l			x	AG	Quercus robur					
	BF	l			x	AG	Fraxinus excelsior					
	BEF	IPCC			x	AG						
	BEF	IPCC			x	BG						no-pot
	BEF	*IPCC*	*x*	*x*		*AG*				*NIR 2007*		
	BEF	*IPCC*	*x*	*x*		*BG*						
NL-Netherlands	BF	int	x	x		AG		*total AG + BG BM*	growing stock volume	(23)	yes	
	BF	int	x	x		BG		*see AG*				no
NO-Norway	BF	int			x	AG/*BG*	*Norway spruce, Scots pine, birch*	*stem, stem bark, living and dead branches, needles, stumps, roots (fine and coarse)* *deci. Foliage is calculated by assuming to be 1.1% of stem volume*	dbh, height (dbh> 10cm); only dbh (5-10 cm dbh; mean dbh and mean height (young forests)	(21)	yes	yes
	BF	int			x	BG	*Norway spruce, Scots pine, birch*	see AG		(21); (22)		yes
PT-Portugal	BEF	l			x	AG	Eucalyptus globulus				yes	
	BEF	l			x	AG	Pinus pinaster					

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BEF	l			x	AG	Pinus pinea					
	BEF	l			x	AG	Castanea sativa					
	BEF	l			x	AG	Quercus suber					
	BEF	l			x	AG	Quercus ilex					
	BF	l			x	AG	Eucalyptus globulus			(24)		
	BF	l			x	AG	Pinus pinaster			(24)		
	BF	l			x	AG	Pinus pinea			(24)		
	BF	l			x	AG	Castanea sativa			(26)		
	BF	l			x	AG	Quercus suber			(25)		
	BF	l			x	AG	Quercus ilex			(25)		
	BF	l			x	AG	Quercus spp; other hardwoods			(27)		
	BF	l			x	BG	Pinus pinea			(24)		no
	BF	l			x	BG	Pinus pinaster and other soft woods			(24)		
	BF	l			x	BG	Eucalyptus globulus			(28)		
	BF	int/*IPCC*			x	BG	other species					
RO-Romania	BEF	l	x	x		AG	oak				no - pot.	
	BEF	l	x	x		AG	beech					
	BEF	l	x	x		AG	spruce					
	BEF	l	x	x		AG	fir					
	BF	l	x	x		AG	oak					
	BF	l	x	x		AG	beech					
	BF	l	x	x		AG	spruce					
	BF	l	x	x		AG	fir					
	BEF	l	x	x		BG	oak					no

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BEF	l	x	x		BG	beech					
	BEF	l	x	x		BG	spruce					
	BEF	l	x	x		BG	fir					
	BF	l	x	x		BG	oak					
	BF	l	x	x		BG	beech					
	BF	l	x	x		BG	spruce					
	BF	l	x	x		BG	fir					
	BEF	*IPCC*	*x*			*AG*				*NIR 2007*		
	BEF	*IPCC*	*x*			*BG*				*NIR 2007*		*no*
SE-Sweden	BF	l			x	AG	*Scots pine (pinus sylvestris)*	*needles (no leaves), branches, stem incl. bark (AG BM = above stump height – 1% of tree height)*		*(21); (29)*	yes	
	BF	l			x	AG	*Norway spruce*					
	BF	l			x	AG	*birch (betula pendula and pubescens)*					
	BF	*l*			*x*	AG	*other broadleaves (based on birch)*					
	BF	l			x	BG	*Scots pine (pinus sylvestris)*	*living BM below stump height (1% of of tree height), roots >2mm*		*(22)*		yes
	BF	l			x	BG	*Norway spruce*					
	BF	l			x	BG	*birch (betula pendula and pubescens)*					
	BF	l			x	BG	*other broadleaves (based on birch)*					
SL-Slovenia	BEF	l			x	AG	Fagus Sylvatica				yes	
	BEF	l			x	AG	Picea abies					
	BEF	int			x	AG						

Country	BF/BEF	Local (l)/Intern. literature(int.)/ IPCC	Increment	Removal	Stock change	AG/BG	Tree species	Tree compartments	Input parameter	Literature	Use of NFI data for AG biomass	Use of NFI data for BG biomass
	BEF	IPCC			x	AG						
	BEF	IPCC			x	BG						yes
SK-Slovakia	BEF	l	x	x		AG	*main tree species*		*stem wood biomass*	*(30)*	no - pot.	
	BF	l	x	x		AG						
	BEF	int	x	x		AG						
	BEF	IPCC	x	x		AG						
	BEF	IPCC	x	x		BG						no

[a] *incl. maple (Acer pseudoplatanus L.), elm (Ulmus sp.), ash (Fraxinus excelsior L.) and red oak (Quercus rubra L.)*

[b] *VEF are used to convert standing timber into AG BM; VEF provide a functional relationship between standing timber and wood.*

[c] *BEF=BEFD (incl. density)*

no-pot: no but potential use of NFI-data

SW: solid wood – combination of stem and branches

Other abbreviations see also page iv

References for the ANNEX

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* refers to the countries where the BEF/BF are applied

* refers to the countries where the BEF/BF are applied

7. Overview of Allometric Procedures Applied in National GHG Inventories of the EU Member States

Emil Cienciala and **Zuzana Exnerova**
IFER - Institute of Forest Ecosystem Research, Ltd., Czech Republic
Email: emil.cienciala@ifer.cz and zuzana.exnerova@ifer.cz

Abstract

In Europe, the information needed to assess forest carbon sequestration and CO_2 emissions by sources and sinks is mostly provided by the National Forest Inventory (NFI) programs. These may be based at stand or tree level, depending on the system implemented. While stand level inventory was mostly set-up for forest management and planning purposes, the more recent and modern type of inventory is a tree-level type of statistical forest inventory, commonly established with more ambitious goals in terms of assessment accuracy and wealth of information provided. In any case, the key information provided from NFIs has always been growing stock, whereas information on carbon stock and carbon stock changes is needed for reporting purposes under the United Nations Framework Convention on Climate Change (UNFCCC). This contribution provides an analysis of the procedures used by the EU Member States for translating NFI data of timber volume into carbon stock based on the information from the National Inventory Reports (NIR) submitted to UNFCCC. Secondly, this material highlights the difference in the default biomass factors as recommended by GPG for LULUCF (IPCC 2003) and by the 2006 IPCC Guidelines for the National Greenhouse Gas Inventories (AFOLU; IPCC 2006). This is shown to be an issue particularly for the factors applicable for temperate region.

7.1. *Introduction*

To use the available information from NFIs for assessment of carbon and carbon stock change, one has to apply a suitable set of biomass functions and/or biomass factors to translate tree and/or stand volumes of timber to biomass and subsequently carbon. Unfortunately, suitable biomass functions or biomass factors are often not readily available in individual member states. In order to aid assessment of carbon stock changes for the purpose of emission inventory in the Land Use, Land-Use Change and Forestry (LULUCF) sector, the methodological guidance of IPCC (2003), the so called Good Practice Guidance for LULUCF, also includes broadly applicable default factors applicable for major forest categories and geographical regions. Obviously, the application of such factors may easily introduce an error and contribute to overall uncertainty of emission inventory. Since forests represent a dynamic system with particularly vital changes of carbon stock in biomass, IPCC (2003) recommends application of higher tier methods (specifically for the purpose of reporting under Kyoto Protocol), which take into account the local conditions and tree species. They also links better to country-specific NFI programs to secure more reliable estimates of carbon held in biomass and its changes. The change in biomass stocks can be estimated either as a difference between the biomass increment and removals (thinning and felling) or as a change of biomass stocks between consecutive inventories (IPCC 2003). These two principal estimation approaches have consequences to the application of appropriate conversion procedure: while one must deal with increment, the other is applied on stocks. Although the selection and application of suitable volume to carbon conversion routine is seemingly trivial, the topic certainly requires adequate methodological attention. An attempt to clarify usage and guide the selection of suitable biomass functions and biomass factors was made by Somogyi et al (2007). In this study, specific attention is paid to biomass factors, commonly, but not exclusively, applicable to stand level aggregated volume or biomass information. The other way to estimate biomass, suitable at tree level, is applying appropriate biomass equations that predict tree biomass as a function of diameter at breast height, resp. other data of measured sample trees.

The aim of this work is to analyze of the procedures currently used by MS for translating NFI data of timber volume into carbon stock and annual carbon increment. It is mostly based on the information from the National Inventory Reports (NIR) submitted to UNFCCC, respectively their review reports. This work is built on the MASCAREF output captured in Chapter 4 targeting specifically the approaches used within sample-based NFI programs in Europe.

Secondly, this material also demonstrates the difference in the biomass factors as recommended by GPG for LULUCF (IPCC 2003) and by the 2006 IPCC Guidelines for the National Greenhouse Gas Inventories (AFOLU; IPCC 2006). Currently (as of 2008), the Parties to UNFCCC and KP are required to compile their emission inventory according to the adopted methodological instructions of Practice Guidance for LULUCF (GPG for LULUCF; IPCC 2003). At the same time, IPCC released a revised methodology applicable, namely the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). Its chapters 4.1 and 4.2 concern the sector LULUCF, which is in the mentioned volume treated jointly with Agriculture and form the Agriculture, Forestry and Other Land Use (AFOLU). Although the AFOLU volumes are not mandatory for emission inventory compilation, the parties are encouraged to use these whenever feasible. This is because AFOLU represents a revision, update and enhancement of the previously released methodological materials. This issue is specifically important for the use of biomass expansion factors (BEFs) under Tier 1 approaches. Therefore, one of the aims of this chapter is also to highlight the differences and similarities of the biomass factors and their default values as given in GPG in LULUCF and AFOLU.

Finally, related information on compilation of the available biomass factors and functions for major tree species and forest types is also included.

7.2. *Data and Methods*

7.2.1. Data source and parameters

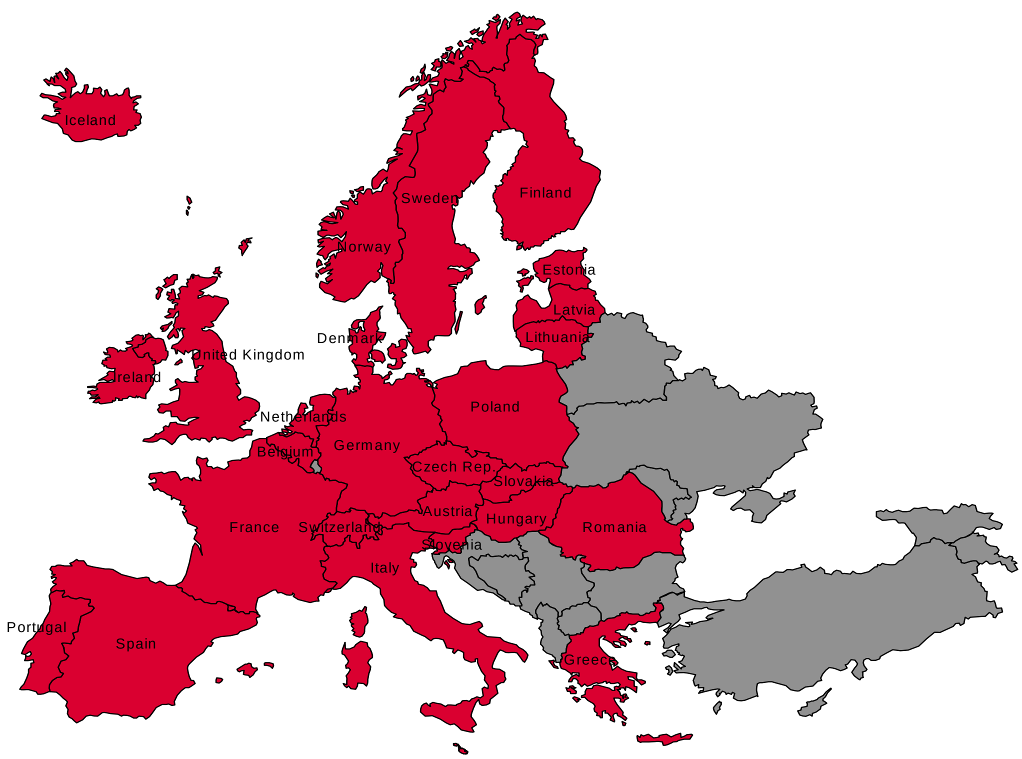

Figure 7-1 European countries included in the analysis of the National Inventory Reports (2007 submission).

The analysis of this working paper is based on the information from the National Inventory Reports of the 2007 submission. They include the following countries: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom. This is altogether 26 countries (Figure 7-1). Data and information from Bulgaria, Cyprus and Malta were not available. The reports were screened for information relevant to the use of BEF and BF for estimations on carbon stock changes in living tree biomass. The list of the relevant national references was also compiled and included in this report as Annex I (within the references).

The analysis is concerned with the follow parameters of the GPG for LULUCF (IPCC 2003):

- basic wood density (D) - Default values in Table 3A.1.9 of IPCC GPG 2003;
- biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment (BEF1) – Default values in Table 3A.1.10 of IPCC GPG 2003;
- biomass expansion factor for conversion volumes of extracted roundwood to total aboveground biomass (including bark) (BEF2) – Default values in Table 3A.1.10 of IPCC GPG 2003;
- root-to-shoot ratio (R) – Default values in Table 3A.1.8 of IPCC GPG 2003
- carbon content in wood

7.2.2. Biomass factors from the reference work

The comparison of the currently adopted methodological material of Good Practice Guidance for LULUCF (GPG for LULUCF; IPCC 2003) and the new 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006), namely the chapters 4.1 and 4.2 covering Agriculture, Forestry and Other Land Use (AFOLU) was made.

The above methodological volumes, i.e., GPG for LULUCF and AFOLU, provide biomass factors in two different forms. GPG for LULUCF provides biomass expansion factors BEF1 (applicable to increment data) and BEF2 (applicable to growing stock data) as one mean single value, indicating also a possible range from the literature compilation available at that time (Table 7-1). These factors are used on connection of the equations 3.2.5 and 3.2.3. of GPG for LULUCF that also explicitly include wood density to convert wood volume to mass weight of biomass and/or carbon.

Table 7-1 Table 3A.1.10 from the GPG for LULUCF (IPCC 2003) - The default values of biomass expansion factors (BEFs)

TABLE 3A.1.10
DEFAULT VALUES OF BIOMASS EXPANSION FACTORS (BEFS)
(BEF_2 to be used in connection with growing stock biomass data in Equation 3.2.3; and BEF_1 to be used in connection with increment data in Equation 3.2.5)

Climatic zone	Forest type	Minimum dbh (cm)	BEF2 (overbark) to be used in connection to growing stock biomass data (Equatoin 3.2.3)	BEF 1 (overbark) to be used in connection to increment data (Equation 3.2.5)
Boreal	Conifers	0-8.0	1.35 (1.15-3.8)	1.15 (1-1.3)
	Broadleaf	0-8.0	1.3 (1.15-4.2)	1.1 (1-1.3)
Temperate	Conifers: Spruce-fir	0-12.5	1.3 (1.15-4.2)	1.15 (1-1.3)
	Pines	0-12.5	1.3 (1.15-3.4)	1.05 (1-1.2)
	Broadleaf	0-12.5	1.4 (1.15-3.2)	1.2 (1.1-1.3)
Tropical	Pines	10.0	1.3 (1.2-4.0)	1.2 (1.1-1.3)
	Broadleaf	10.0	3.4 (2.0-9.0)	1.5 (1.3-1.7)

Note: BEF_2s given here represent averages for average growing stock or age, the upper limit of the range represents young forests or forests with low growing stock; lower limits of the range approximate mature forests or those with high growing stock. The values apply to growing stock biomass (dry weight) including bark and for given minimum diameter at breast height; Minimum top diameters and treatment of branches is unspecified. Result is above-ground tree biomass.

Sources: Isaev et al., 1993; Brown, 1997; Brown and Schroeder, 1999; Schoene, 1999; ECE/FAO TBFRA, 2000; Lowe et al., 2000; please also refer to FRA Working Paper 68 and 69 for average values for developing countries (http://www.fao.org/forestry/index.jsp)

On the contrary, AFOLU adopts the concept of biomass conversion and expansion factors (BCEF), which are intended to provide both expansion and conversion in one step, meaning that wood density (D) is included implicitly. Hence, one may relate and compare the corresponding factors as follows:

$$BCEF = BEF*D \quad (1)$$

$$BEF = BCEF/D \quad (2)$$

Secondly, besides climatic zones and forest types, AFOLU provides the biomass factors also for different growing stock levels (Table 7-2). These were compiled using a broader and more recent literature and should generally constitute a preferable source as compared to the older GPG for LULUCF. In any case, it is vital to assess to what extent the recommended factors of the two resources match.

Table 7-2 Table 4.5 of the AFOLU (IPCC 2006) default biomass conversion and expansion factors (BCEFs) classified by climatic zone, forest type, type of BCEF (stock, increment, root) and growing stock level

TABLE 4.5
DEFAULT BIOMASS CONVERSION AND EXPANSION FACTORS (BCEF), TONNES BIOMASS (M^3 OF WOOD VOLUME)$^{-1}$

BCEF for expansion of merchantable growing stock volume to above-ground biomass ($BCEF_S$), for conversion of net annual increment ($BCEF_I$) and for conversion of wood and fuelwood removal volume to above-ground biomass removal ($BCEF_R$)

Climatic zone	Forest type	BCEF	Growing stock level (m^3)				
Boreal			<20	21-50	51-100	>100	
	pines	$BCEF_S$	**1.2** (0.85-1.3)	**0.68** (0.5-0.72)	**0.57** (0.52-0.65)	**0.5** (0.45-0.58)	
		$BCEF_I$	0.47	0.46	0.46	0.463	
		$BCEF_R$	1.33	0.75	0.63	0.55	
	larch	$BCEF_S$	**1.22** (0.9-1.5)	**0.78** (0.7-0.8)	**0.77** (0.7-0.85)	**0.77** (0.7-0.85)	
		$BCEF_I$	0.9	0.75	0.77	0.77	
		$BCEF_R$	1.35	0.87	0.85	0.85	
	firs and spruces	$BCEF_S$	**1.16** (0.8-1.5)	**0.66** (0.55-0.75)	**0.58** (0.5-0.65)	**0.53** (0.45-0.605)	
		$BCEF_I$	0.55	0.47	0.47	0.464	
		$BCEF_R$	1.29	0.73	0.64	0.59	
	hardwoods	$BCEF_S$	**0.9** (0.7-1.2)	**0.7** (0.6-0.75)	**0.62** (0.53-0.7)	**0.55** (0.5-0.65)	
		$BCEF_I$	0.65	0.54	0.52	0.505	
		$BCEF_R$	1.0	0.77	0.69	0.61	
Temperate			<20	21-40	41-100	100 -200	>200
	hardwoods	$BCEF_S$	**3.0** (0.8-4.5)	**1.7** (0.8-2.6)	**1.4** (0.7-1.9)	**1.05** (0.6-1.4)	**0.8** (0.55-1.1)
		$BCEF_I$	1.5	1.3	0.9	0.6	0.48
		$BCEF_R$	3.33	1.89	1.55	1.17	0.89
	pines	$BCEF_S$	**1.8** (0.6 -2.4)	**1.0** (0.65 -1.5)	**0.75** (0.6-1.0)	**0.7** (0.4-1.0)	**0.7** (0.4-1.0)
		$BCEF_I$	1.5	0.75	0.6	0.67	0.69
		$BCEF_R$	2.0	1.11	0.83	0.77	0.77
	other conifers	$BCEF_S$	**3.0** (0.7-4.0)	**1.4** (0.5-2.5)	**1.0** (0.5-1.4)	**0.75** (0.4-1.2)	**0.7** (0.35-0.9)
		$BCEF_I$	1.0	0.83	0.57	0.53	0.60
		$BCEF_R$	3.33	1.55	1.11	0.83	0.77
Mediterranean, dry tropical, subtropical			<20	21-40	41-80	>80	
	hardwoods	$BCEF_S$	**5.0** (2.0-8.0)	**1.9** (1.0-2.6)	**0.8** (0.6-1.4)	**0.66** (0.4-0.9)	
		$BCEF_I$	1.5	0.5	0.55	0.66	
		$BCEF_R$	5.55	2.11	0.89	0.73	
	conifers	$BCEF_S$	**6.0** (3.0-8.0)	**1.2** (0.5-2.0)	**0.6** (0.4-0.9)	**0.55** (0.4-0.7)	
		$BCEF_I$	1.5	0.4	0.45	0.54	
		$BCEF_R$	6.67	1.33	0.67	0.61	

Using the GPG for LULUCF as a reference, we have used the equation (2) to convert the AFOLU CBEF values into BEF that are directly comparable to those given in the GPG for LULUCF. The required reference wood density (D) for the major tree species was taken from the Table 3A.1.9-1 (IPCC 2003), which is basically identical to Table 4.14 of IPCC (2006). The corresponding BEFs for increment and volume data were expressed as a ratio of AFOLU/(GPG for LULUCF) BEF and - plotted for reference growing stock volumes as used in Table 7-2.

7.2.3. Complementing the database of biomass factors

A complementary project work related to the topic of this chapter was a compilation of available biomass functions and factors. This concerned primarily biomass expansion factors, because an extensive database of allometric functions applicable in European conditions is currently administered by METLA, Finland (Zianis et al. 2005). That database originates from the effort of COST 21[1].

II. Základní objemové jednotky v hlavních porostech (u mýtní těžby) dřeviny smrk — Basic volume units in main stands (final felling) of the spruce species

Střední tloušťka hlavního porostu	Zásoba kmenová	Zásoba hroubí s čepem 7 cm		Posunutí čepové tloušťky hroubí ze 7 cm na 4 cm						Objem dříví mezi čepy 4→0 cm (celé stromy)	Zásoba stromová	Objem dříví standardních pařezů
				Zásoba dříví s čepem 4 cm			Objem dříví mezi čepy 7 až 4 cm					
		jen kmenů	jen větví	jen kmenů	jen větví	u celých stromů	jen kmenů	jen větví	u celých stromů			
cm	Podíl ze zásoby hroubí (čep 7 cm)											
1	2	3	4	5	6	7	8	9	10	11	12	13
10	1,1775	1,0000	—	1,1466	—	1,1466	0,1466	—	0,1466	0,0960	1,2426	0,0181
11	1,1255	1,0000	—	1,1030	—	1,1030	0,1030	—	0,1030	0,0812	1,1842	0,0169
12	1,0876	1,0000	—	1,0713	—	1,0713	0,0713	—	0,0713	0,0697	1,1410	0,0165
13	1,0580	1,0000	—	1,0525	—	1,0525	0,0525	—	0,0525	0,0625	1,1150	0,0163
14	1,0396	1,0000	—	1,0319	0,0003	1,0322	0,0319	0,0003	0,0322	0,0591	1,0913	0,0163
15	1,0339	1,0000	—	1,0272	0,0004	1,0276	0,0272	0,0004	0,0276	0,0579	1,0855	0,0164
16	1,0282	1,0000	—	1,0226	0,0004	1,0230	0,0226	0,0004	0,0230	0,0567	1,0797	0,0164
17	1,0242	1,0000	—	1,0194	0,0005	1,0199	0,0194	0,0005	0,0199	0,0562	1,0761	0,0166
18	1,0203	1,0000	—	1,0161	0,0006	1,0167	0,0161	0,0006	0,0167	0,0558	1,0725	0,0168
19	1,0173	1,0000	—	1,0136	0,0007	1,0143	0,0136	0,0007	0,0143	0,0557	1,0700	0,0170
20	1,0143	1,0000	—	1,0112	0,0008	1,0120	0,0112	0,0008	0,0120	0,0554	1,0674	0,0173
21	1,0130	1,0000	—	1,0098	0,0010	1,0108	0,0098	0,0010	0,0108	0,0554	1,0662	0,0176
22	1,0116	1,0000	—	1,0084	0,0012	1,0096	0,0084	0,0012	0,0096	0,0553	1,0649	0,0179
23	1,0102	1,0000	—	1,0076	0,0014	1,0090	0,0076	0,0014	0,0090	0,0555	1,0645	0,0182
24	1,0089	1,0000	—	1,0068	0,0015	1,0083	0,0068	0,0015	0,0083	0,0558	1,0641	0,0185
25	1,0080	1,0000	—	1,0062	0,0016	1,0078	0,0062	0,0016	0,0078	0,0560	1,0638	0,0189
26	1,0072	1,0000	—	1,0055	0,0018	1,0073	0,0055	0,0018	0,0073	0,0563	1,0636	0,0193
27	1,0066	1,0000	—	1,0050	0,0020	1,0070	0,0050	0,0020	0,0070	0,0565	1,0635	0,0196
28	1,0060	1,0000	—	1,0045	0,0021	1,0066	0,0045	0,0021	0,0066	0,0568	1,0634	0,0199
29	1,0056	1,0000	—	1,0042	0,0023	1,0065	0,0042	0,0023	0,0065	0,0569	1,0634	0,0202

Figure 7-2 Basic volume units in main stands of the spruce species – example from Parez et al (1990)

The first step was collecting and compilation of data/factors. This work included also checking and verifying data with the original sources (articles, reports and project results). They included regional and local studies, where the factors used for biomass estimation were described. For example, the source from the Czech Republic utilized data of the national survey (1960-1987), and include information based on 3090 harvested spruce trees and 3104 pines representing the conditions of the Czech managed forests (Parez *et al*. 1990). This compilation presents biomass factors that are dimensionless and allow expansion from stem/timber volume under bark to i) to stem over bark, ii) tree aboveground biomass (AB) and iii) stump (Figure 7-2). Unfortunately, the tree level source data are not available any more.

Secondly, the collected information was prepared for database entry, which followed the communication with JRC expert (M. Theobaldelli). The biomass functions and expansion factors were formatted to appropriate forms and uploaded in SQL format to JRC database. The uploaded entries were verified in its final form and set as “checked” in the output tables.

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[1] It should be noted, however, that the database is limited to functions using diameter at breast height and/or tree height as independent variables. Other functions, which use additional information (e.g., crown parameters or site altitude, readily available from NFIs that might significantly improve biomass prediction (Wirth *et al*. 2004, Joosten *et al*. 2004, Cienciala *et al*. 2006)), are not included.

7.3. *Results and Discussion*

7.3.1. Source of functions, factors and parameters used in European GHG Emission Inventories

The analysis of the National Emission Inventory Reports (NIR), submission 2007, revealed that the estimation of carbon stock in biomass in the European countries is still dominantly based on biomass expansion factors (ca. 70 %; Table 7-3). Biomass functions are mostly applied in those countries with good tradition of statistical forest inventory with data on individual tree level. However, the application of default IPCC (2003) factors remains high (see below). This complements the findings of the analysis performed in Chapter 6 that focused on the use of biomass functions and factors in the European National Forest Inventories. Specifically, it becomes evident that European countries do commonly have available their national biomass functions and factors, but their use in emission inventories is for some reasons limited.

As for aboveground biomass, NIRs indicate that IPCC default BEFs were used on about 40 % of the 26 European countries analyzed here (Table 7-3). Only a slightly larger share (42 %) was observed for the component of below-ground biomass. However, this information is likely biased, because most of the countries derive belowground biomass on the basis of aboveground biomass. Additionally, the estimation of belowground biomass can be based on different proxies, such as growing stock volumes or above-ground biomass.

The countries with repetitive or continuous statistical forest inventory on tree level, e.g., Norway, Sweden and the Netherlands, use exclusively biomass functions for estimation of tree biomass. Finally, some countries such as France, United Kingdom and Estonia utilize other methods to estimate aboveground or belowground biomass that cannot be classified with the categories of BF and/or BEF used here.

About 38 % of the analyzed countries use some species-specific biomass functions and 54 % use species-specific BEFs to estimate aboveground biomass (Table 7-3). The specific biomass functions for species groups or individual tree species are available in Austria, Czech Republic, Iceland, Lithuania, Norway, Portugal, Sweden, Switzerland and United Kingdom. As for belowground biomass, the detail of tree species for biomass functions and BEFs is even less common (Table 7-3). The biomass functions on the level of species groups or individual tree species are available in 23 % (Austria, Norway, Portugal, Romania, and Sweden). The species-specific BEFs are used in 31 % of the analyzed countries (Belgium, Czech Republic, Denmark, Finland, Germany, Italy, and Iceland).

Linked to estimation of belowground biomass is also the information on root/shoot ratio. This information is taken either from the IPCC tables (IPCC 2003) or estimated based on country-specific information on above- and belowground biomass (Table 7-4). Unfortunately, 11 countries did not report any information on R in their NIR. From the remaining 15 countries, about one half relies on IPCC default data.

Table 7-3 List of biomass functions and biomass expansion factors using by MS countries in emission inventory reports for calculation of biomass stocks (N/A - not applicable, o - information not available, IPCC – default values)

	Biomass Functions (BF)						Biomass expansion factors (BEF)					
	AB			BB			AB			BB		
Country	Dec.	Con.	Spec.	Dec.	Con.	Spec.	Dec.	Con.	Spec.	Dec.	Con.	Spec.
Austria	●	●	●			●	N/A	N/A	N/A	N/A	N/A	N/A
Belgium	N/A	N/A	N/A	N/A	N/A	N/A	●	●	●	●	●	●
Czech R.			●						●			●
Denmark	N/A	N/A	N/A	N/A	N/A	N/A	●	●	●			●
Estonia		IPCC			IPCC				●		IPCC	
France	N/A	N/A	N/A	N/A	N/A	N/A		o		●	●	
Finland	N/A	N/A	N/A	N/A	N/A	N/A	●	●	●	●		●
Germany	N/A	N/A	N/A	N/A	N/A	N/A			●			●
Greece		o			o			IPCC			IPCC	
Hungary	N/A	N/A	N/A	N/A	N/A	N/A		o			IPCC	
Italy		o					●	●	●	●	●	●
Ireland	N/A	N/A	N/A	N/A	N/A	N/A			●		o	
Iceland			●									●
Latvia	N/A	N/A	N/A	N/A	N/A	N/A		IPCC			IPCC	
Lithuania			●				●	●	●		IPCC	
Norway			●			●	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands		o					N/A	N/A	N/A	N/A	N/A	N/A
Poland		N/A		N/A	N/A			IPCC			IPCC	
Portugal			●			●			●			
Romania			●			●		o			o	
Slovakia		o							●		IPCC	
Slovenia		IPCC					●	●	●		IPCC	
Spain					IPCC		●	●	●		IPCC	
Sweden			●			●	N/A	N/A	N/A	N/A	N/A	N/A
Switzerland			●		o		●	●			o	
UK			●			●			●			●

Other important parameters affecting the biomass and carbon estimation are wood density and wood carbon content. While the latter parameter does not substantially vary for the range of European species, wood density is specific to tree species (see below). Therefore, it is important to note that most of the European countries (about 70%) report use of country and species-specific wood density in their biomass estimation (Table 7-4). On the contrary, wood carbon fraction different than the default value of 0.5 t C per t of biomass (default IPCC value) is reported in only 30 % of the countries (Table 7-4).

Table 7-4 List of wood density, root-shoot ratio and carbon content parameters using by MS countries in emission inventory reports for calculation of biomass stocks (o – information not available)

Country	Wood Density			Root-shoot ratio			Carbon content		
	IPCC	National		IPCC	National		IPCC	National	
		Con/Dec.	Spec.		Con/Dec.	Spec.		Con/Dec.	Spec.
Austria		•			o			•	
Belgium		•	•		o			•	•
Czech R.	•		•	•			•		
Denmark			•		o		•		
Estonia			•		o				•
France									
Finland		•	•		o			•	•
Germany			•	•			•		
Greece	•			•			•		
Hungary			•		o		•		
Italy		•	•		•	•	•		
Ireland			•		o		•		
Iceland		o			o			o	
Latvia	•			•			•		
Lithuania		•	•		•	•	•		
Norway			•			•		•	
Netherlands			•		o		•		
Poland	•				o		•		
Portugal			•	•		•	•		
Romania		•	•	•			•		
Slovakia		•	•	•			•		
Slovenia	•				•		•		
Spain	•		•	•	•		•		
Sweden			•			•		•	
Switzerland		•			o		•		
UK			•			•	•		

It should be stressed that in most European countries, the use of biomass functions and BEFs is under ongoing revision and development in connection to the quickly approaching 1st Commitment period of the Kyoto protocol. This applies to both West-European and the new EU member countries. Specifically for the latter group, it can be expected that new statistical forest inventories will be available for use in emission inventories. This will also mean that these countries would gradually change their methodology to calculate changes in biomass carbon stock that would utilize biomass functions. Among these countries are the Czech Republic, Slovakia, Romania and some others. This would also imply that the methodology level would qualify to higher tiers.

7.3.2. Specific values of factors used in European NIRs

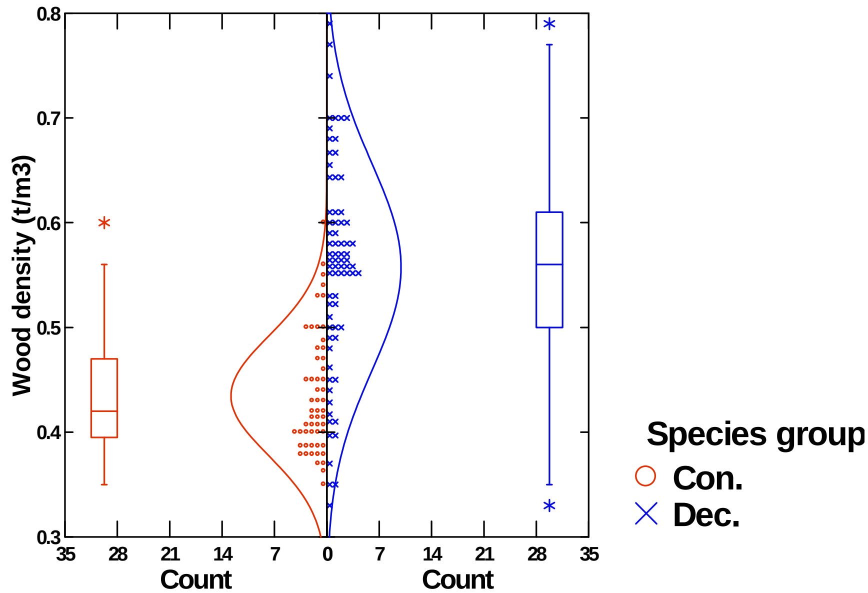

Figure 7-3 Wood density - parameters used in NIRs of the European countries for coniferous (Con.) and deciduous (Dec.) tree species

Wood density (*D*) is one of the most important factors affecting the estimation of carbon stock and stock changes. Screening the 2007 submission of NIRs, 19 of the 26 European countries analyzed here specified the specific values used in their biomass carbon stock estimates. For coniferous species, *D* reached a mean value of 0.435 t/m^3 with standard deviation of 0.057 t/m^3. For broadleaved species, a mean value of *D* was 0.558 t/m^3 with standard deviation of 0.099 t/m^3. With respect to variability around the mean, the difference between *D* fro coniferous and broadleaved species was significant (two-sample t-test; $p<0.001$). It can be observed that the spread of *D* values is larger for broadleaved species as compared to coniferous species (Figure 7-3).

With regard to carbon fraction, vast majority of countries, namely 83 % use a standard value of 0.50 for to estimate carbon in woody biomass of coniferous species. A similar proportion, namely 76 % of the countries analyzed here, used the default value of 0.50 to estimate carbon in woody biomass for deciduous species. The values besides the default one were only marginally different (Figure 7-4). Hence, those values do not have any significant importance in the estimation with respect to other uncertainties involved in the overall estimation of emissions and removals related to biomass carbon stock change.

With respect to biomass expansion factors such as those applied for increment and stock (BEF1 and BEF2, IPCC 2003) and also the fraction of root biomass (R), no quantitative analytical evaluation is feasible. This is mostly due to a variety of definitions applied and specific conditions in individual countries. These commonly result in country-specific approaches that should be further documented in NIRs. Comparable information on the biomass expansion factors requires identical definitions of input variables and strict adherence to the prescribed methodology. Unfortunately, these conditions are often not met. This has already been recognized by the research and policy related to forest and emission inventory process and currently ongoing efforts attempt to address these shortcomings. Specifically, the COST action E43 targets the issue of harmonized definitions relevant for the use of the data from the national forest inventories in Europe. Similarly, IPCC works on further LULUCF/AFOLU methodology consolidation. The effort of JRC to create database of key factors required for emission inventory such as BEF1, BEF2 and R (see also Section 3.4 below) is in the above context specifically important.

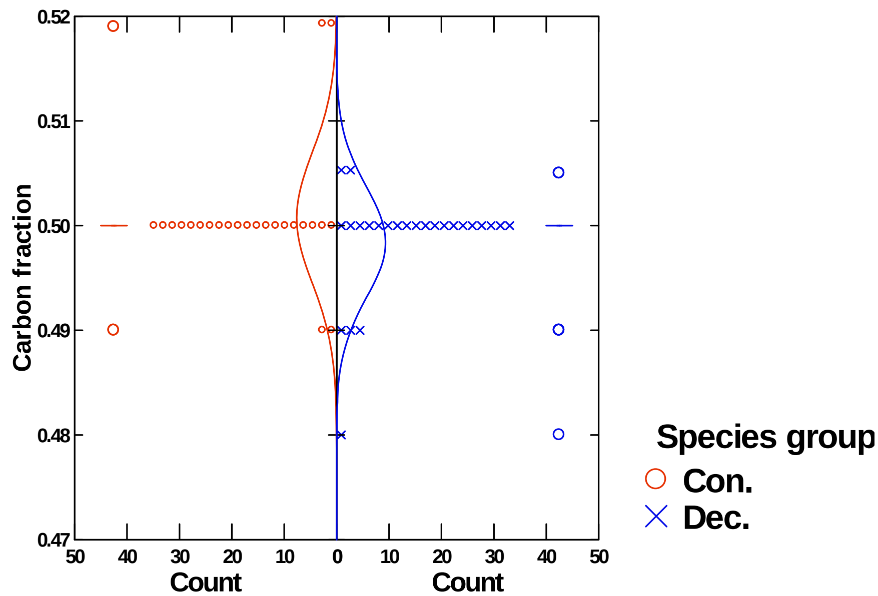

Figure 7-4 Carbon fraction in woody biomass – parameters used in NIRs of the European countries for coniferous (Con.) and deciduous (Dec.) tree species.

7.3.3. IPCC guidance on biomass expansion factors: comparing GPG LULUCF (IPCC 2003) and AFOLU (IPCC 2006)

The results applicable to boreal region are shown in Figure 7-5. It can be observed that the ratio of BEF applicable to increment (Figure 7-5 left) expressed for pine and spruce stands is rather close to unity (1.0). For pine, the BEF value derived from AFOLU is only about 4 % smaller as compared to GPG default BEF. Even better correspondence was for spruce, with exception of the smallest growing stock values, for which would the AFOLU-derived BEF result in 20 % larger factor. The importance of factors specifically expressed also for different growing stock levels is fully revealed on the comparison of BEFs applicable to growing stock (Figure 7-5 right). Similarly for both pine and spruce, the match of BEFs derived from AFOLU and GPG for LULUCF is rather good for medium and high growing stock levels. However, for stands with low growing stocks (younger stands and stands on extreme locations) the specific BEF derived from AFOLU tables becomes about twice as large as compared to GPG.

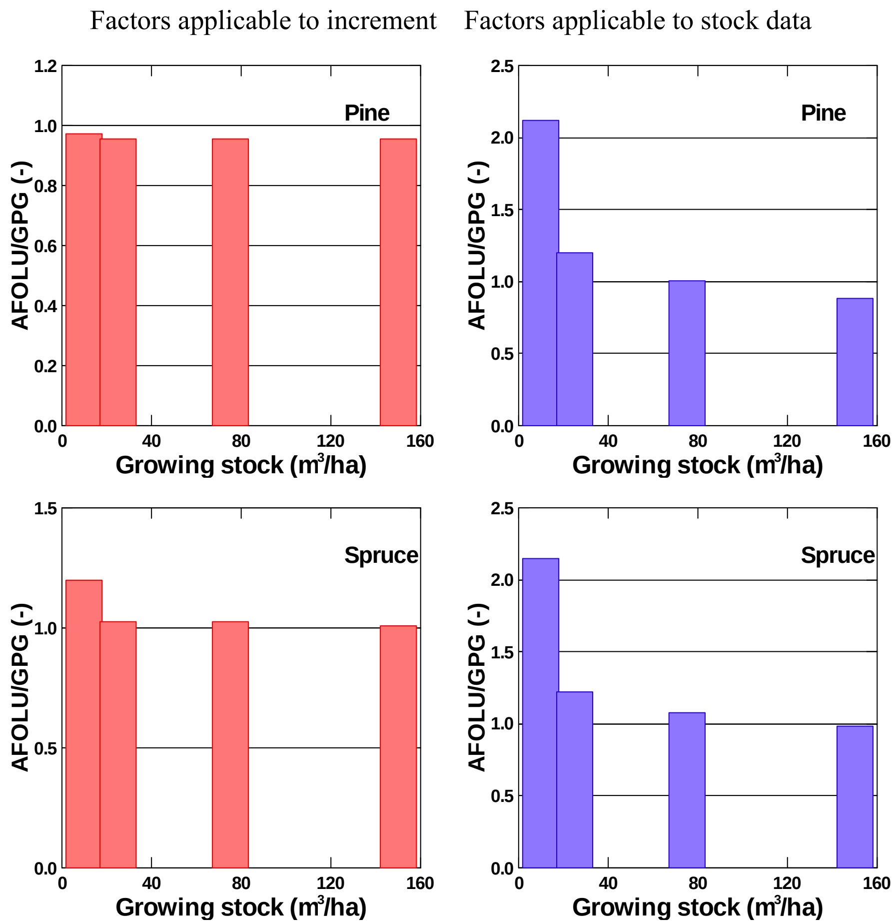

Figure 7-5 The comparison of factors applicable to increment (left) and growing stock (right) recommended by AFOLU in relation to those recommended by GPG for LULUCF, expressed as a fraction AFOLU/GPG – unity (1.0) means that the factors match well, while the values above (below) 1.0 means overestimation (underestimation) by AFOLU with respect to GPG for LULUCF. **Examples of factors for boreal zone and major tree species are shown**

A similar analysis performed with the factors applicable to temperate regions showed significantly larger differences between the factors from AFOLU and GPG for LULUCF (Figure 7-6). Generally, AFOLU-recommended expansion factors are mostly larger than those given in GPG for LULUCF. The expression of growing stock level (and implicitly age) is much stronger for temperate forests as compared to boreal ones. With exception of BEF applicable for increment and broadleaved species, the overestimation of AFOLU-recommended factors is obvious for all species and factors applicable to both increment and stock data. While the higher factor values of AFOLU are to be expected for stands of low growing stocks, it is surprising to see that the factors derived from AFOLU are also significantly higher than the GPG for LULUCF default BEFs for medium and high growing stock levels (Figure 7-6), commonly by tens of %.

Unfortunately, no straightforward comparison is possible for the factors applicable to the Mediterranean zone, which is also important within European emission inventory context. However, it can be expected that the differences may also be similarly large as observed for the factors applicable for temperate regions.

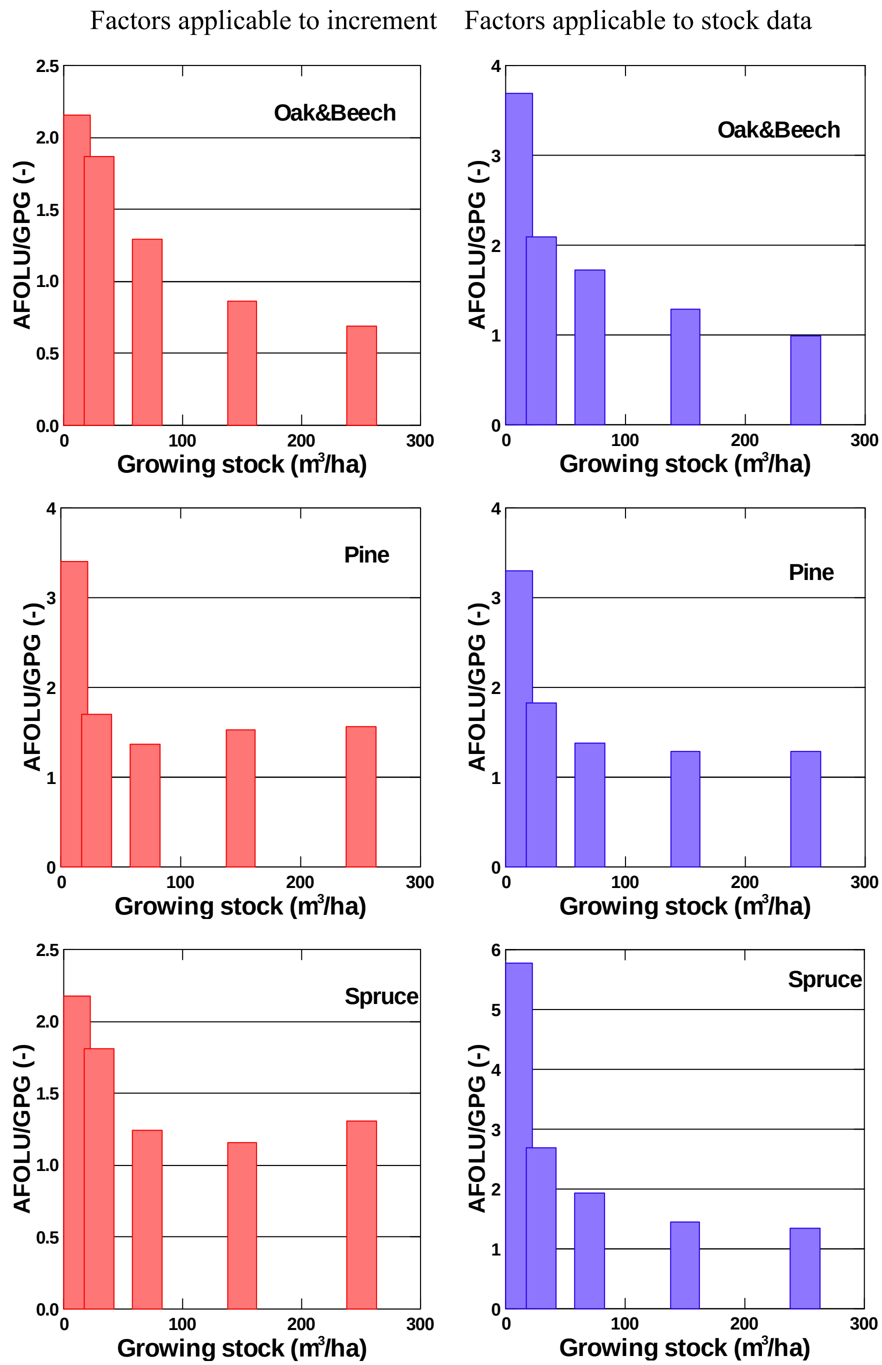

Figure 7-6 The comparison of factors applicable to increment (left) and growing stock (right) recommended by AFOLU in relation to those recommended by GPG for LULUCF, expressed as a fraction AFOLU/GPG – unity (1.0) means that the factors match well, while the values above 1.0 means overestimation by AFOLU with respect to GPG for LULUCF. **Examples of factors for temperate zone and major tree species are shown**

The above results demonstrate that the application of default BCEF values from AFOLU would result in significantly higher carbon sink (increment) and carbon stock as compared to the estimate aided by the factors from GPG for LULUCF. While the application of AFOLU values for boreal zone would mostly affect only the stands with low growing stock levels, the effects for the temperate zone carbon estimates would be rather strong. The total increment of coniferous species would be larger by about 30 % or more. On the contrary, the total increment calculated for broadleaved species would result in underestimation in comparison with the calculation based on the values from GPG for LULUCF. As for the calculation applicable to stock data and broadleaved species, the factors of the two resources matched well only for the high growing stock levels. Lower growing stock levels for broadleaves, and also the full range of conifers showed that using the AFOLU factors would result in larger estimates of biomass and carbon stocks by about 30 % for medium and high growing stock levels and even more for the stands with low growing stocks (Figure 7-6).

The above simple analysis indicates that the uncertainty of BEFs remains large. This will affect the overall uncertainty of emission inventory for the forest land-use category in those countries that have to rely on aggregated forest taxation data. On the contrary, this should not be an issue for those countries that utilize statistical forest inventory and tree-level data. These permit application of more reliable biomass functions, which should generally result in more accurate forest emission/removal estimates.

GPG for LULUCF (2003) and AFOLU (IPCC 2006) may both be used in compiling the emission inventory under UNFCCC and KP. BEF and BCEF concepts are based on different (in AFOLU updated) literature and hence the factors also differ. Note, however, that higher tier methods are required for key categories, for which the country specific BEFs should be used instead of the Tier-1 default values.

7.3.4. New biomass factors for AFOLU-database

Supporting the effort to create database of key factors required for emission inventory such as BEF1, BEF2 and R, this project also aids compilation of factors usable for the conditions of European countries. MASCAREF compiled and delivered to the AFOLU database at JRC about 800 biomass factors, including increment-related factors (BEF1), stock-related factors (BEF2), harvest–related factors (BEFH), wood density and carbon fraction parameters. These factors were mostly collected from the most recent National inventory reports (NIRs) of the European countries and the related source literature. The factors originate from 15 European countries, including Austria, Belgium, Belorussia, Czech Republic, Estonia, Finland, Great Britain, Hungary, Latvia, Lichtenstein, Lithuania, Portugal, Romania, Spain and Switzerland. More than 580 biomass expansion factors come from the results of the Czech national survey during the period of 1960 to 1987 as basic volume units for the main stands of major temperate tree species – beech, oak, pine and spruce. The example of these biomass expansion factors are shown in Figure 7-7, in which the species-specific factors are plotted against the mean stand diameter. The references supplied by the MASCAREF project to the AFOLU database are also available in a literature reference format (GetARef).

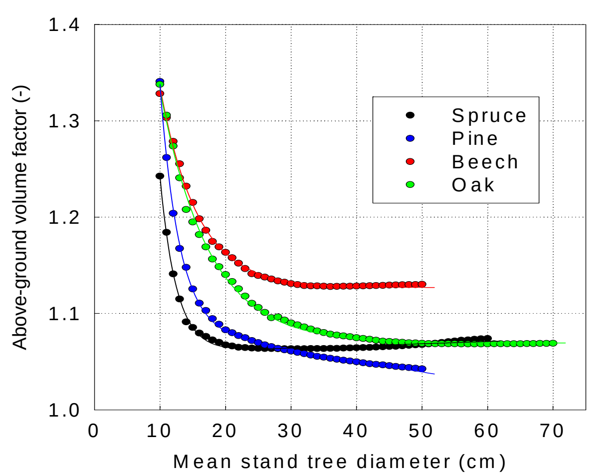

Figure 7-7 Expansion factors applicable to above-ground stand volumes (Pařez *et al)* for the main tree species (spruce, pine, beech and oak) plotted against mean stand tree diameter

The current status of the AFOLU database as administered by JRC can be found on http://afoludata.jrc.it. The AFOLU database permits specific analysis of the biomass factors using queries (Figure 7-8).

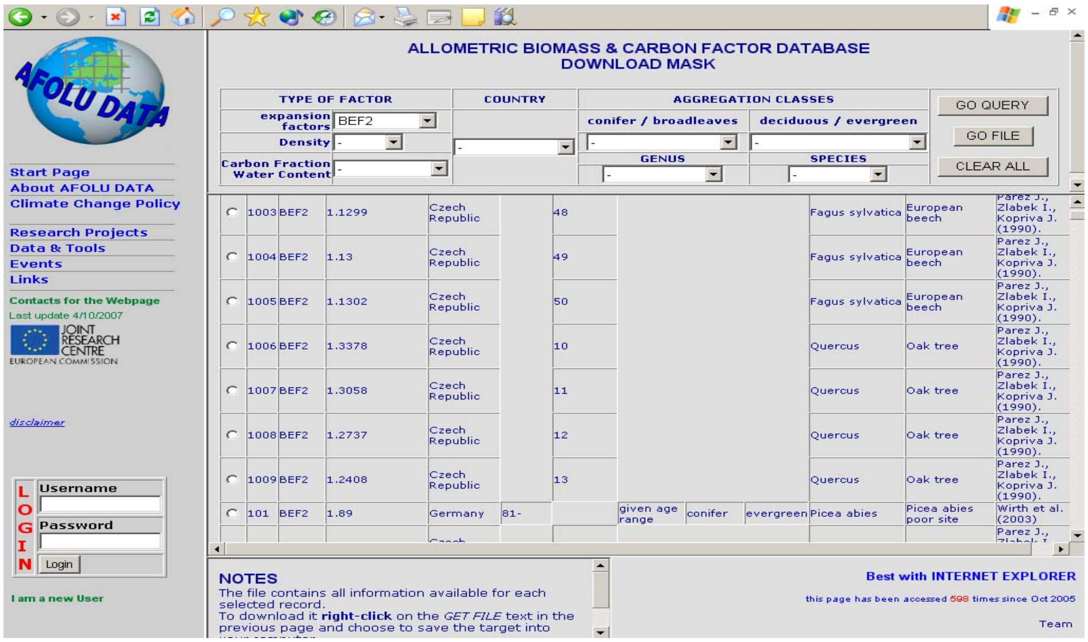

Figure 7-8 The screenshot of the AFOLU database of JRC and example of biomass expansion factors from the Czech Republic

The user-defined database queries may reveal the factors used, e.g., by type of factors, tree species group, genus and species. It is expected that the AFOLU database will be continuously updated and hence become useful reference tool for inventory compilers and research community.

7.4. *Conclusions*

This report shows the status of the conversion/expansion procedures used by the European member countries when compiling emission inventory from forests within the LULUCF sector. It confirms the findings of other studies (see Chapter 6) devoted to factors used in the European National Forest Inventory programs. Namely, the emission inventory challenges the wide variety of conditions within European countries, which is also reflected by different meaning of definitions and input parameters. This applies specifically to the most important parameters used in carbon stock change estimation, namely BEF1, BEF2 and R. The other parameters, such as conventional wood density and wood carbon fraction remain easily comparable. It becomes obvious that the differences in BEFs remain an issue for temperate and Mediterranean regions, which was demonstrated by the comparison of the GPG for LULUCF (IPCC 2003) and AFOLU (IPCC 2006) default factors. On the contrary, the information applicable for boreal zone is generally consistent. The inventory compilers should further focus on transparent reporting as in many instances the relevant information on biomass parameters used is lacking.

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8. Procedures for Expanding from Timber Volume to Carbon Stocks of Forests in MASCAREF Test Countries

Emil Cienciala and **Zuzana Exnerova**
IFER - Institute of Forest Ecosystem Research, Ltd., Czech Republic
Email: emil.cienciala@ifer.cz and zuzana.exnerova@ifer.cz

Kestutis Armolaitis
Lithuanian Forest Research Institute, Lithuania
Email: k.armolaitis@mi.lt

Olivier Bouriaud
Forest Research and Management Institute, Romania
Email: obouriaud@gmail.com

Giorgio Matteucci
National Research Council, Institute of Agro-Environmental and Forest Biology, Italy
Email: giorgio.matteucci@isafom.cs.cnr.it

Kalliopi Radoglou
Forest Research Institute, National Agricultural Research Foundation, Greece
Email: radoglou@fri.gr

Tibor Priwitzer and **Vladimir Šebeň**
National Forest Centre, Slovakia
Email: priwitzer@nlcsk.org

Abstract

The aim of this report is to summarize the current use and availability of allometric function and factors used in five countries of sub-contracted partners of the MASCAREF project. They include Greece, Italy, Lithuania, Romania and Slovakia. For these countries, information on biomass parameters adopted in National inventory reports is provided, together with other available and potentially applicable resources. It is shown that the available data and its utilization in emission inventory largely differ among the countries reflecting the country specific conditions. Overall, it is evident that a further improvement in reporting CO_2 emissions and removals in forestry can be expected once the results of statistical forest inventories become more readily available and countries would be able to adopt appropriate tree biomass and carbon estimation procedures.

8.1. *Introduction*

The information on tree biomass is required to assess the amount of carbon held in trees, which in turn represent the basis of the assessment of carbon stock held in forests. The estimation of tree volume and biomass in forests is needed for sustainable planning of forest resources. In addition, the United Nations Framework Convention on Climate Change and in particular the Kyoto Protocol recognizes the importance of forest carbon sink and the need to monitor and enhance terrestrial carbon stocks. The existing knowledge on the allometry of trees is available in the form of biomass equations. Tree biomass equations are tools to express biomass components in term of dry mass on the basis of easily measurable variables. These are most commonly tree diameter at breast height (D) and tree height (H). These can be applied directly to tree level inventory data or biomass expansion factors (BEFs) applicable to stand level inventory data. The development of biomass equations is time consuming process, especially the destructive harvesting of large trees, existing equations need to be compiled and evaluated to facilitate identification of the gaps in the coverage of the equations. The carbon stocks and stock changes are difficult to assess (IPCC 2003). The suitable biomass functions or biomass factors are often not readily available in individual member states. In order to aid assessment of carbon stock changes for the purpose of emission inventory in the Land Use, Land-Use Change and Forestry (LULUCF) sector, the methodological guidance of IPCC (2003), they so called Good Practice Guidance for LULUCF, also includes broadly applicable default factors applicable for major forest categories and geographical regions. Obviously, the application of such factors may easily introduce an error and contribute to overall uncertainty of emission inventory. In this study, specific attention is paid to biomass factors, applicable to stand level aggregated volume or biomass information.

8.2. *Data sources and parameters*

The selected test areas are located in the following countries:

- Lithuania (representing Northern CEE/Baltic countries and a new member state to EU)
- Romania (representing a Southern CEE and a new member state to EU)
- Italy (representing Central Mediterranean region, a former EU15 country, with highly diverse environmental conditions, presence of coppice stands and only a recent history of NFI)
- Greece (representing Eastern Mediterranean region, a former EU15 country, a country with incomplete inventory/monitoring system)
- Slovakia (representing Central region of CEE and problems related to integration of stand-wise inventory from forest management plans and a new NFI program)

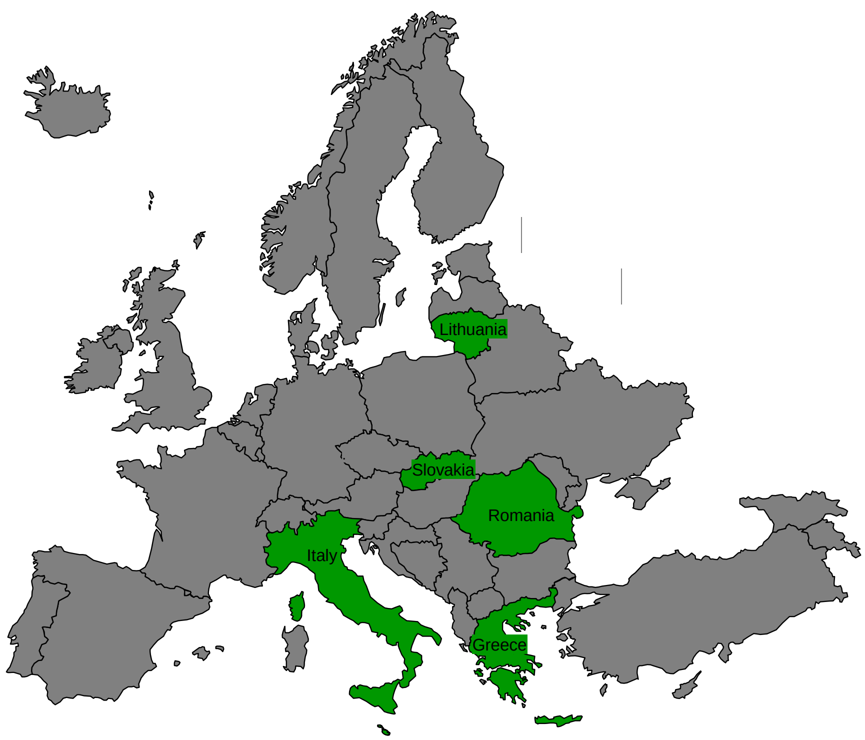

Figure 8-1 Five European countries included in the gap sensitivity analysis

The analysis of this working paper is based on the information from the National Inventory Reports (NIRs) of the 2007 submission, and also from the national and regional studies that are not included in NIRs. The reports were screened for information relevant to the use of BEF and BF for estimations on carbon stock changes in living tree biomass. The list of the relevant national references was compiled at the end of this work.

The analysis is concerned with the following parameters of the GPG for LULUCF (IPCC 2003):

- basic wood density (D) - Default values in Table 3A.1.9 of IPCC GPG 2003;
- biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment (BEF1) – Default values in Table 3A.1.10 of IPCC GPG 2003;
- biomass expansion factor for conversion volumes of extracted roundwood to total aboveground biomass (including bark) (BEF2) – Default values in Table 3A.1.10 of IPCC GPG 2003;
- root-to-shoot ratio (R) – Default values in Table 3A.1.8 of IPCC GPG 2003
- carbon content in wood

8.3. *Results*

8.3.1. Overview of information available in NIRs

The analysis of the National Emission Inventory Reports (NIR), submission 2007, revealed that the estimation of carbon stock in biomass in the selected areas is still dominantly based on biomass expansion factors. While Greece, Lithuania and Romania use for the calculation of aboveground biomass the IPCC default factors, Italy and Slovakia apply country-specific factors. Biomass functions are mostly applied in the countries with individual tree level data that are based on statistical forest inventory. Each of tested countries applied the default IPCC (2003) factors and none of them presents any BFs in their NIR (Table 8-1). This complements the findings of the analysis performed within Chapter 6 that focused on the use of biomass functions and factors in the European National Forest Inventories. Specifically, it becomes evident after analysis of regional studies that these countries do commonly have available their national biomass functions and factors, but their use in emission inventories is for some reasons limited.

Linked to estimation of belowground biomass is also the information on root/shoot ratio. This information is taken either from the IPCC tables (IPCC 2003; Greece, Romania, Slovakia) or estimated based on country-specific information on above- and belowground biomass (Italy and Lithuania).

Table 8-1 List of biomass functions and biomass expansion factors using by five sub-contracted partners in emission inventory reports for calculation of biomass stocks (NA – not available data, IPCC – using of default values)

	Biomass Functions (BF)						**Biomass expansion factors (BEF)**					
	AB			BB			AB			BB		
Country	Dec.	Con.	Spec.	Dec.	Con.	Spec.	Dec.	Con.	Spec.	Dec.	Con.	Spec.
Greece	NA			NA			IPCC			IPCC		
Italy	NA			NA			•	•	•	•	•	•
Lithuania	NA			NA			IPCC			IPCC		
Romania	NA			NA			IPCC			IPCC		
Slovakia	NA			NA					•	IPCC		

Other important parameters affecting the biomass and carbon estimation are wood density and wood carbon content. While the latter parameter does not substantially vary for the range of European species, wood density is specific to tree species. Therefore, it is important to note that most of the selected countries (except Greece) report use of country and species-specific wood density in their biomass estimation. On the contrary, the default IPCC value of wood carbon fraction (0.5 t C per t of biomass) is reported in each of selected countries (Table 8-2).

Table 8-2 List of wood density, root-shoot ratio and carbon content parameters using by MS countries in emission inventory reports for calculation of biomass stocks (na – not available data)

Country	**Wood Density**			**Root-shoot ratio**			**Carbon content**		
	IPCC	National		IPCC	National		IPCC	National	
		Con/Dec.	Spec.		Con/Dec.	Spec.		Con/Dec.	Spec.
Greece	●			●			●		
Italy		●	●		●	●	●		
Lithuania		●	●		●	●	●		
Romania		●	●	●			●		
Slovakia		●	●	●			●		

A majority of EU countries has their biomass functions and BEFs under ongoing revision and development in connection to the approaching 1st Commitment period of the Kyoto protocol. Specifically for the new EU member countries it can be expected that new statistical forest inventories will be available for use in emission inventories. This will also mean that these countries would gradually change their methodology to calculate changes in biomass carbon stock that would utilize biomass functions. Among these countries are Lithuania, Romania and Slovakia. This would also imply that the methodology level for estimation biomass carbon stock change would qualify to higher tiers.

The case countries use either the IPCC default or various national or regional-specific biomass and conversion factors. The BEFs and BFs are used in connection with other available data and additional information. For example a regional species composition or national forest type classification could affect stratification and types of these factors. This report presents the five selected countries in terms of i) tree species composition ii) forest type categorization iii) BEF (biomass expansion factors) and BF (biomass functions) used so far for the calculation of biomass carbon stock for and/or available in the latest NIR submissions and iv) the other sources of information on locally applicable biomass functions and factors.

8.3.2. Country-specific data for Greece

Tree species composition

Based on data from the Greek Forest Inventory (GSFNE, 1992) Greek forests & woodlands consist mainly of broadleaves if calculated on an area basis (78% of the forested area). Most abundant are evergreen broadleaves species (48% of the area) with *Quercus* species classified separately (together 22% of the area). *Abies* (8% of the area) and Mediterranean *Pinus* species (all *Pinus* species accounting for 13.5% of the area) are the most common conifers.

Description of forest types / main classification

For the purpose of GHG inventory, Greece distinguishes six major forest types, which are based on the major tree species. These types are presented in Table 8-3, including their areas. There are also tree forest plantations in Greece, such as those of poplar. However, their share is small (about 10 kha, NIR Greece, 2007) and that area is included in the Cropland category. For the estimation of carbon stock changes in areas affected by wildfires a stratification of 21 forest types has been used, since more detailed activity data are available.

BEF and BF (biomass functions) available in NIR

The last GHG inventory submission of Greece (NIR Greece 2007) contains the information on factors D, BEF1, BEF2 and R (Table 8-3). These were based on the default factors based on GPG (IPCC 2003).

Table 8-3 Forest types distinguished in the emission inventory of Greece and the key factors used in calculation biomass carbon stock (NIR Greece 2007)

Forest type	Area (kha)	D (t d.m. m^{-3})	BEF1 (-)	BEF2 (-)	R (-)
Abies sp.	543.31	0.40	1.15	1.30	0.46
Picea abies	2.75	0.40	1.15	1.30	0.23
Pinus sp. & other Conifers	883.55	0.42	1.05	1.30	0.46
Fagus sp.	336.64	0.58	1.20	1.40	0.43
Quercus sp.	1 471.84	0.58	1.20	1.40	0.35
Other Deciduous	121.10	0.55	1.20	1.40	0.43

Other country-specific BEF and BF

The biomass equations for various aboveground components refer to two tree species (*Fagus moesiaca* and *Quercus conferta*) growing in southern Europe (Greece). The majority of the biomass equations took the simple linear form log (M) = A + B × log (D)

where log (M) is either the natural or the 10-base logarithmic transformation of the biomass data for different tree components, log (D) is the diameter at breast height (either in natural or 10-base logarithmic transformation) and a and b the estimated parameters. The value of the coefficient of determination (R^2) is reported in most of the regressions and varied from 0.50 to 0.99. Number of sampled trees (n), R^2, and range of diameter (D) and height (H) of sampled trees are presented in the

Table 8-4and Table 8-5

Table 8-4 Biomass equations for *Fagus moesiaca* (Beech, Oxia). Number of sampled trees (n=16), range of DBH (5.4-41cm), range of tree height (9.2-28 m) are reported in original article Zianis & Mencuccini 2003

Biomass components	Format of Equation	Parameters		R^2
		a	b	
Aboveground	ln(AB)=a+b·ln(D)	–1.3816	2.3485	0.99
Branches	ln(BR)=a+b·ln(D)	–5.8980	2.9353	0.97
Foliage	ln(Fl)=a+b·ln(D)	–4.1814	1.6645	0.90
Total stem	ln(ST)=a+b·ln(D)	–1.6015	2.3470	0.98
Stump	ln(SU)=a+b·ln(D)	–1.7716	1.0730	0.78

Table 8-5 Biomass equations for *Quercus conferta* (Hungarian oak, Platifilos dris). Number of sampled trees (n=27), range of DBH (2-19 cm), range of tree height (2.2-14.7 m) are reported in original study Matis & Alifragis 1983-4)

Biomass components	Format of Equation	Parameters		R^2
		a	b	
Branch biomass	$\ln(ABW)=a+b\cdot\ln(D)$	–2.1686	2.4407	0.98
	$\ln(ABW)=a+b\cdot\ln(D^2 H)$	–2.5259	0.8605	0.98
	$\ln(BR)=a+b\cdot\ln(D)$	–3.3508	1.7235	0.80
	$BR=[a+b(1/D)+c(1/D2)]\cdot D^2$	0.0536	–0.3269	0.65
	$\ln(BR)=a+b\cdot\ln(D)$	–11.433	4.9391	0.73
	$\ln(BR)=a+b\cdot\ln(D)$	–4.1909	2.5403	0.89
	$\ln(BR)=a+b\cdot\ln(D^2 H)$	–3.5363	0.5957	0.79
	$BR=[a+b(1/D2 H)]\cdot D^2\cdot H$	0.0015	0.0402	0.50
	$\ln(BR)=a+b\cdot\ln(D^2 H)$	–12 .7333	1.8202	0.68
	$\ln(BR)=a+b\cdot\ln(D^2 H)$	–4.4702	0.8791	0.86
Stemwood biomass	$\ln(SW)=a+b\cdot\ln(D)$	–2.5518	2.3887	0.96
	$\ln(SW)=a+b\cdot\ln(D)$	–3.8649	2.4261	0.89
	$\ln(SW)=a+b\cdot\ln(D)$	–2.32	2.4147	0.97
	$\ln(SW)=a+b\cdot\ln(D^2 H)$	–2.9275	0.8468	0.98
	$\ln(SW)=a+b\cdot\ln(D^2 H)$	–4.2122	0.854	0.89
	$\ln(SW)=a+b\cdot\ln(D^2 H)$	–2.6916	0.8546	0.98

8.3.3. Country-specific data for Italy

Tree species composition

In Global Forest Resource Assessment 2000, the composition of growing stock and the diversity of tree species of Italy was reported. The three main species (*Fagus sylvatica, Picea abies, Castanea sativa*) were making up 34.4% of growing stock. The following seven species, *Quercus* spp, *Pinus* spp, *Quercus cerris*, *Larix decidua*, *Carpinus* spp, *Ostrya carpinifolia*, *Abies alba*, *Populus* spp, represent an additional 32.2% of growing stock. A total of 117 native tree species was reported.

For what concern area cover of tree species, the results of the most recent NFI are available (reference for forest area: 2005, all data from http://www.infc.it). Total area of forest (FAO definition) summed up to 8.76 Mha (forests + plantations in Table 8-6) while other wooded land totalised 1.71 Mha. Data on tree species cover are reported in Table 8-7.

Table 8-6 Area of forest tree species (of stand type) in Italy (NFI 2005, http://www.infc.it)

Species/types	Area (ha)	Error %
Forests		
Quercus petraea, Q. pubescens, Q. robur	1084247	1.8
Fagus sylvatica	1035103	1.8
Quercus cerris (Q. frainetto, Q. macrolepis, Q. trojana)	1010986	1.7
Other deciduous broadleaved	994777	1.8
Ostrya carpinifolia, Carpinus betulus	852202	2
Castanea sativa	788408	2.1
Quercus ilex	620318	2.3
Picea abies	586082	2.2
Larix decidua, Pinus cembra	382372	3
Pinus nigra, P. laricio, P. leucodermis	236467	3.9
Floodplain/riverside forests	229054	4
Mediterranean pines	226101	4
Quercus suber	168602	4.5
Pinus sylvestris, P. mugo	151671	4.9
Other evergreen broadleaved	84712	6.6
Abies alba	68460	7.4
Other conifers	63407	7.7
Areas temporarily without forest cover	53981	8.1
Plantations		
Poplars	66269	5.8
Plantations, other broadleaved	40985	8.6
Plantations, conifers	14998	15.8
Other wooded land		
Mediterranean macchia and shrubs	690811	2
Unclassified or unreachable Forest or other wooded land	398095	2.9
Shrub woodland, temperate climate	178581	4.5
Other wooded land, low density (> 5%, < 10%, ≥ 5m)	146415	4.9
Other wooded land, low forest (> 2m, < 5 m)	124229	5.5
Subalpine shrub woodland	121524	5.6
Other wooded land (below 2 m, > 10%)	48678	8.7

The species cover for Umbria, the Region selected for the proof of concept study is presented in Table 8-7. Total forest cover in the region is 371575 ha (44% of land area), the other wooded land represents 18692 ha (2.2% of land area).

Table 8-7 Area of forest tree species (of stand type) in Umbria (NFI 2005, http://www.infc.it)

Species/types	Area (ha)	Error %
Forests		
Quercus cerris, (Q. frainetto, Q. macrolepis, Q. trojana)	120918	4.7
Quercus petraea, Q. pubescens, Q. robur	96587	5.5
Ostrya carpinifolia, Carpinus betulus	59255	7.4
Quercus ilex	39815	9.2
Fagus sylvatica	15115	15.3
Other deciduous broadleaved	9216	19.8
Mediterranean pines (mostly *Pinus pinaster*)	8479	20.6
Floodplain/riverside forests	7742	21.6
Pinus nigra (P. laricio, P. leucodermis)	5899	24.8
Castanea sativa	2581	35.6
Other conifers	1843	44.6
Pinus sylvestris (P. mugo)	737	70.6
Plantations		
Plantations, other broadleaved	3019	26.8
Poplars	369	99.8
Other wooded land		
Shrub, temperate climate	7816	21.1
Unclassified or unreachable Forest or other wooded land	4795	27.1
Other wooded land, low forest (> 2m, < 5 m)	3318	33.2

Description of forest types/main classification

The most of Italian forest cover is made up of broadleaved species (70%). Deciduous oaks cover more than 2 Mha, while beech and other broadleaved 1 Mha each. In North Italy, conifers (*Picea abies*, *Larix decidua*, *Abies alba*, Pines) cover 1.2 Mha, with Norway spruce representing 50%. Evergreen oaks are spread over 0.80 Mha (*Q. ilex*, 80%; *Q. suber*). Mediterranean and temperate pines (*P. nigra, P. laricio, P. leucodermis*) and floodplain/riverside forests represent 0.23 Mha each. Within the other wooded land, Mediterranean macchia and shrubs are distributed over 0.70 Mha which represent the 7th more important type in Italian tree cover (forest and other wooded land). Nearly 0.4 Mha resulted unclassified or unreachable.

In Umbria, 92% of the forest cover is made up by broadleaved species. Conifers make up a low proportion (less than 5%), mostly represented by Mediterranean pines (mostly *Pinus pinaster*, 8500 ha) and *Pinus nigra* (6000 ha).

BEF and BF (biomass functions) available in NIR

In the Italian report of Forest Land carbon pools to UNFCCC, different Biomass Expansion Factor are used for each forest typology, with specific wood basic density values for the main tree species. Used BEF and wood densities are presented in Table 8-8.

Table 8-8 BEF and wood basic density used in the Italian report to UNFCCC (NIR 2006, 2007)

Inventory typology	*BEF*	*Wood basic density*
High stands		
Norway spruce	1.29	0.38
Silver fir	1.34	0.38
Larches	1.22	0.56
Mountain pines	1.33	0.47
Mediterranean pines	1.53	0.53
Other conifers	1.37	0.43
European beech	1.36	0.61
Turkey oak	1.45	0.69
Other oaks	1.42	0.67
Other broadleaves	1.47	0.53
Partial total	*1.35*	*0.51*
Coppices		
European beech	1.36	0.61
Sweet chestnut	1.33	0.49
Hornbeams	1.28	0.66
Other oaks	1.39	0.65
Turkey oak	1.23	0.69
Evergreen oaks	1.45	0.72
Other broadleaves	1.53	0.53
conifers	1.38	0.43
Partial total	*1.39*	*0.56*
Plantations		
Eucalyptuses coppices	1.33	0.54
Other broadleaves coppices	1.45	0.53
Poplars stands	1.24	0.29
Other broadleaves stands	1.53	0.53
Conifers stands	1.41	0.43
Others	1.46	0.48
Partial total	*1.36*	*0.40*
Protective forests		
Rupicolous forest	1.44	0.52
Riparian forest	1.39	0.41
Shrublands	1.49	0.63
Partial total	*1.46*	*0.56*
Total	***1.38***	***0.53***

Using the preliminary results of the *RiselvItalia Project* carried out by ISAFA (ISAFA, 2004), belowground biomass was estimated applying a root-shoot ratio to the growing stock (Table 8-9). Wood density of belowground biomass was assumed to be equal to aboveground biomass values.

Table 8-9 Root to shoot ratio used in italian reporting to UNFCCC (NIR 2006, 2007)

Inventory typology	*Root-Shoot ratio* *weight of belowground biomass / weight of growing stock*
Stands	
Norway spruce	0.29
Silver fir	0.28
Larches	0.29
Mountain pines	0.36
Mediterranean pines	0.33
Other conifers	0.29
European beech	0.20
Turkey oak	0.24
Other oaks	0.20
Other broadleaves	0.24
Partial total	*0.28*
Coppices	
European beech	0.20
Sweet chestnut	0.28
Hornbeams	0.26
Other oaks	0.20
Turkey oak	0.24
Evergreen oaks	1.00
Other broadleaves	0.24
conifers	0.29
Partial total	*0.27*
Plantations	
Eucalyptuses coppices	0.43
Other broadleaves coppices	0.24
Poplars stands	0.21
Other broadleaves stands	0.24
Conifers stands	0.29
Others	0.28
Partial total	*0.25*
Protective forests	
Rupicolous forest	0.42
Riparian forest	0.23
Shrublands	0.62
Partial total	*0.50*
Total	***0.30***

The deadwood biomass was estimated applying a dead mass conversion factor (DCF21) of 20%.

Total litter carbon amount is estimated from the aboveground carbon amount with linear relations, deduced from the results of the European project CANIF (CArbon and NItrogen cycling in Forest ecosystems) which has reported such relations for a number of European forest stands. Different relations are used for different forest type (conifers, broadleaves, mixed stands) and coppices. Relations are reported in Table 8-10.

Table 8-10 Relations used to obtain litter [t C ha-1] from aboveground carbon [t C ha-1] (NIR 2006, 2007)

Inventory typology	Relation litter – aboveground C per ha
All coniferous typologies	y = 0.0659 x +1.5045
All broadleaves typologies	y = −0.0299 x + 9.3665
Other plantations	y = −0.0165 x + 7.3285
Rupicolous forest	y = −0.0165 x + 7.3285
Riparian forest	y = −0.0299 x + 9.3665
Shrublands	y = −0.0299 x + 9.3665

Total soil carbon is estimated from aboveground carbon, with linear relations, deduced from level II monitoring sites (CONECOFOR Programme, Corpo Forestale, 2005; Cutini, 2002), for different forest type (conifers, broadleaves, mixed stands) and coppices. Relations are reported in Table 8-11.

Table 8-11 Relations used to obtain soil carbon [t C ha-1] from aboveground carbon [t C ha-1] (NIR 2006, 2007)

Inventory typology	Relation soil– aboveground C per ha
All coniferous typologies	y = 0.4041 x + 57.874
All broadleaves stands	y = 0.9843 x + 5.0746
Broadleaves coppices	y = 0.3922 x + 65.356
Other plantations	Y = 0.7647 x + 33.638
Rupicolous forest	Y = 0.7647 x + 33.638
Riparian forest	y = 0.9843 x + 5.0746
Shrublands	y = 0.3922 x + 65.356

Other country-specific BEF and BF

The most recent NFI included also the sampling of more than 2000 model trees that have been used to derive allometric relationship. Hence, it is expected that the BEF database will be updated when data will become available.

In 2008-2009, a soil and litter survey on 1500 NFI plots is planned. The results will increase the reliability and lower the large current uncertainty of litter and soil carbon reporting to UNFCCC.

During 2008 the results of BioSoil - Soil sampling will become available. The project will sample litter and soil on 234 plots of the former NFI (1985). As those plots were characterized also for forest structure, it will be possible to test the relationship among biomass and soil carbon on a much larger number of sites.

8.3.4. Country-specific data for Lithuania

Tree species composition

Lithuanian forest stand area by species composition: *Pinus sylvestris* – 34.1%; *Betula sp. (B. pendula and B. pubescens)* – 19.9%; *Picea abies* – 17.6%; *Alnus glutinosa* – 8.9%; *A. incana* – 6.9%; *Populus tremula* – 6.3%; *Quercus robur* – 2.5%; *Fraxinus excelsior* – 2.4% and others – 1.4% (according to the Lithuanian NFI of 1998-2002; Kuliešis *et al*., 2003).

Description of forest types / main classification

Forest type is described according to the main tree species (n=8, see above) of the stand in Lithuanian NFI. However Lithuanian territory could be divided into some forest regions (Kuliešis *et al*., 2003):

1. Mixed spruce forests in western part of Lithuania;
2. Mixed broadleaved-coniferous forests in central part;
3. Mixed pine-spruce forests in south-eastern Lithuania
4. South Lithuanian pure pine forests

BEF and BF (biomass functions) available in NIR

The biomass of separate tree species was estimated using the Basic Wood Density of Stem wood, presented in FRA 2005, appendix 5.2 and according to the species composition for all species was 0.438.

BEF1 were not applied and carbon stock changes in connection to the increment data were not presented in Lithuanian country report for Global Resources Assessment 2005.

For the Lithuanian country report (2005) the biomass of the foliage and root was estimated as percentage from the total stem volume according to the models designed by V. Usoltcev (Usoltcev, 2001; 2002; 2003) for separate tree species that was adopted to Lithuanian models (Kuliešis *et al*., 1997). For the estimation of above-ground biomass, the following factors were used: for coniferous – 1.216, for broadleaves – 1.164 from stem biomass. The mean weighted factor for all tree species is 1.197 (Table 8-12).

The root-to-shoot ratio values provided in the Lithuanian Country Report on Global Forest Resources Assessment 2005 were: 0.26 for coniferous; 0.19 for deciduous and 0.23 for all tree species. The default value 0.5 tonne C (tonne d.m.)$^{-1}$ provided in the Good Practice Guidance for LULUCF was used for carbon fraction of dry matter CF.

Table 8-12 Major tree species and key factors used in calculating carbon stock in the Lithuanian NIR

Species	D	BEF_2	R
Pinus sylvestris	0.42		0.26
Picea abies	0.40		0.26
total conifers	0.41	1.216	0.26
Betula sp.	0.51		0.18
Populus tremula	0.35		0.24
Alnus sp.	0.45		0.18
Quercus robus	0.58		0.25
Fraxinus excelsior	0.57		0.20
total deciduous	0.48	1.164	0.19
overall total	0.44	1.197	0.23

Other specific BEF and BF

Original equations for the calculation of total phytomass of Lithuanian Scots pine, Norway spruce and birch stands (Kairiūkštis *et al*., 1997) and for the calculation of above-ground biomass of Scots pine could be applied (Mikšys *et al., 2007*) (Table 8-13).

Table 8-13 The equations for biomass estimation of different above-ground components of Scots pine trees in Lithuania. 25 trees were sampled, stand of ages 10, 20, 30, 40, 50 and 65 were chosen, D (diameter at breast height) is in cm, H (height) is in m and biomass measurements are dry weight in kg. More detailed information is presented in Mikšys *et al.* 2007

Biomass components	Format of Equation	Parameters			R^2
		a	b	c	
Needles	$a*D^b*H^c$	0.295	2.071	-1.114	0.84
Branches	$a*D^b*H^c$	0.143	3.043	-1.523	0.88
Dead branches	$a*D^b*H^c$	0.074	2.632	-1.202	0.76
Total crown	$a*D^b*H^c$	0.381	2.768	-1.383	0.89
Stem	$a*(D^2*H)^b$	0.043	0.893		0.98
Stem wood	$a*(D^2*H)^b$	0.039	0.896		0.98
Stem bark	$a*(D^2*H)^b$	0.0051	0.846		0.98

8.3.5. Country-specific data for Romania

Tree species composition

For 30 years, the forest area and woodlands has varied around 6.3 million hectares. This area represents some 27 % from the national territory, and is approximately 0.27 ha per inhabitant. The Romanian forests are mainly based on broadleaves species (69.3%), while the conifers account for 30.7% of their total surface. Structure of forest fund is as follows: resinous forests (29.9 %), beech forests (31.5 %), oaks forests (18 %), hardwood forests (17.7 %) and softwood forest (4.9 %). According to Inventory of Forest Fund1984, the standing wood volume is 1350 Mm^3, the average volume is 218 m^3/ha and the annual average increment is 5.6 m^3 y^{-1} ha $^{-1}$.

Description of forest types / main classification

Forest types range from top of the mountain coniferous to steppe oaks forest structures. The annual growing stock in the forest area is of 1.341 million cubic meters. Almost 90 % of forest area is covered by regular high forest, the remaining part includes selection forests and coppices.

Stands age reflects an uneven distribution of area in the elder classes. Romanian forests growth largely exceeds its harvests, with a ratio growth to harvest of around 2. Forest management is done according to a decennial management plan elaborated for every single management unit or owner, according to the circumstances.

Romanian forests fulfill both productive and protective functions. Actually 52.1 % of Romanian forests have a prevailing function of protection of different objectives, which still does not prohibit wood extraction. All forests under the national forest fund are under management. However, an area of inaccessible forests of 220 000 ha “under forest management“ is “unmanaged forest“ (currently included in different nature reserves).

Forests and wooded lands comprise both state and private forests. Romanian forests management is close to nature, based on natural regeneration, a control of the seed provenances and seedling. Fire is not a management practice. Forest fire is only occasional and accidental, is always human-induced and affects only the forest floor (litter, dead organic matter). The forestry sector is still under ”transition“ process. Long lasting property restoration of the forests lands (nationalized by communist regime in mid of 20th century), as well as progressing market economy facing forestry, generate concerns on private forest administration, forest management and status of deforestation on short term.

Fire wood represents an important share of the national energy consumption, which is ensured by a sound forest management of all type of forests.

Reporting in the NIR is made based on 5 types of forest: coniferous, beech, oaks, softwood and hardwood. This grouping is made as one of the species in the group has a very significant share above the others and other similar features (annual growth, wood density). Data on these classes is annually reported by forest statistics and aggregated at country level.

BEF and BF (biomass functions) available in NIR

Historically available databases allow using default methods (annual biomass increment, annual biomass loss).

Different data sources have been used for different parameters took into account for average annual increment rate in total biomass calculation:

1. average annual net increment in volume on species (IV) - Synthesis of Inventory of Forest Forest, Institutul de Cercetări □i Amenajări Silvice/ICAS - Forestry Ministry, 1984;
2. basic wood density (D) – Studies and research for expansion of wood industry row material base taking into account the structure, the physical-mechanical and technological characteristics of national species. ICPIL Manuscript, 1985;
3. biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment (BEF1) – Table 3A.1.10 of IPCC GPG 2003;
4. root-to-shoot ratio (R) – Table 3A.1.8 of IPCC GPG 2003
5. Forest area on species is provided by Forest statistics (statistical report, code SILV- 1, Anuarul Institutului National de Statistica)

According to SNFI 1984 root-to-shoot ratio values were chosen taking into consideration the following:

- aboveground biomass density of 50-150 t/ha for coniferous species;
- aboveground biomass density > 150 t/ha for beech species;
- aboveground biomass density < 75 t/ha for hardwood and softwood species

By expert judgment according to discussions with NIS and forestry experts all bark and branches volume is included in the annually extracted volume provided by NIS (the bark and branches volume is estimated also before wood leaves the forest as part of legally procedures).

Annual decrease of carbon stock due to biomass loss is based on harvest statistics (statistical report, code SILV- 1). Commercial felling reports refers to volume of a whole tree in broadleaved (stem and branches) and only stems one in resinous (reported in statistical report SILV – 4, Anuarul Institutului National de Statistica). By expert judgment, according to provisions in specific dendrometrical studies, in order to have a full closed balance of carbon related to living biomass in forests, we accounted to root volume remaining in forest soils after logging by applying a biomass expansion factor value. as follows: coniferous (1.16); beech (1.18); oak (1.16); hardwood species (1.14); softwood species (1.1) (Table 8-14).

Table 8-14 Major tree species and key factors used in calculating carbon stock in the Romanian NIR

Species	D	BEF1	R
Coniferous	0.4	1.15	0.32
beech	0.655	1.2	0.24
oak	0.645	1.2	0.35
hardwood species	0.6	1.2	0.43
softwood species	0.41	1.2	0.43

Other country-specific BEF and B

Biomass equations have been developed for young trees (< 6 years old) for main species used in afforestation of degraded lands in Romania: oaks, black locust, white poplars (ICAS, 2007).

A currently financed project has just started, with the purpose to establish biomass equations for main species used in afforestation till plantations age of 20-25 years old.

8.3.6. Country-specific data for Slovakia

Tree species composition

In Slovakia, conifers account for 30.8 percent, broadleaves for 49.7 percent, and mixed forests for the remaining 18.9 percent of the Slovak forests.

Description of forest types/main classification

In 2006, the area of forests in Slovakia reached 2,007 thousand hectares. At the same time, the total area of forest crop land reached 1,932 thousand hectares. Forest cover calculated as the total forest plot/country area ratio was estimated at 41 percent. The average stock per hectare was estimated at 231 m^3.

Slovak forests grow in a very wide range of different natural conditions. According to the climatic conditions changing with the rising altitude the following seven forest vegetation stages have been distinguished: oak, beech-oak, oak-beech, beech, fir-beech, beech-fir-spruce, spruce, dwarf pine.

First three vegetation stages are accompanied by dominating grass species. Beside *Quercus petraea* and *Quercus cerris* and *Fagus sylvatica*, also *Carpinus betulus*, *Acer campestre* as well as *Tilia cordata* and *T. platyphyllos* make themselves felt in these stages. In the 3rd vegetation stage it is already intensively shading beech that begins to assert itself. Beech along with so-called beechwood species find their optimum in the 4th vegetation stage, but remain abundant in both the 5th and 6th stages as well. In the 5th stage, along with beech also fir becomes an important species, accompanied by submountain and mountain species. In the Carpathian forest *Acer pseudoplatanus*, *Fraxinus excelsior* and *Ulmus glabra* have also established themselves as an important forest admixture. These forests belong to the most productive ones in Slovakia. In the 6th stage beech is weaker and less competitive compared to fir and spruce. Spruce eventually takes over in the 7th stage with a typical admixture of *Sorbus aucuparia* or *Larix decidua*. Along the upper timberline (around 1450 m a.s.l.) spruce is no longer able to establish a closed canopy and its stands gradually give way to *Pinus mugo* stands.

The high forest is considered a basic type of forest origin. Coppice covers only 1.85 percent of the total forest crop land (7, 286 hectares) and is continues to decrease in area.

The age structure of forests is best described through the classification using 10-year age classes. The age structure of Slovak forests shows the above standard presence of middle age and oldest age classes. The oldest age class forests can be mostly found in protection forests. All age classes are typical for a higher presence of conifer species.

BEF and BF (biomass functions) available in NIR

In Slovak NIR are used conversion/expansion factors for conversion annual wood volume increment data to annual tree biomass increment. The basic inventory component in Slovak forestry is merchantable volume (tree stem and branch volume under bark with a minimum diameter threshold of 7 cm). The conversion/expansion factors were estimated for main forest tree species (Table 8-15), according to data published by Požgaj et al. (1993), Šebík and Polák (1990) and from database of Permanent Forest Inventory.

The biomass conversion/expansion factors consist from conversion part (coefficient of wood density) and from expansion part (expansion factor). The coefficients of wood density for main tree species have been published by Požgaj et. al. (1993). The expansion factors were calculated using formula:

$$EF_i = \frac{W_i}{V}$$

W_i - sum of different part of tree (bark+stump+roots+branches) (dm/ha)

V – merchantable volume (m^3/ha)

The average values of % portion for individual components (bark, stump, roots, branches) of total tree biomass have been published by Šebík and Polák (1990). They are: 65% - merchantable volume, 5% - thin branches under 7 cm, 10 % - stump and 20 % - roots. The carbon content estimated for Slovak main tree species was 49.7% for wood, for other parts of trees in range 46.7-52.8%, than mean value 50 % was used for carbon fraction of dry matter, CF.

Table 8-15 Major tree species and biomass expansion/conversion factors used in calculating carbon stock in the Slovakian NIR

Tree species	Coefficients of wood density	Expansion factors	Biomass Con./Exp. factors
Spruce, fir	0.4	0.2	0.6
Pine	0.5	0.3	0.8
Larch	0.6	0.2	0.8
Other coniferous	0.4	0.2	0.6
Beech	0.7	0.5	1.2
Oak	0.7	0.6	1.3
Poplars	0.4	0.2	0.6
Other broadleaves	0.6	0.5	1.1

Other country-specific BEF and BF

The new original BEFs were estimated for conversion stem volume directly to the dry weight of different biomass component (stem, branches, foliage, roots, aboveground biomass, whole tree) for 4 main tree species (spruce, pine, beech and oak) under 10 years old (Pajtik *et al*. 2008).

8.4. *Discussion*

The woody biomass in forest ecosystems is commonly identified as a key category of national emission inventories. It means that it is prioritized within the national inventory system, because its estimate has a significant influence on a country’s total budget of greenhouse gases. This can occur either in terms of the absolute level of emissions and removals, and/or in terms of emission trends. Therefore, a rigorous estimation of carbon stock change related to forest biomass is vital and determines the importance of the whole LULUCF sector in the national budget of greenhouse-gas emissions. Of the five selected countries, the most important share of the LULUCF sector was reported for Italy, Lithuania and Romania: the sector represented an offset of emissions reaching 23, 67 and 32 % in the respective countries as of 2005. Obviously, the more rigorous deployment of available biomass functions and biomass expansion factors should be considered to reflect the importance of carbon stock changes in forest biomass in the emission inventory.

The above analysis shows that the available data and its utilization in emission inventory largely differ among the countries.

Italy developed and applied a set of biomass factors and functions based on data from statistical forest inventories (ISAFA 2004). They were developed specifically for different forest typologies and/or forest stands characterized by major tree species. However, although the data are available at tree level, the allometric functions have not yet been used to improve calculation of forest biomass and carbon stocks.

On the contrary, Greece is a country with exclusive deployment of the basic Tier 1 methodology approaches. At the same time, the specific biomass functions are available in Greece (Zianis 2005).

Although Lithuania has its NFI program in operation (1st cycle conducted during 1998-2002, and was followed by the re-inventory in 2003-2007), it has not used any biomass functions in its emission inventory yet. Original equations for the calculation of total biomass of pine, spruce and birch stands (Kairiūkštis *et al*., 1997) are available. Recently, a new article on species-specific functions (Scots pine) was published (Miksys *et al*. 2007). Hence, it can be expected that this resource will be utilized in the LULUCF emission inventory soon.

Slovakia have available data from its first statistical forest inventory cycle, performed during 2005-2006. However, until the second cycle is performed, the country will most likely rely on the aggregated stand-level data from forest management plans. Therefore, it is desirable to develop a set of applicable BEFs on the level of major tree species. These could serve as interim tool to calculate biomass and carbon stock in forests (see Chapter 13).

Romania faces a similar situation as in the case of Slovakia. Their NFI program is scheduled to start in 2008.

It is apparent that the issue of suitable allometric functions and biomass factors receives attention. Several specific projects focused on this issue are just running (NFIs, BioSoil, national or regional studies). A currently financed project in Romania has just started, with the purpose to establish biomass equations for main species used in afforestation till plantations age of 20-25 years old. In Slovakia, new original BEFs were recently estimated to convert stem volume directly to the dry weight of different biomass component for four main tree species under 10 years old (Pajtik *et al*. 2008 and unpublished national study).

8.5. *Conclusions*

This report shows the current use and availability of allometric function and factors applicable for compilation of emission inventory from forests within the LULUCF sector in the five selected European regions/countries. The emission inventory challenges the wide variety of conditions within European areas, which is also reflected by different meaning of definitions and input parameters. This applies specifically to the most important parameters used in carbon stock change estimation, namely biomass expansion/conversion factors (BEF1, BEF2), conventional wood density (D), wood carbon fraction (C) and root-shoot ratio (R).

It becomes evident that the selected countries commonly have available (or would have them soon) their national biomass functions and factors, but their use in emission inventories is for some reasons limited. In three of the studied countries, the statistical forest inventory is already available and in one country it is to be initiated soon. This constitutes a sound data basis that would greatly aid the national emission inventories once combined with corresponding set of biomass functions. This would fulfill the requirement of more detailed and accurate estimation of emissions and removals related to forest carbon stock change, which is often a key category of the national emission inventories. The inventory compilers should further focus on transparent reporting as in many instances the relevant information on biomass parameters used is lacking.

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Anuarul Institutului National de Statistica, statistical report, code SILV-1

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9. Eurogrid Aggregation of Plot Data of Forest Monitoring Schemes

Isabel Van den Wyngaert, Dick Brus, Dennis Walvoort and **Gert-Jan Nabuurs**
ALTERRA, The Netherlands
Email: isabel.vandenwyngaert@wur.nl

Abstract

In this report we give proof of concept of the calculation of a spatially explicit carbon sink, including an estimate of the uncertainty and error budgeting to identify the main sources of variance and possible gaps, at the 10 km x 10 km grid cell scale. This report introduces a set of methodologies to aggregate the forest carbon source/sink functioning based on National Forest Inventory plot data to 10 km x 10 km European Reference Grid. The propagation of the uncertainty of the estimate is explicitly considered, both as a result of model calculations and as a result of aggregation. Based on the GPG-LULUCF equations and default parameters (if no country specific values were available), plot level C sinks were calculated including an estimate of the uncertainty. This was based on Monte Carlo simulations. For each of the realisations, the values were aggregated and spatial uncertainty was incorporated numerically by another set of drawings from the grid cell distributions. The total grid cell uncertainty was calculated from the total grid cell distribution based on the total set of calculated and drawn values. This concept was applied in The Netherlands, in Lithuania (only the uncertainty calculations for aggregated values) and in Umbria. Design based methods were used in The Netherland and Umbria, where sampling density was high. Kriging was applied in Lithuania, where only few plots were available for these calculations. At plot level, there were large differences between countries in relative importance of input parameters, and also for one region (Umbria) between different methods to define the uncertainty of the input parameters. At grid cell scale, most uncertainty originated from spatial heterogeneity and –to a lesser extent- uncertainty in the forest cover, rather than from model parameters. Grid cell uncertainty strongly depended on the number of forested plots in it, and rose steeply with decreasing number of plots for grid cells with less than 10-20 plots. No attempt was made to include pools other than carbon stock changes due to changes in biomass from growth, to include any assessment of temporal uncertainty or to deal with uncertainty rising from differences between NFI systems.

9.1. *Introduction*

Within the European Union, information for assessing carbon emissions from forests are available from national as well as international sources, collected for different purposes and by different communities. Previous work in the MASCAREF project identified the National Forest Inventories as potentially important sources of information for carbon sink/source estimates and covered the different issues to be solved.

This report investigates a set of methodologies to make use of the information contained in diverse data types from different origins to construct a harmonized carbon budget of European forests with a spatial resolution of 10 x 10 km. It inventories methods to estimate the uncertainties associated with different types of data manipulation going from primary information on the state of the forest at plot level to calculated carbon emissions at 10 km x 10 km. The way carbon emissions are calculated should fulfill the requirements of carbon emission reporting of UNFCCC and complies with GPG-LULUCF. It is based on actual data and has an estimate for the uncertainty per grid cell. Therefore different methods are proposed to include uncertainty from different sources, making explicit which kind of uncertainty is included in the overall value and which not.

The basis for the calculations are the National Forest Inventory (NFI) variables, that describe the actual state of the forest, in combination with model parameters that describe relations between variables (e.g. factors to convert from volume to biomass, root-to-shoot ratio's, wood density, but also decomposition constants etc…). The model equations follow GPG-LULUCF for Tier 1 mostly, sometimes Tier 2. The application of Tier 3 models is beyond the scope of this proof of concept, as model results can be aggregated similar to Tier 1 & 2 model results. The application of a (very simple) model for the carbon budget means that plot scale results are not just realizations from a certain sampling procedure, but have a model uncertainty as well. On top of that, aggregation to a 10 km x 10 km European reference grid causes additional uncertainty on spatial representation and sampling. The different steps between primary data and 10 km x 10 km aggregated estimates of the source/sink functioning of forested land are illustrated in Figure 9-1.

The main aim of this report is to provide proof of concept on how reach a carbon source/sink functioning at the scale of a 10 km x 10 km European reference grid, including associated uncertainties and gaps, based on plot level NFI data. Three test areas were selected for the test runs, i.e. The Netherlands, Lithuania and Umbria (Italy). The analysis should be seen as a proof of concept, not necessarily as the best possible estimate of carbon fluxes for these regions, and the results of these regions should be interpreted as such. If data were not available, assumptions were made to demonstrate the methodology rather than investing a lot of effort in receiving the best possible data.

After Li & Wung (2006), we distinguish 3 categories of uncertainty sources: uncertainty related to input data, to models and model parameters and to the scaling algorithms and aggregation. As uncertainty related to input data was not the main focus of this study and is typically low compared to other sources of uncertainty, it was not considered. If needed, it is possible to quantify its effects in the same way as for the model parameters. One exception is the uncertainty related to missing values, for which there is not a straightforward way to quantify. A attempt was made for The Netherlands, where a significant share of the plots had missing values. Uncertainty associated with the use of models was limited to the uncertainty related to model parameters. The main focus was on the uncertainty associated with aggregation, and the combination of this with uncertainty on plot level (in this study uncertainty at plot level was entirely defined by the uncertainty in model parameters, but the techniques used are also applicable to other sources of uncertainty at plot level). Gaps and uncertainty related to temporal aspects (e.g. the discontinuity of NFI data and an inventory cycle of several years) were explicitly not addressed.

In chapter 2, the methodologies are introduced from a general and theoretical perspective. In chapter 3 the general and country specific set-up of the model and the aggregation is presented, and the specific issues addressed for each country are discussed. In chapter 4 the results of a sensitivity analysis are presented, and discussed with respect to application for gap identification and prioritization. In chapter 5 the overall uncertainty analysis is presented and discussed. The conclusions are summarized in chapter 6.

9.2. *Aggregation methodologies and uncertainty estimates from a theoretical perspective*

Going from primary data to a 10 km x 10 km aggregated estimate of the source/sink functioning of forested land involves a series of steps, each introducing some uncertainty to the final result, as illustrated in Figure 9-1. In the following paragraphs (par. 9.3, 9.4 and 9.5) these steps are discussed, with the effects on uncertainty discussed together in the last paragraph (par. 9.6).

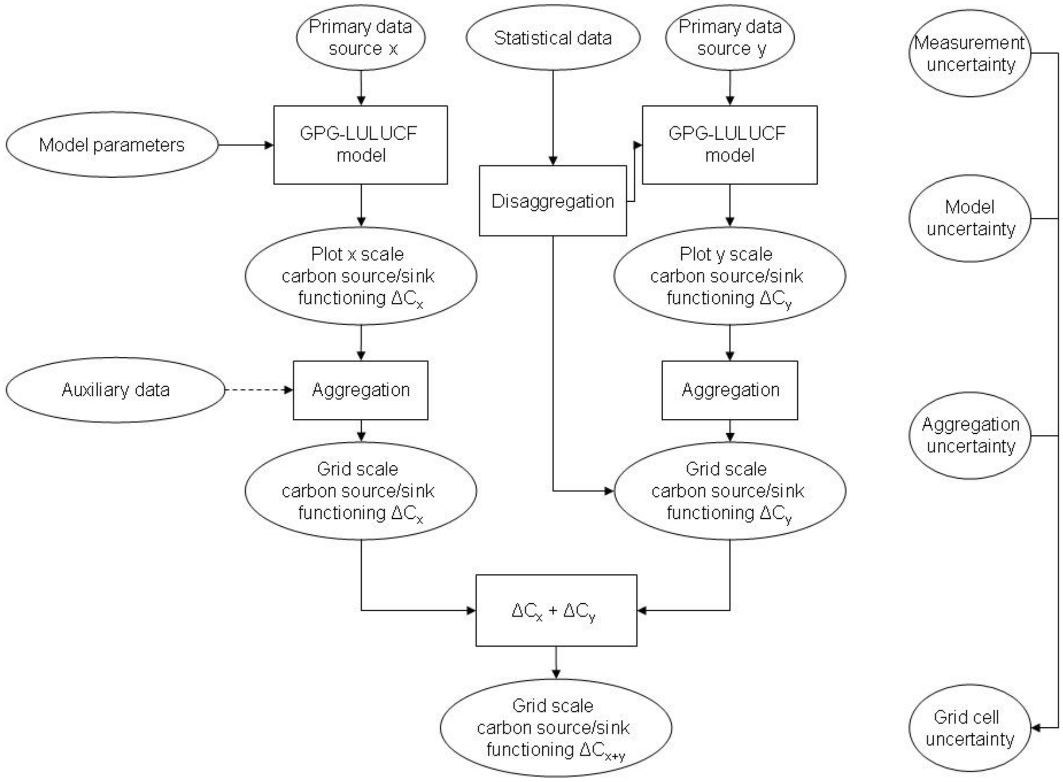

Figure 9-1 Calculation and aggregation scheme from primary data and parameters to 10 km x 10 km Eurogrid cell

9.3. *Characteristics of available data*

9.3.1. National Forest Inventories

National Forest Inventories have a long history in many countries in Europe. In most countries, sampling design has changed over time, with changing aims, insights, resources and (technical) possibilities. Harmonization of NFI information is carried out under COST E43 Action and most of the information on sampling design is derived from summary reports submitted by member state countries. MASCAREF project deals in more detail with information from NFI's to calculate carbon emissions (i.e. Chapter 4 and 5 of current report).

Most countries nowadays apply a variant of a two stage sampling design, with grids varying from 1 km x 1 km to 10 km x 10 km (northern areas of Scandinavia). The first stage consists of an overlay between the entire territory in aerial photographs or other land cover data, and the selected grid. The grid centre may be drawn randomly or chosen arbitrarily. Sampling locations in the grid may be fixed at or near grid intersections (most countries) or somewhere on the cell surface (e.g. UK) or may be drawn randomly from the cell surface (e.g. Netherlands). For each sampling location the land cover is determined. Forested plots are retained for stage two.

In the second stage, the sampling locations within forested area are assigned a status of permanent location or temporary location. Some inventories have only permanent locations, very few have only temporary locations, many have both. For most inventories, not all sample locations are visited within one year and thus sample locations or clusters of sample locations (e.g. transects in Sweden) are assigned a measurement year. Most countries explicitly mention that this is organised so that each year selected sampling locations are spread evenly / in good representation over the country.

Some exceptions have their inventories organised by smaller administrative units, with complete national coverage only over the full inventory cycle (e.g. France, www.ifn.fr).

Sampling locations may contain one (no clustering) or multiple (clustering) sample plots, which may be organised in a variety of ways. In many countries, different plots are used for different sets of variables.

9.3.2. ICP monitoring plots

The ICP Forest Level I plots constitute a systematic transnational monitoring grid in forests at the European level. The network was launched in 1985 under the Convention on Long-range Transboundary Air Pollution of the United Nations Economic Commission for Europe (UNECE). The aim was to monitor the (adverse) effects of air pollution on forest vitality. About 6000 plots are arranged on a 16 km x 16 km grid, including only forested grid intersections. Variables measured are mainly related to forest vitality (defoliation, discoloration, damages,…) but also include some relevant to carbon monitoring. The most important relate to forest soils, which are not always well covered in NFI systems. A lower number of intensive monitoring plots (about 800) has been installed in the 90's in selected forest ecosystems. In these, it should be possible to construct a full carbon budget. Chapter 3 in this report deals more in detail with the use of data from ICP monitoring plots to calculate carbon emissions.

9.3.3. Auxiliary data

Auxiliary data should meet two criteria: they should have a higher coverage in comparison to the property to be upscaled, and they should explain some of the variance of the target property. It is not necessary for the auxiliary variable to have exhaustive coverage and it can be quantitative or qualitative.

In a study designed to create full cover tree species maps over Europe based on NFI and ICP plot data, relevant auxiliary data were (Hengeveld et al., in prep.):

- the EFI forest cover map (total, coniferous and deciduous)
- maps with climatic variables (precipitation, mean temperature, radiation)
- elevation & slope
- map of the biogeographic regions
- FAO soil map

Other available GIS data with full coverage and relevance for forest carbon functioning are e.g. EFI forest volume map. However, all of these auxiliary data are themselves based on aggregated variables and/or model calculations, each involving their own assumptions and uncertainties. As the aim is to create the most accurate estimate for carbon emissions on a 10 km x 10 km basis including an unambiguous uncertainty estimate, great care should be taken when deciding to make use of auxiliary variables.

9.4. *Carbon budget model*

9.4.1. Model structure

Though it is possible to measure carbon fluxes directly in the field using flux tower eddy covariance techniques, these are not used for routine inventories. Instead carbon fluxes are calculated from other variables that are measured in the field, and the carbon flux is calculated using simple to complex models ("GPG-LULUCF model" in Figure 9-1). The choice for any kind of model or calculation is determined by the Tier level that the country assumes for a certain flux. Tier 1 calculations are primarily based on default values and calculation methods. Tier 2 uses basically default calculation methods, but country specific data derived from NFI and other studies. For Tier 3, the level of detail increases further and use of peer-reviewed ecosystem models is an accepted methodology. The term "model" will be used for any set of equations grouped together to calculate a (part of) the carbon source sink functioning of forests, independent of Tier or complexity. Annex B gives the basic equations used to calculate carbon emissions from Forests remaining forests according tot GPG-LULUCF.

These models are themselves also subject to scale, as aggregation of the model results will not necessarily give the same value as the model result of the aggregated data. An exception is formed by entirely linear models. The equations in Annex B are all linear, and this allows some freedom with the order of calculation and aggregation. However, for this linearity to go beyond the summation of the different sources of carbon emission, assumes the conversion factors to be constant. The use of different conversion factors based on different plot characteristics (species, soil type, management type, etc…) may cause discrete and thus non-linear effects even when this does not show in the equations. In view of the low calculation time needed for these equations, there is little to no gain in aggregating variables before model calculations. Additionally, it is much more simple to aggregate one quantitative variable than a set of quantitative (e.g. increment) and qualitative (e.g. species) plot characteristics. In general it is proposed to calculate the source/sink functioning as much as possible at the plot or stand level.

Another situation arises when data from different sources and sampling design have to be combined (e.g. NFI vegetation data and soil survey data). Then separate aggregation may be the more simple option, as each sampling design may follow its most appropriate aggregation scheme.

9.4.2. Model parameters and conversion factors

Conversion factors or functions are used to convert volume increment data into carbon emissions. For living biomass they contain information about wood density, tree and forest allometry and carbon fractions of dry matter. Task 4 of MASCAREF (Chapter 8 of this report) deals more in detail with factors and functions for the conversion of volume to whole tree carbon. The work performed under Task 2 of MASCAREF (see Chapter 3 of this report) may also contribute to this as far as conversion factors and functions can be derived from data in European research networks.

Conversion factors imply a simple multiplication with one value. Thus, the order of aggregation and application of a conversion factor is interchangeable, assuming that the categories distinguished for the conversion factor (e.g. species, forest types,…) are aggregated separately. In contrast, conversion functions often include a non-linear part. In these cases, the result before and after aggregation is not the same and it is paramount to use the function at the aggregation level it was developed. In most cases, this is the stand level and functions have to be applied using individual plot data.

For many conversion factors and functions, the spatial dimensions are poorly defined. On the one extreme, IPCC defaults distinguish between climatic zones only. For their carbon reporting, countries also define conversion factors presumed valid within their boundaries. On the other extreme, values are available from individual studies on one location or a limited number of locations. These locations are not necessarily selected to assure an unbiased estimate of the conversion factors in a certain region. Interpolation between geo-referenced sample locations might be possible for simple multiplication factors, but is much more complicated if at al possible for any function with two or more coefficients, whether these are linear or not.

For this report, it will be assumed that an uncertainty can be calculated for the use of a certain conversion factor at a certain location. How to do this depends to a large extent on the kind of data that are available, and can be better developed based on the information from other tasks of the project. This will be worked out in on the case studies in The Netherlands, Lithuania and Umbria (Italy) performed in MASCAREF project.

9.5. *Aggregation*

This chapter discusses the methods for aggregation from plot level data to 10 km x 10 km Eurogrid cells ("Aggregation" in Figure 9-1). The main subjects for aggregation in this chapter are (calculations based on) the NFI plot level data, yes or no in combination with data from other sources. For most countries, these data are structured in some kind of regular grid. This grid may be the basis for stratification of randomly chosen locations (design-based inference) or plots may be located fixed relative to the intersections resulting in a systematic sampling pattern (model based inference). The size of the grid and the area of forest in a region determine how many sampling units are located in a 10 km x 10 km Eurogrid cell. With grid cells varying from 0,5 km x 1 km to 10 km x 10 km, this may vary between 0 and 200 plots.

Being spatial data, NFI plots can also be described using the components of scale: extent, support/grain, coverage and, if support is very small compared to extent (i.e. point observations), the spacing or distance d between observations (Bierkens, 2000; Wu & Li, 2006a). The extent of NFI systems is typically the forested land in the whole country, though this may be not so straightforward in countries with areas overseas. For the first phase of forest area determination, the extent of NFI is the whole country as it is, while plots for field measurements are selected in forested areas only. The size of NFI plots, i.e. the support, ranges between [opzoeken] (Lithuania: 500 m^2). The plots can be considered as point measurements, with distance d between tracts (clusters of plots) varying with the size of the grid. If clustered, distance between plots in one cluster or tract vary typically between 200 and 500 m, though in Northern Scandinavia distances may be much larger (with tracts up to 1800 m long).

In the following paragraphs, we follow the decision trees defined by Bierkens et al. (2000) to decide between different methods of aggregation. As the model equations used to calculate the target variable(s), it requires little calculation time and can be easily applied at many locations, aggregation by direct averaging of model outputs is the most appropriate type of aggregation (Class I aggregation methods, Annex G), independent of NFI sampling design (Bierkens et al., 2000). Within this class of methods, both design based and geostatistical methods can be applied, yes or no in combination with auxiliary variables. Averaging of exhaustive information is not relevant for NFI data (as these are sample based and never exhaustive), while deterministic methods are meant for situations where the restrictions of geostatistical methods cannot be met. They make little to no use of most the information that is included in the spatial structure of the NFI sample, nor do they give an estimate of the uncertainty associated with the aggregation. However, for the European NFI systems enough information is available to use better methods.

One method which is not explicitly considered in Bierkens et al. (2000) is averaging by expected value (Wu & Li, 2006). In this case, the target variable at 10 km x 10 km scale is derived by drawing from a known distribution at plot scale rather than actual plot data. So whereas direct extrapolation requires a full representation of the heterogeneity in a spatially explicit manner, extrapolation by expected value requires only the fine-scale heterogeneity in statistical terms. .(Wu and Li, 2006) This method could be suitable if exact plot locations are not available, e.g. for privacy reasons.

9.5.1. Design based estimates

If sample units have been selected at random and inclusion probabilities are hgher than zero for the whole universe (e.g. country or region where NFI is applied), it is possible to use a design-based method to aggregate the plot scale model outputs to the 10 km x 10 km Eurogrid cell. Random selection of sampling units is carried out only in a few countries and the potential importance of design based methods is thus limited. The Netherlands has a stratified random sampling design, with 1 km x 1 km grid cells as strata and one randomly selected sample unit for each stratum. Lithuania has a 4 km x 4 km grid, the centre of which has been drawn randomly. Thus, design based methods can be applied, though with only one degree of freedom, estimating variance is problematic. Many countries have grid based designs with plots at or near intersections, but for most it is not clear whether the grids centers have been placed randomly or not.

However, whereas design-based inference absolutely requires sample units to be selected at random, random selection does not absolutely require a design based inference. The major advantages of design based inference are that calculations are usually simple and that unbiased estimates are available of global parameters, including mean and variance (uncertainty), of the frequency distribution of the target variable in the universe as a whole (de Gruijter et al., 2006). A complication for our study is that the universe of the NFI (i.e. the forested part of the country) is not identical to the universe of interest in this study (i.e. the 10 km x 10 km grid cells). Thus, whereas a well designed random selection of sampling units assures that enough sample units are present to estimate these global parameters with sufficient accuracy, this is not necessarily the case when the universe is reduced to a 10 km x 10 km grid cell. Still, because of the objective estimate of a sampling variance, it is recommended to use design based methods if possible.

A general course for design based methods cannot be given, as the sampling design determines the calculation method for the global parameters mean and variance. However, some general remarks can be made based on the NFI designs in The Netherlands and Lithuania.

If a two phase approach has been applied and sample units with measurements have been located in forested land only, any results based on just these data give average values for forested land, not for the entire grid cell. The plot locations which were allocated but were not in forested land also should be taken into account, with a carbon emission set to zero (the land use there actually may have a carbon emission, but the carbon emission reported under category 5A Forest Land is by definition zero if the land use is not forest). This may be quite easy for grids with random centre, as a few sample unit locations are sufficient to calculate all of them. However, for random sample unit locations, yes or no stratified, these data may be difficult to obtain. If a stratified design is applied with strata are included in a 10 km x 10 km grid cell, it is enough to know the number of empty grid cells in a stratum, with the exact location of little relevance. If, however, strata are only partially included, it is unknown whether the empty plots were in- or outside of the 10 km x 10 km grid cell. A possible solution is to include the full stratum, weighted for the surface that is inside the 10 km x 10 km grid cell.

If exhaustive auxiliary information is available, e.g. soil maps or forest maps, the inference method can be adapted to include this information using a posteriori stratification. The post-stratification estimator assumes that the auxiliary information is known for each sampling unit, and that the surface of each class of auxiliary information is known (de Gruijter et al., 2006). Both conditions are met if exact locations are given for the NFI sample units.

9.5.2. Geostatistical predictions

If a sufficient number of sampling units have been measured to estimate a semivariogram (> about 150), geostatistical methods can be applied with or without combining with auxiliary variables. This requirements is actually met for all NFI systems, and geostatistical methods can be used for sample units that were selected at random or that were placed systematically. Only for the latter, no really good alternative is present. As kriging explicitly takes into account the spatial structure of sampling units, all types of NFI systems basically come down to the same type of aggregation. Block kriging refers to kriging where the support is changed in the process from the finite sample unit to an area of specific dimensions, in this report a 10 km x 10 km Eurogrid cell (Goovaerts, 1997). Whether the plots are clustered or not does not have special importance for the interpolation, but the estimate of the nugget of the semivariogram is greatly improved if plots at close distance are present.

If a two phase approach has been applied and sample units with measurements have been located in forested land only, the more simple aggregation has the following sequence of events:

- define sensible units for estimation of the semivariogram, i.e. the country level or smaller units

An alternative to this method would be to apply a moving window and to estimate the semivariogram in an automated way for each single window. However, this has a number of theoretical and practical problems, among which the calculation time and the problems with automated semivariogram fitting are the most important ones. Instead of fitting a series of moving window semivariograms, which all need to be checked, interpolation is based on all points in a moving window with the semivariogram based on the sample units within the country or defined unit.

- estimate the semivariogram of the target variable (carbon emission values) based on ALL samples in the defined units, i.e. the sample units where no measurements have been done in the second stage due to absence of forest are included with value zero

This method entwines the effects of growth rate (increment values for forested areas) with the occurrence of forest over the area. The average for the grid cell resulting from the kriging is thus the average over the entire surface area, and the total can be calculated by multiplying it with the surface of the entire grid cell (100 km^2). In many countries, the total area of forest is estimated from the occurrence of forest as land cover on all sample units of the entire grid. However, in case of large grids with few points per 10 km x 10 km Eurogrid cell, the deviations from the real situation may be large at the 10 km x 10 km scale. It may then be more accurate to estimate the average carbon emission for forested land, and multiply it with the integrated forest cover over the grid cell. Below still another method is proposed to include auxiliary information on forest cover.

- use ordinary block kriging with local estimation of the mean for interpolation, including ALL sample units (also those from other countries) within the radius for plot inclusion, assuming a similar semivariogram and support for sample units in other countries

A limited radius for inclusion of sample units is common in kriging, and increases performance of the kriging algorithm. By including plots from other countries or defined units better use is made of all relevant information and edge effects between countries are smoothed. Even if the other country has random plot locations and has its estimates based on design based methods, the plots can still be used for estimating the local average of the specific block. Care should only be taken to make sure also the plot locations without measurements are included, or a correction is made for this (as random plot locations usually cannot be derived from the locations of other plots).

If exhaustive auxiliary information is available, the model can be adapted to include this information. Several methods exist, among which cokriging, but the most simple and applicable to this situation is universal block kriging, also called (bock) kriging with a trend model. Whereas ordinary (block) kriging assumes a constant average within the radius for inclusion of sample units, universal (block) kriging assumes that the mean varies as predicted by one or more auxiliary variables. The most simple example is the use of a forest cover map as an auxiliary variable to better predict the effect of forest land cover on average (= averaged over entire surface, including non-forested land) carbon emissions. Another example may be to use slope as an auxiliary variable, or climate variables.

In case of a qualitative auxiliary variable, both universal (block) kriging or stratified kriging may be applied. An example could be the use of a soil map with qualitative soil types as an auxiliary variable to aggregate soil carbon emissions.

9.5.3. Disaggregation of national or regional data

For many countries, harvested volume is known at the regional or national scale, but not at the plot scale. In order to calculate changes in carbon stock due to losses at a 10 km x 10 km Eurogrid scale, these national or regional totals need to be distributed over either NFI plot level data or over the 10 km x 10 km grid cells directly ("Disaggregation" in Figure 9-1). Which is the best option depends on the level of detail in the data (a total harvested volume or a harvested volume by species or assortment) and the kind of model used to calculate changes in living biomass.

In both cases, a choice has to be made between a deterministic method or a conditionally stochastic method. If the choice is made to disaggregate in a deterministic way, one single function is used to describe the spatial variation of the harvested volume such that the total sums up right. If a conditionally stochastic method is chosen, a family of equally probable functions is defined such that the total of each function sums up to the national or regional total. The latter does not result in one solution, but rather in a large number or results which could be summarized in a probability distribution. The variance of this distribution expresses the uncertainty introduced by downscaling to plot or grid cell scale.

The functions used to disaggregate can be empirical, mechanistic or using auxiliary information. For harvest data, auxiliary information is available through the NFI plot level data (in case of scaling to plots) or aggregated 10 km x 10 km data. Relevant auxiliary variables for disaggregation to plot scale are age, standing volume, tree number and diameter and in case species specific harvest data are provided: species. On 10 km x 10 km scale forest area, total volume and mean volume, yes or no on a per species basis, can be used.

Some other variables may also be available only at national or regional scale. For these, a similar approach as described here can be followed.

9.6. *Uncertainty analysis and error propagation*

Li & Wu (2006) distinguish three sources for uncertainty in the final aggregated result:

- uncertainty due to the model(s) used and the accuracy of the model parameters
- uncertainty in the accuracy of the input data
- uncertainty associated with the scaling algorithms

In this report, the focus is on the uncertainty associated with the scaling algorithms. This is extended towards methods for propagation of uncertainty from other sources during calculations. However, the quantification of uncertainties introduced with model structure and GPG-LULUCF assumptions and default values, NFI measurements as well as national definition of parameters, are outside the scope of this research work.

The sequence followed here is first to calculate the uncertainty of primary values at plot level and of parameters. Then different methods are discussed to calculate the uncertainty of the target variables at plot level based on the uncertainty of the primary variables and parameters. Finally, methods are proposed how to calculate the uncertainty of the aggregated carbon emission on a 10 km x 10 km scale. For some methods, the uncertainty of the target variable at plot level is not needed as long as the probability distribution of the primary variables and parameters is known.

9.6.1. Propagation of errors to plot level uncertainty

Uncertainty of plot level primary data

Uncertainty introduced with input data can be separated into (Li & Wu, 2006):

- uncertainty related to data quality (measurement errors, sampling errors, database errors)
- uncertainty related to natural variation (spatial heterogeneity and stochastic or random effects)
- uncertainty due to lack of data (missing values)

Measurement errors related to instrument accuracy are expressed as absolute or relative errors. By definition, de absolute measurement error is the largest difference possible between the real and the measured value, assuming correct use of the instruments. It is equal to the smallest unit on the measurement instrument and can only be reduced by using a more accurate instrument. A set of calculation rules is available to propagate measurement errors from individual tree measurements to plot level data based on absolute and relative measurement errors (Annex A). However, instrument inaccuracy is typically low compared to other sources of errors. Therefore, more commonly is a system of control measurements, which allows a direct estimate of all uncertainty associated with data quality. E.g. in the Lithuanian NFI, about 5-7% of all plots are fully remeasured within the same month by a different team and without referring to the primary data. These serve a double purpose: removal of large errors and check on sampling accuracy. The resulting calculated mean errors of the latter are probably the best estimate for plot level uncertainty of primary data (Kuliešis et al., 2003).

Quantification of uncertainty due to natural variability is the main topic of statistics and it basically involves replication. Spatial heterogeneity is considered in the paragraph on aggregation algorithms. Stochastic or random effects are partly spatially independent and thus will show as part of the spatial heterogeneity, with some plots affected and some not. Part of the random effects will consist of variation between years of an inventory. This is at present not considered.

The presence of missing values is a source of uncertainty that in most cases cannot be quantified (Li & Wu, 2006).

Uncertainty of model parameters

The uncertainty caused by model parameters may be resulting from a lack of data or understanding, the use of model parameters outside their range of validity and because model parameters were based on a set of measurements/estimates which themselves had an unknown accuracy (Li & Wu, 2006).

The only element of this that falls directly within the scope of this report is the use of model parameters outside their geographical range of validity.

For most model parameters, the geographical validity is poorly defined. For carbon reporting, countries define model parameters with a presumed validity within their boundaries. However, these can be based on measurements in one location, or a limited number of locations without spatial design. Studies based on a large set of data all over Europe are rare (e.g. Wirth et al.,2004).

In Task 4 of MASCAREF (see Chapter 7 and 8 of this report) a compilation is made of model parameters used for the conversion of volume data to carbon stocks within Europe. Based on this information, uncertainties related to the spatial dimensions of model parameters will be estimated for concrete cases in The Netherlands, Lithuania and Umbria (Italy).

Error propagation

For linear models, it is possible to calculate the variance of the model result exactly and analytically using probability theory. If independence of data can be assumed, the means and variances of the primary data and model parameters suffice for the calculations. If this is not a likely assumption, the covariance between the input variables are also needed. Implicitly, the method assumes normal distribution of all input variables.

If the criteria for the use of probability theory (linear model, independence of data or covariance known, normal distribution of input parameters) are not met and in the absence of observed output data, the variance of the model result can be estimated or approximated using either Taylor expansion or Monte Carlo simulation (Li & Wu, 2006).

Using the Taylor series expansion, any differentiable function can be approximated by a linear function in a certain point. The mean and variance of this approximation can then be calculated using probability theory. In most cases, a first or second order Taylor approximation is used, as the increased accuracy of using higher terms does not outweigh the increased calculation complexity. This method is quite flexible for functional forms of model functions, as long as they are differentiable. However, the error introduced by using an approximation instead of the exact function is unknown.

The Monte Carlo simulation computes output statistics by random sampling of input variables and model parameters. This implies that the statistical distributions of input variables and model parameters are known, but does not put any requirements as to what form these should have. As this method also does not put any strict requirements for the formulation of the model functions, it is very flexible and therefore widely applied. A disadvantage of the use of sampling is that joint distributions of correlated variables are often poorly known and difficult to derive. If no joint distributions are included, the method thus de facto assumes independence between these variables. Furthermore, the method is computationally intensive, and the outcome is a long list of values which do not necessarily exactly follow a predefined distribution. This method has been applied by The Netherlands to estimate the uncertainty for the national total for carbon emissions by Forest Land remaining Forest Land (Van den Wyngaert et al., 2007).

Li and Wu (2006) distinguish also the method "sequential partitioning", which essentially comes down to breaking up a model into parts which can be combined linearly using probability theory. For each of these model parts the variance or uncertainty is estimated using (a combination of) any of the three methods described above. For the calculation of carbon emissions at 10 k x 10 km Eurogrid, sequential partitioning could be applied to separate error calculation for carbon emissions due to changes in living biomass, dead organic matter and soil carbon.

9.6.2. Uncertainty of the aggregation

Design based estimates

Design based methods are allow the calculation of an unbiased sample variance as a measure of uncertainty. This incorporates information on the (spatial) heterogeneity between sample units as well as the number of sample units. It can however, not analytically be combined with uncertainty from other sources like plot level uncertainty from measurement and model errors (paragraph 9.6.1 Error propagation). To estimate the total uncertainty from different sources, Monte Carlo simulation (described also in 9.6.1 Error propagation) is the most used method.

Geostatistical predictions

Geostatistical methods give an estimate of the uncertainty of the aggregated data given that the model used for inference is correct. Thus, an uncertainty estimate is provided, but it does not include the whole uncertainty, only the part related to spatial heterogeneity.

In contrast to design based estimates, kriging algorithms are able to incorporate the uncertainty estimates on a plot level. As the semivariogram is translated into a covariance function, the plot level uncertainties can be subtracted from the values on the diagonal (Knotters et al., 1995). The final uncertainty estimate then takes into account the local uncertainties resulting from the methods described in paragraph 9.6.1 Error propagation. The Monte Carlo method can also be applied but will in general be less efficient.

9.6.3. Uncertainty of disaggregated information

The uncertainties associated with disaggregation of data (e.g. national harvest values) may be large and difficult to quantify. If a conditionally stochastic method is used for aggregation, an uncertainty estimate follows from the disaggregation process. This uncertainty estimate expresses the variance between the results given a set of equally probable disaggregation functions. It does not include uncertainty about the suitability of the disaggregation functions themselves, or about the underlying assumptions. It is, however, probably the best estimate of uncertainty caused by the disaggregation of statistical data that can be obtained.

9.7. *Test runs per country: methods, set-up and specifications*

Three data sets were selected to provide a proof of concept of the developed methodologies. These regions were selected for their availability, their coverage of the European spectrum with respect to ecological conditions and their involvement in the MASCAREF project. Two entire countries were selected, i.e. The Netherlands and Lithuania, and one Italian region, i.e. Umbria. The methods and principles developed were consequently applied to the NFI data from the three test regions.

Each region had a specific methodological focus. For The Netherlands this was the presence of missing values and the inclusion/exclusion of background information which is not usually readily available for internationally available NFI data. For Lithuania this was how to deal with lower spatial coverage using kriging. For Umbria, the main focus was on estimating uncertainty intervals for model parameters and how this affected the outcome of the test runs.

The default settings and values for these studies are discussed below. More specific information for each region as well as a more detailed description of the main focus is given in paragraphs 9.7.5 to 9.7.7.

9.7.1. General methods and set-up

Spatial information

All NFI plot information was stored in one harmonized plot database. The plot locations were transformed from their own coordinate systems to the ETRS1989 European Lambert Azimuthal Equal Area Projection (INSPIRE, 2007a). Consequently a grid system was applied that complies with the proposal on a European reference grid (EUR 21494 EN)). An overlay between the plots and the grid system attributed grid cell codes to all plots. All grid cells containing plots of a specific country or region were included, irrespective of whether this region made up all or just a small part of the grid cell.

For the two countries Lithuania and The Netherlands the grid cells were grouped according to NUTS 1 (Nomenclature des Unités Territoriales Statistiques). The carbon sink was aggregated to NUTS 1 level to demonstrate the influence of different spatial scales. For Umbria, which is a NUTS 1 level entity and contained only 107 grid cells, the effect of aggregating grid cells on uncertainty estimates was analysed using artificial aggregation units with varying number of grid cells.

9.7.2. Carbon budget model(s) and default parameters

The carbon source/sink functioning is calculated at NFI plot level using the GPG-LULUCF (see also Annex B at the end of this chapter). For this report, no data sets with repeated biomass measurements were available, and all calculations were performed using the default methods. Default parameter values available from GPG-LULUCF were used if not indicated otherwise. A normal distribution was assumed and standard deviations were taken from the GPG-LULUCF if available. The coefficient of variation was set to a default 10% if no estimates for variance or standard deviation were available. If this resulted in ecologically impossible values (i.e. negative values) when drawing randomly from the distribution, then those were rejected.

Table 9-1 Model parameters, source for default values and for calculation of carbon source/sink functioning according to GPF-LULUCF

Variable	Distinctions	Variance	Source
BEF1	Coniferous/broadleaves Level of growing stock	SD estimated from min-max	GPG-LULUCF Table 3A.1.10
CF	None	CV = 10%	GPG-LULUCF
D	Species	CV = 10% or 15%	GPG-LULUCF Table 3A.1.9-1; Singh, 1986
R	Coniferous/broadleaves Amount of above ground biomass	SD given in table	GPG-LULUCF Table 3A.1.8

9.7.3. Aggregation methods

For the proof of concept aggregation, both design based methods and geostatistical methods were considered. For each of the regions, a choice was made between design and model based aggregation. The considerations to choose between the one or the other were:

- the method of plot selection ((partially) randomized versus completely systematic)
- the density of plots with available data in the 10 km x 10 km grid cells
- the difference in calculation time between design based and geostatistical methods (geostatistical methods imply a much higher time investment)

In The Netherlands and Umbria, the NFI plot density was high (1 km x 1 km grid for plots, with for Umbria only plots in forest included) and design based estimates were preferred for the aggregation. In Lithuania, the NFI plot density is lower and only one fourth of the national total of plots was available (4 km x 4 km grid over 4 years, only 1 year of data available). Therefore, for Lithuania kriging was carried out.

9.7.4. Uncertainty calculation and sources of error

The total uncertainty was calculated through double Monte Carlo simulations. A first set of N runs is made over the model parameters and for each run the grid cell mean or total values with the sampling variance are calculated. From this grid cell distribution, a second set of M values is drawn that reflect the spatial uncertainty per run. The final set of N x M values then incorporates both the sampling and model uncertainty.

One of the main aims of quantifying uncertainty was to identify and prioritize gaps. This was done by quantifying uncertainty from different sources by error budgeting. In contrast to sensitivity analysis, for error budgeting the variation in input variables reflects real variation, also used for total uncertainty analysis (Jager and King, 2004). A relatively simple, though calculation intensive, method was chosen, i.e. the absence effect method (Li and Wu, 2006). The "total" uncertainty is calculated by applying a Monte Carlo analysis, varying all parameters. Then, for each parameter, the parameter is fixed to its mean value and the remaining uncertainty is calculated according to the same method used for total uncertainty. The reduction in uncertainty between remaining uncertainty and total uncertainty is a good measure for the sensitivity of the final result to this parameter and is calculated as:

$$U_{-X} = \sigma^2_{-X} / \sigma^2_Z$$

$$\sigma^2_{-X} = \sigma^2_Z - \sigma^2_{ALL-X}$$

With U_{-X} as the relative error contribution of the parameter X, σ^2_Z is the variance when varying all factors and σ^2_{ALL-X} is the variance varying all parameters except X.

In some cases it was not possible to set a parameter to a fixed value (e.g. for missing values) and this method was complemented with the presence effect method, which is the more simple version: all parameters are fixed to their mean value, except the parameter for which the effect on the total uncertainty is studied. The contribution to the total uncertainty of parameter X is then calculated according to

$$U_X = \sigma^2_X / \sigma^2_Z$$

With U_X as the relative error contribution of the parameter X, σ^2_Z is the variance when varying all factors and σ^2_X is the variance when varying only X.

9.7.5. The Netherlands

NFI data availability & sampling scheme

The last national forest inventory in The Netherlands was carried out between 2001 and 2005, with no data collected in 2003 (no field work was possible due to a contagious cattle disease). It was designed as a systematic unaligned random sample, with one plot per 100h of forest (based on a digital forest map). Both permanent plots (50%) and temporary plots (50%) are included. A 1 km x 1 km grid was laid over the country, and in each grid, one XY coordinate was drawn as a sample point. An overlay was made between the points and a digital forest map (1:10000) and points falling within the forest became part of the inventory. All of these 3622 points were visited, however not for all data could be collected because 1) some could not be reached physically and 2) not all plots proved to actually be situated in forest. Plots situated in forest on the map but not in reality were treated as missing, as it was unknown to what extent plots rejected (based on the map) were in reality in forest. The full set of coordinates of drawn plots, in forest or not (on the map) was available for this study.

Model parameters

The Netherlands has selected a set of (international) biomass functions to convert from plot variables to total biomass (Nabuurs et al., 2005). This is done based on the plot volume data, and the plot volume data after adding the increment (and distributing it over diameter and height). As such there is a different ratio between volume increment and change in above-ground biomass for each plot. This ratio is the product of wood density and biomass expansion factor as defined in GPG-LULUCF, and is comparable to the biomass conversion and expansion factors (BCEF) in the IPCC Guidelines

2006 and will be abbreviated as such. The distribution of these BCEF's was determined from the plot data, distinguishing levels of growing stock volume according to (0-50 m^3, 50-150 m^3 and > 150 m^3) as well as main species groups. A separate set of biomass functions was available to estimate below-ground biomass on plot level, and these results were used to construct similar distributions for R.

Sample sizes were extremely small for plots with low volumes and the distributions were irregular. However, combining species groups into broadleaves and needle-leaves yielded bimodal distributions for R (mainly Quercus robur + petraea vs Fagus sylvatica for broadleaves and Pinus sylvestris vs Picea abies) in higher volume classes and this was rejected. Distributions were not significantly different from normal for lower volume classes, but often were for higher ones. Mean values and standard deviations are given in Table 9-2 and Table 9-3. For the carbon fraction the default value was used (see par. 9.7.2).

Table 9-2 Root-to-shoot ratio's for increment per species groups and growing stock (GS) volume classes: mean values and standard deviations as calculated from the Dutch plot level values

	GS < 50 m³		***50 m³ < GS < 150 m³***		***GS > 150 m³***	
Species Group	***Mean***	***± St Dev***	***Mean***	***± St Dev***	***Mean***	***± St Dev***
Acer spp	-	-	0.184	± 0.040	0.175	± 0.024
Alnus spp	0.264	± 0.105	0.248	± 0.044	0.246	± 0.088
Betula spp	0.225	± 0.045	0.196	± 0.153	0.192	± 0.026
Fagus sylvatica	0.227	-	0.225	± 0.006	0.216	± 0.005
Fraxinus excelsior	0.165	± 0.008	0.160	± 0.008	0.150	± 0.007
Larix kaempferi	0.277	-	0.265	± 0.014	0.252	± 0.010
Picea spp	-	-	0.273	± 0.017	0.256	± 0.011
Pinus other	0.234	± 0.039	0.204	± 0.024	0.191	± 0.016
Pinus sylvestris	0.243	± 0.038	0.202	± 0.022	0.189	± 0.016
Populus spp	0.255	± 0.037	0.227	± 0.027	0.215	± 0.022
Quercus spp	0.165	± 0.011	0.152	± 0.009	0.144	± 0.006
Other broadleaved	0.175	-	-	-	0.145	± 0.007
Other coniferous	0.299	-	-	-	0.253	± 0.014

Table 9-3 Biomass Conversion and Expansion Factors for increment per species groups and growing stock (GS) volume classes: mean values and standard deviations as calculated from the Dutch plot level values

	GS < 50 m³		***50 m³ < GS < 150 m³***		***GS > 150 m³***	
Species Group	***Mean***	***± St Dev***	***Mean***	***± St Dev***	***Mean***	***± St Dev***
Acer spp	-	-	592	± 157	493	± 147
Alnus spp	612	± 194	508	± 89	388	± 81
Betula spp	642	± 136	791	± 308	952	± 186
Fagus sylvatica	1895	-	675	± 389	824	± 436
Fraxinus excelsior	902	± 221	715	± 164	600	± 89
Larix kaempferi	528	-	517	± 27	492	± 17

Picea spp	-	-	503	± 38	450	± 25
Pinus other	454	± 17	470	± 16	478	± 12
Pinus sylvestris	439	± 49	470	± 33	479	± 25
Populus spp	506	± 36	530	± 33	538	± 28
Quercus spp	1135	± 340	829	± 188	705	± 156
Other broadleaved	1157	-	-	-	763	± 144
Other coniferous	565	-	-	-	488	± 28

Aggregation and uncertainty calculation

Grid cells of the European reference grid contain between 98 and 102 NFI plot coordinates (deviations from 100 are due to a difference in orientation between the sampling grid and the European reference grid). Depending on the surface of forest in the grid cell, grid cells contain between 0 and 68 plots that were visited in the field (including plots with missing values). For the uncertainty analysis, the distribution of the plot C source/sink results were calculated using Monte Carlo simulation (N = 500 runs) over the model parameters BCEF1, R and CF using hypercube sampling (McKay et al., 1979). For each of these runs, the NFI plot data were then aggregated to 10 km x 10 km carbon source sink functioning using a design based approach. This yielded an estimate of the spatial mean with an estimate of the spatial uncertainty (= variance) for each run. For each of these distributions again 500 values (M=500) were drawn using stratified sampling to incorporate the spatial uncertainty in the final result.

Two different approaches were applied to aggregate plot level data, expressed on a per hectare basis, to a grid cell total:

1) as the coordinates of ALL NFI locations were available (not only those actually visited because the map indicated them as forest) we set the carbon emission in forest of plots outside forest equal to zero. Averages and variations were then calculated over all NFI plot coordinates using 1) stratified random with 2 km x 2 km strata or 2) simple random for each 10 km x 10 km grid cell.

2) as for most countries the coordinates of plots outside forest are not readily available, the NFI forested plots were used to estimate the carbon emission on a per ha basis (mean and variance) for each grid cell (with variance approximated as simple random design per 10 km x 10 km grid cell). This was then multiplied with an estimate of the area of forest, either based on the number of NFI plots and their representative surface (calculated from national or regional statistics if not available from the NFI background information) or based on a European map with forest surface estimates on a 1 km x 1 km basis (Schuck et al., 2003).

Annex G described both the π-estimators (based on the chance of inclusion of a plot) and the ratio-estimators for the mean and sampling variance of the carbon source/sink functioning of the total grid cell and the forested part of the grid cell. The ratio-estimator was selected and the mean and sampling variance were calculated. The approximation of the variance as is proposed here is in agreement with Fatteroni et al (2009).

The uncertainty associated with missing values was incorporated through a random drawing from the whole or a selected part of the data set:

- if the species of the plot was known, but volume and increment were not measured, an increment value was drawn from the existing increment values of that species and model calculations were performed on this filled increment value using the species specific parameters
- if nothing of the plot was known (not even the species), a random value was drawn from the national distribution of plot results

Error budget analysis & gap identification

An error budget analysis was carried out using the estimated variance in model parameter distributions to attribute relative values to the different sources of uncertainty in the analysis based on all NFI plot coordinates. Monte Carlo analysis (N=500; M = 500) was performed varying all or all except one of the parameters BCEF, R and CF.

For the Netherlands, special focus was on the uncertainty introduced through the presence of missing values in the NFI inventory as 658 of 3621 plots had missing increment data or more. There were no "real" or nominal values to substitute the filled ones, therefore all other parameters were set to their nominal value instead, with only the process of filling missing values contributing to variation between Monte Carlo runs. The variance of the filling of missing values was compared with the total variance. Additionally, model runs were made with plots with missing values filtered out. This introduced a bias (as only plots with forest could have missing values and were filtered out), which was estimated.

As this is a proof of concept rather than a detailed analysis, the error budget analysis was done for a subset of cells only. This reduced calculation efforts and data storage, without really affecting the outcome. Thirty cells were selected over the Netherlands, in three categories:

- ten cells with many (> 20) forest plots and no missing values
- ten cells with few (1-10) forest plots and no missing values
- ten cells with forest plots with missing values

The last category was filled using values from the full data set of plots over The Netherlands.

9.7.6. Lithuania

NFI data & sampling scheme

The continuous Lithuanian National Forest Inventory began in 1998 (1998-2002) and the first re-inventory of the permanent sample plots occurred 2003-2007. Thereafter a five-year invent cycle is planned. It was designed as a purely systematic 4 km x 4 km grid with clusters of 4 circular plots at the grid intersections. The field inventory covers Forest land, and in the case of afforestation/deforestation Grassland and Wetlands as well. In total 5600 permanent plots are laid out, but at the moment only of 744 plots data are available for international purposes. From the plots that were available, none had missing data.

Model parameters

For the kriging analysis the plot level data were converted into carbon emissions using default conversion factors from GPG-LULUCF. The standard deviations were taken from the GPG-LULUCF if available and set to 10% of the mean value if not available in GPG-LULUCF.

Aggregation and uncertainty calculation

1.Simulation of carbon fluxes at plot scale; At each plot n = 100 carbon fluxes (Mg/ha) have been simulated by sampling the multivariate parameter distribution of the carbon model. The following parameters have been sampled: BEF1, R, CF. For reasons of efficiency, Latin hypercube sampling has been applied (McKay et al., 1979). The procedure resulted in n = 100 equiprobable maps of simulated carbon fluxes at plot scale. The ensemble of maps represents parameter uncertainty

2.Spatial interpolation and aggregation of carbon fluxes at plot scale to Eurogrid cells by geostatistical simulation;

Each map with carbon fluxes at plot scale have been interpolated and aggregated to 10 × 10 km2 Eurogrid cells by means of geostatistical simulation. See for example Deutsch & Journel (1992) or Goovaerts (1997) for an overview of geostatistical simulation methods.

In this study, sequential Gaussian block simulation will be applied to simulate m = 100 equiprobable realizations of carbon fluxes at 10 x 10 km2 Eurogrid cells for each realization obtained in the previous section. Hence, a total of n × m = 10000 Eurogrid maps will be generated.

For sequential Gaussian simulation it is assumed that the data are multivariate normally distributed, an assumption that is hard to validate. Nevertheless, sequential Gaussian simulation is more convenient, has a sound theoretical basis and is less computationally demanding compared to alternative procedures.

In sequential Gaussian block simulation, all prediction cells (EuroGrid cells) are visited once by following a random path. At each prediction cell, a block kriging system is solved yielding a prediction ŷ and a variance σe2 of the prediction error. Next, a value will be drawn from a normal distribution with mean ŷ and variance σe2. This value will be added to the data and used to simulate the remaining values along the random path. The procedure is repeated for each realization. For more details see the references cited above.

The ensemble of n × m = 10000 Eurogrid maps can be used to derive maps of the mean carbon flux, and measures of dispersion like the variance and prediction intervals.

3. Spatial aggregation of Eurogrid cells

Sequential Gaussian block simulation resulted in an ensemble of n × m = 10000 Eurogrid maps. Each realization can be further aggregated to areas that consist of multiple Eurogrid cells by arithmetic averaging. Indeed, as long a the new aggregation units are spatial clusters of contiguous Eurogrid cells, it is not necessary to repeat the sequential Gaussian block simulation procedure.

Sensitivity analysis & gap identification

In view of the calculation time needed for kriging including an uncertainty estimate, no sensitivity analysis or error budgeting was carried out using kriging. An error budgeting procedure was carried out at plot scale.

9.7.7. Umbria (Italy)

NFI data & sampling scheme

The first national forest inventory in Italy was carried out between 1983 and 1985. Since 2003, a second NFI was started at national scale. However, between 1985 and 2003 about half of the Italian regions organised a regional or sub-regional forest inventory, which differed in sampling design and survey procedures. The forest inventory in Umbria was organised as a 1 km x 1 km regular grid, with only forested points included.

Model parameters

Biomass expansion factors, wood density and aboveground to belowground ratio's were taken from the values provided in the Italian NIR's (del 6.2, ref NIR). The biomass expansion factors in the NIR were factors for growing stock rather than for increments. They were corrected using the ratio between mean BEF1 and BEF2 from the GPG-LULUCF.

The Italian values were presented without an error or minimum-maximum interval. To use these parameters for uncertainty calculations, runs were made with the following estimates for

1. distributions were assumed to be normal and standard deviations were set at 10% of the mean values
2. distributions were assumed to be normal and standard deviations were based on the errors and intervals given in the GPG-LULUCF
3. no assumption of normality was made as some intervals showed clear asymmetry around the mean, and a triangular distribution defined by a minimum, a mean and a maximum was used (Saucier, 2000).

The standard deviations and minimum and maximum values were calculated according to the following:

- for the root-to-shoot ratio's an estimate of the standard deviation, minimum and maximum was given in Table 3A.1.8. The coefficient of variation was calculated for temperate forests. For each Italian forest type the coefficient of variation of the corresponding broader category in GPG-LULUCF was taken and multiplied with the mean value to calculate the Italian standard deviation for an estimated Gaussian distribution. The minimum and maximum values were taken over without change, except if one of them was approximated or even exceeded by the mean value. In these few cases, the minimum and maximum values were shifted one unity, respecting the with of the interval.
- for the BEF values the standard deviations were not given in the table but estimated from the minimum – maximum interval presented in the table. Following the fact that about 95% of all observations of a normal distribution are within 2 standard deviations from the mean, a standard deviation and coefficient of variation were calculated. This procedure was checked with the standard deviations and min-max intervals of the root-shoot ratio's and gave satisfying results.
- for wood density, no information was available on intervals or uncertainty, and information from the literature was used to estimate the coefficient of variation and minimum and maximum values (Singh, 1986; Zangh, 1998). Based on this literature, the coefficient of variation was set at 15% while the minimum and maximum values were set at fixed intervals of the mean (minimum = mean value - 110 kg m^{-3} ; maximum = mean value + 170 kg m^{-3}).
- for the carbon content of woody biomass, the coefficient of variation was kept at default 10%.

The final sets of mean, minimum and maximum values used as input for the uncertainty calculations are given in Annex F.

Aggregation and uncertainty calculation

Grid cells of the European reference grid contain between 1 and 64 NFI plot coordinates, all of which had a set of plot characteristics with valid data for standard and fro coppice forest (i.e. no missing values). For the uncertainty analysis, the distribution of the plot C source/sink results were calculated using Monte Carlo simulation over the model parameters BEF1/2, D, R and CF.

The NFI plot data were then aggregated to 10 km x 10 km carbon source sink functioning using a design based approach. This resulted in a mean carbon emission on a per ha basis (mean and variance) for each grid cell. This was then multiplied with an estimate of the area of forest based on the number of NFI plots, assuming that one plot represented the square kilometre of forest. Alternatively, the forest surface was based on a European map with forest surface estimates on a 1 km x 1 km basis. The systematic grid was approximated as a stratified random, using a collapsed stratum method to approximate the sampling variance. For grid cells with very little forest are, and thus very few sampling points, the sampling variance was calculated as a simple random.

Error budget analysis & gap identification

An error budget analysis was carried out using the estimated variance in model parameter distributions to attribute relative values to the different sources of uncertainty in the analysis. Monte Carlo analysis (N=500; M = 500) was performed varying all or all except one of the parameters BEF, D, R and CF, with errors determined according to the three different methods outlined in par 0. For Umbria, special focus was on the uncertainty in the uncertainty estimation, as the country specific values had no error estimate.

9.8. *Sensitivity analysis for gap identification / prioritization*

This paragraph deals with sensitivity analysis for gap identification and prioritization. As such, the main issue discussed is the relative uncertainty from different sources and how to quantify and compare this.

9.8.1. The Netherlands

Plot level sensitivity to model parameters

At the plot level, three model parameters affected the outcome for plots with measured data: BCEF1, R and CF. An uncertainty analysis was conducted varying all three of them, and then keeping in turn each one of them constant for error budget analysis. This yielded The effect was evaluated by comparing the variance per plot over the different Monte Carlo runs for plots with measured data and missing data separately (Table 9-4).

Keeping one of the parameters constant decreased mean plot level variance with around 50% in case of BCEF1 and CF for plots with measured data. It decreased mean plot level variance, however, with less than 2% if it was R that was kept constant. This low value for R reflects the low investment of carbon into roots (about 20% for the most occurring species) and the relative low variance in estimates from biomass functions (incorporated as standard deviation) over plots. It should be stressed that this does not reflect real uncertainty in belowground biomass estimates, but rather the variance over the different plots with estimated below ground biomass from biomass functions.

As each plot is assumed homogeneous in tree species and tree characteristics, it is possible to analyze the effects of these on overall uncertainty and its main sources.

With R contributing little to overall uncertainty, the contribution of BCEF1 and CF are strongly negatively correlated (R = -0,995). This was manily driven by BCEF1: tree species with low uncertainty in BCEF1 had in general lower total plot uncertainty and a lower contribution of BCEF1 to total plot uncertainty. Annex XX gives examples of the distributions of a plot with high (*Fagus sylvatica*) and low (*Pinus sylvestris*) uncertainty in BCEF1.

For plots with missing values which were filled, keeping one of the parameters constant reduced the variance of the distributions to draw from, but this summed to only 40% of total variance. Almost 60% of the variance remained when all parameters were kept constant and this was attributed to the gapfilling itself.

Table 9-4 Results of error budget between model parameters at plot level

Plot type	*Parameter*	*Mean contribution to total uncertainty*
Measured plots	BCEF1	0,469
Measured plots	R	0,016
Measured plots	CF	0,531
Filled plots	BCEF1	0.302
Filled plots	R	0,011
Filled plots	CF	0,092
Filled plots	gapfilling	0.582

Grid cell sensitivity: model parameters, missing values and aggregation

At the grid cell scale total uncertainty is expressed as the variance of the grid cell total over the Monte Carlo runs. The sources of uncertainty are in this case the model parameters, the filling of missing values and the sampling variance resulting from the spatial heterogeneity of the gridcells. As there is no "nominal value" or constant for the missing values, the effect of the sampling can only be distinguished for grid cells without missing values.

Most of the variance was caused by sampling and spatial heterogeneity. The filling of missing values seemed to have little effect on the total non-model parameter uncertainty ("all parameters fixed").

This is also confirmed by the very few and small differences in error sources between the aggregation according to simple random with and without including filled values. However, plots with few forest plots and many non-forest plots had a higher contribution of sampling tot total variance. The contribution of single model parameters is in proportion with the effects of the respective parameter on plot level for R (which is very low) and BCEF1. In contrast, the contribution of CF to grid cell scale uncertainty is considerably lower than expected from the plot level estimates. The values for CF are all drawn from the same one distribution for all species (though drawing occurs per species). The values for R and BCEF1 are drawn from three distributions per species: one for each volume class. As in many countries, tree species do not occur in random distributions, but tend to cluster into the same or neighbouring grid cells. Thus, many grid cells will have several plots of the same species, but with different volume classes. If CF is kept constant, one drawing out maximally 7 is set to the nominal value. If BCEF1 or R are kept constant, maximally 3 drawings out of maximally 7 are set to their nominal value over all MC runs. As such, the effect of the latter could weigh more heavily on total grid cell uncertainty.

For the aggregation two approximations of the sampling variance were used: a simple random and a stratified random using strata of 2 km x 2 km. The latter gives a more accurate estimate (but still overestimate) of the sampling variance. However, not for all designs would it be possible to use the stratified random.

Table 9-5 Results of error budget between model parameters at grid cell level

	Parameter fixed at nominal value:			
	BCEF	**R**	**CF**	**all**
Aggregation according to stratified random				
> 20 forest plots, no missing values	0,15	0,00	0,24	0,62
<12 forest plots, no missing values	0,09	0,00	0,14	0,77
cells containing missing values	0,24	0,02	0,14	0,63
Aggregation according to simple random				
> 20 forest plots, no missing values	0,14	0,00	0,21	0,66
<12 forest plots, no missing values	0,07	0,00	0,08	0,86
cells containing missing values	0,21	0,02	0,12	0,68
Aggregation according to simple random, no gapfilling				
> 20 forest plots, no missing values	0,15	0,00	0,20	0,66
<12 forest plots, no missing values	0,06	0,00	0,07	0,86
cells containing missing values	0,21	0,00	0,13	0,66

The effect of gapfilling is much more important at grid cell scale than at plot level. This may be caused by clustering of the plots with missing data into some grid cells. Of the 3622 plots, 889 have missing increment values and/or species information. When points with missing values are filtered out of the analysis, this increases the number of grid cells without any forest from 100 tot 204 on a total of 467 grid cells (at least partially) in The Netherlands (Annex D at the end of this chapter). Thus, for 104 grid cells, all forest plots have missing values. Most of these grid cells have only a few forested plots, but some have up to 20 or even 30 forested plots (out of about 100).

9.8.2. Lithuania

Plot level sensitivity to model parameters

At the plot level, four model parameters affected the outcome for plots with measured data: BEF1, D, R and CF. An uncertainty analysis was conducted varying all four of them, and then keeping in turn each one of them constant for error budget analysis. The effect was evaluated by comparing the variance per plot over the different Monte Carlo runs (Table 9-6). For the parameter configuration used for Lithuania, both R and D dominated the plot level uncertainty. BEF1, on the other hand, contributed little to the uncertainty of the result.

Table 9-6 Results of error budgeting at plot level (= mean relative contribution to total uncertainty over plots)

	BEF1	*D*	*R*	*CF*
Lithuania	0,01	0,41	0,42	0,20

9.8.3. Umbria (Italy)

Plot level sensitivity to model parameters

At the plot level, four model parameters affected the outcome for plots with measured data: BEF1, D, R and CF. An uncertainty analysis was conducted varying all four of them, and then keeping in turn each one of them constant for error budget analysis. The effect was evaluated by comparing the variance per plot over the different Monte Carlo runs (Table 9-6). Three ways to estimate the errors were compared: distributions were assumed to be normal and standard deviations were set at 10% of the mean values (G10), distributions were assumed to be normal and standard deviations were based on the errors and intervals given in the GPG-LULUCF (Gaussian or Gaus) and last no assumption of normality was made as some intervals showed clear asymmetry around the mean, and a triangular distribution defined by a minimum, a mean and a maximum was used (Triangular).

There was a large effect of defining the parameter uncertainty based on GPG-LULUCF compared to assuming a fixed relative error of 10%, and a smaller effect of going from a Gaussian to a triangular distribution (Table 9-7). When all input parameters had the same relative uncertainty of 10% (expressed as coefficient of variation), the total uncertainty was the result of –in equal shares- the uncertainty of the three linear parameters BEF1, D and CF, with the uncertainty in R not really relevant for the final plot outcome.

However, the minimum and maximum values of BEF1 are set defining a symmetric and rather narrow interval in GPG-LULUCF, while for R the interval is both wider and tailed towards high values. For D, with no uncertainty interval from GPG-LULUCF, a symmetric but wider (CV = 15%) interval was derived from literature. This combined to more than half of total uncertainty being explained by the uncertainty in D, while BEF1 contributed less than 10% to total uncertainty. The importance of R increased to 12% and even further increased to 22% when the asymmetry of the distribution was taken into account using a triangular distribution for input parameters (Table 9-7).

There was very good correlation between the three methods to estimate input parameter uncertainty for the resulting plot scale uncertainty. The plot scale uncertainty of model results derived from input parameters with fixed uncertainty at 10% was systematically lower than from input parameters with uncertainty based on GPG-LULUCF assuming a Gaussian distribution. Interestingly, plot scale uncertainty of model results derived from input parameters with fixed uncertainty at 10% was not systematically higher or lower than from input parameters with uncertainty based on GPG-LULUCF NOT assuming a Gaussian distribution. It seems that the tails of the Gaussian distribution, which -in this case- may represent unrealistically high or low values, cause an increase in variance of –in this case- over 30% (over 15% increase on standard deviation).

Table 9-7 Results of error budgeting at plot level (= mean relative contribution to total uncertainty over plots)

	BEF1	*D*	*R*	*CF*
G10	0,34	0,33	0,02	0,33
Gaus	0,09	0,54	0,12	0,24
Trian	0,08	0,49	0,22	0,26

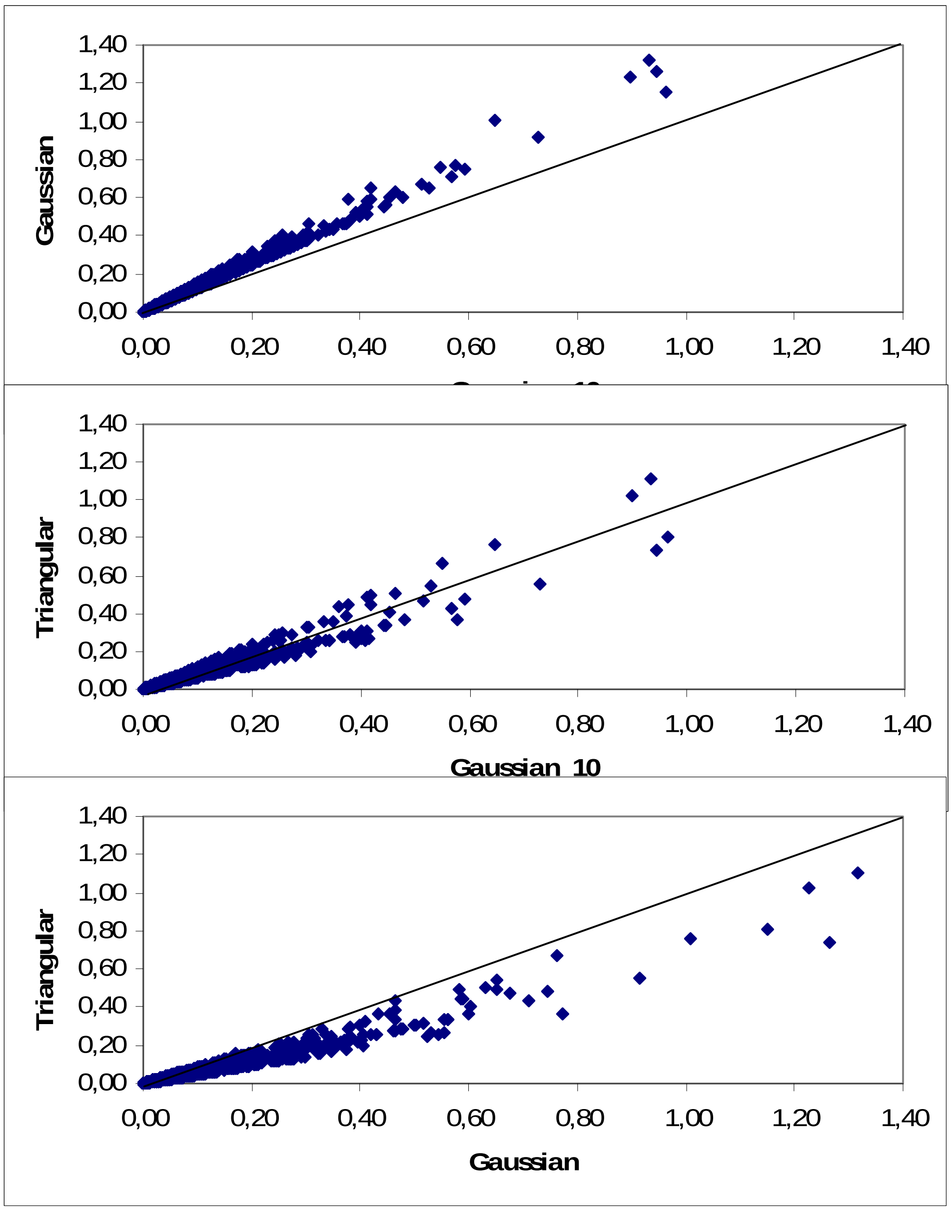

Figure 9-2 Comparison of resulting plot uncertainty between the different methods to estimate input parameter uncertainty

Grid cell sensitivity: model parameters, forest area and aggregation

At the grid cell level total uncertainty is expressed as the variance of the grid cell total over the Monte Carlo runs. The sources of uncertainty in this case are the model parameters, the forest area and the sampling variance resulting from the spatial heterogeneity of the gridcells. Over 90% of the variance (ranging between 80% and near 100%) was caused by sampling of spatial heterogeneity. There was a slight tendency for cells with low forest plot density to be at the higher end of this range, and plots with high forest plot density to be at the lower end of this range, but the differences were small, and could not be distinguished from spatial patterns (compare Figure 9-3 and Figure 9-4)

The uncertainty in forest area per grid cell explained most of the remaining variation. The estimated levels of uncertainty in model parameters contributed less than 1% to total cell uncertainty.

Table 9-8 Results of error budget between model parameters, forest surface and sampling of spatial heterogeneity at grid cell level.

	model parameters	*cell forest area*	*spatial heterogeneity*
Gaussian (CV =10%)	0,00	0,06	0,94
Gaussian	0,00	0,07	0,94
Triangular	0,00	0,08	0,92

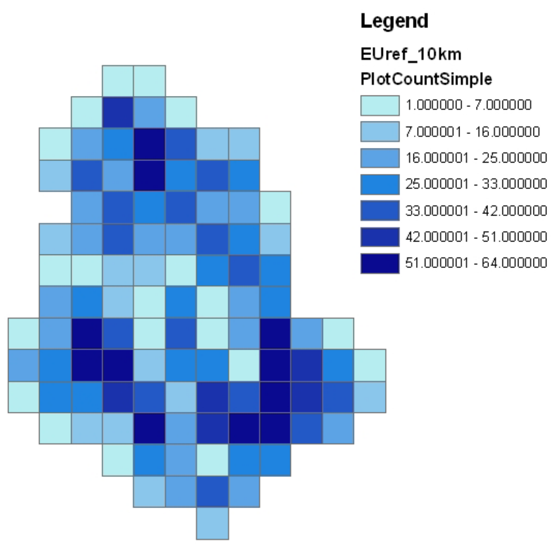

Figure 9-3 Number of plots to be aggregated per grid cell over Umbria

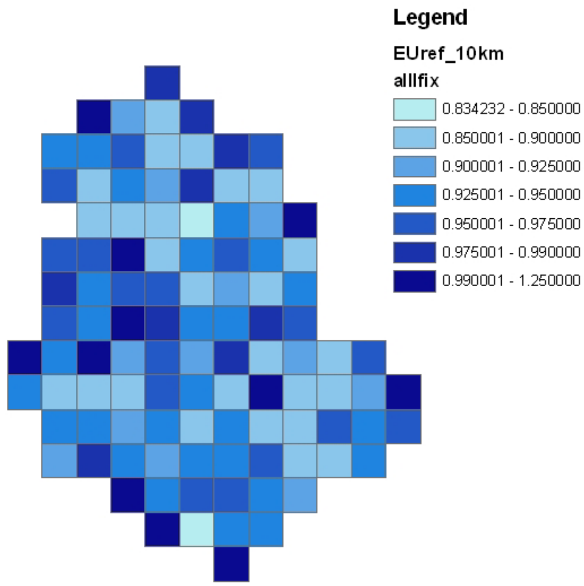

Figure 9-4 Contribution of spatial uncertainty to overall grid cell uncertainty derived from comparing MC analysis with and without including model parameter and forest map uncertainty

9.8.4. Discussion

The foregoing analysis breaks down the uncertainty at plot and 10 x 10 km grid cell scale for the carbon sink from tree growth based on NFI plot level data. This analysis includes certainly not all sources of error that affect the estimates of the mean. Li & Wu (2006) (see also Del 5.1) distinguished uncertainty related to the model(s) used and the accuracy of the model parameters, uncertainty related to the (accuracy of) the input data and uncertainty related to the scaling.

The most important source of uncertainty at the 10 x 10 km grid cell scale was sampling of spatial heterogeneity. This accounted for between 60 and 90% of grid cell uncertainty in The Netherlands and between 80 and almost 100% in Umbria. Despite lower overall uncertainty at grid scale, there was only a very small effect of stratified versus simple random on the relative contribution of spatial heterogeneity. For areas with the locations of forested plots only, the use of a stratified random approximation for variance calculation will in general not be possible, and only simple random is available as approximation to calculate grid cell sampling variance. Results from The Netherlands indicate that this does not essentially affect the relative contributions of different causes to total uncertainty.

Model uncertainty can be separated into uncertainty in the model structure and in the model parameters. The first was not included in our analysis, and falls outside the scope of this project. The model structure used is defined by GPG-LULUCF and as such agreed upon by a large number of experts. It can, therefore, be considered as the best model for the defined purpose. Uncertainty in the model parameters is included explicitly in all analysis. In The Netherlands there was a surprisingly small contribution of the root-to-shoot ratio to overall model parameter uncertainty. This may reflect the low investment of carbon into roots (about 20% for the most occurring species) and the relative low variance in estimates from biomass functions (incorporated as standard deviation) over plots. It should be stressed that this does not reflect real uncertainty in belowground biomass estimates, but rather the variance over the different functions available to estimate below ground biomass. This is illustrated in Umbria, where the contribution of the root-to-shoot ratio to total plot scale uncertainty increases from near zero to over 22% with 1) a more realistic width of the input parameter uncertainty interval and 2) a different formulation of the distribution of the uncertainty of the model parameters. In Lithuania, based on the uncertainty of GPG-LULUCF the root-to-shoot ratio was one of the main sources of uncertainty. It illustrates the importance of good estimates for the uncertainty distribution of input parameters.

Uncertainty in the NFI input data was explicitly considered in our analysis only for the effect of missing values in The Netherlands. The inclusion of measurement errors for increment data was omitted. However, the mathematical calculations to include this are comparable with the calculations to include parameter uncertainty. An additional drawing at plot x MC run level for each input value used (in this model, only increment) from a distribution of the errors would also include plot level data quality. Analysis in The Netherlands showed that the effects of plot level measurement errors are small, especially as they are often assumed to be randomly distributed over plots (Van den Wyngaert et al., 2007). Uncertainty in other than NFI input data was assessed for the map with occurrence of forests (Schuck et al., 2003) in Umbria, in basically the same way.

The uncertainty introduced by missing values, though often difficult or impossible to quantify, may potentially be quite important for the overall uncertainty, especially in regions where data are sparse. In The Netherlands, almost 20% of all forested plots had missing increment values and this made up to 100% of all forested plots in some grid cells.

Given the limitations from this study, it can be concluded that it is feasible to identify the main sources of uncertainty for the carbon source/sink functioning. This was illustrated for the carbon sink due to increase in biomass from growth using NFI data, but the principle can be applied to other types of carbon sources or sinks and other type of data following the steps summarized in par 9.10. It is probable that at the 10 km x 10 km scale, the carbon sink from biomass growth is one of the least uncertain, and that the functioning of litter, dead wood and especially the allocation of harvest to grid cells will be even (much) more uncertain.

9.9. *Spatially explicit calculation of carbon source/sink functioning of forests: uncertainties at different spatial scales*

This chapter presents the results of the aggregation from plot level data to 10 km x 10 km, NUTS1 and national scale.

9.9.1. The Netherlands

The uncertainty on grid cell scale, at NUTS 1 scale and at national scale were calculated according to

- aggregation approximated with stratified random (2 km x 2 km strata) for all (gapfilled) NFI locations
- aggregation approximated with simple random at grid cell scale for all (gapfilled) NFI locations
- aggregation based on (gapfilled) forest plots only, forest area calculated from number of forest plots
- aggregation based on (gapfilled) forest plots only, forest area calculated from map (Schuck et al., 2003) assuming 5% map uncertainty (generic value)
- aggregation based on (gapfilled) forest plots only, forest area calculated from map (Schuck et al., 2003) assuming 50% map uncertainty (estimate for The Netherlands)

These different aggregation methods were used on a 10 km x 10 km grid cells scale and these spatially explicit estimates were then further aggregated to the provincial (NUTS1) and national scale. The uncertainty is expressed as an absolute value in the variance of the cell C sink over the MC runs for comparison between cells and is shown in maps in Annex D. It is expressed as a relative value using the coefficient of variation (i.e. standard deviation / mean) to compare over different scales.

The total C sink functioning on 10 km x 10 km cell scale ranges widely between cells. The spatial patterns for cell C sink functioning and the variance over the MC runs is similar for the different aggregation methods if gapfilling is carried out (Annex D). The relative uncertainty, expressed as the coefficient of variation, shows quite stable values for most cells with much higher values for a small selection of cells (Figure 9-5).

Aggregating cells to a higher level, i.e. NUTS1 or national, yields a lower relative uncertainty. At grid cell scale, the coefficient of variation reaches high values of more than 1 for a limited number of cells (Figure 9-5), which do not occur on a more aggregated scale. The mean, median and 75% percentile values all decrease from cell scale to regional scale and are lowest at national scale (Table 9-9).

Table 9-9 Mean, median and 75% percentile values for the coefficient of variation over cells, regions and national values

	Stratified Random	*Simple random*	*Forest * nr of plots*	*Forest * forestmap_5%*	*Forest * forestmap_50%*
Cell scale					
mean	0,51	0,59	0,43	0,43	0,70
median	0,43	0,48	0,27	0,27	0,55
75% percentile	0,64	0,76	0,50	0,48	0,71
Regional scale					
mean	0,38	0,40	0,25	0,31	0,34
median	0,30	0,33	0,20	0,30	0,34
75% percentile	0,47	0,48	0,27	0,40	0,44
National scale	0,25	0,36	0,18	0,21	0,21

Table 9-10 National total for carbon source/sink functioning in Gg C calculated according to different aggregation methods

Aggregation	*Mean*	*Variance*
Stratified random	1312	111870
Simple random	1319	222853
Forest * nr of points	1046	33572
Forest * forestmap_5%	1126	55632
Forest * forestmap_50%	1159	58672

[1] Map accuracy for The Netherlands

[2] Mean map accuracy

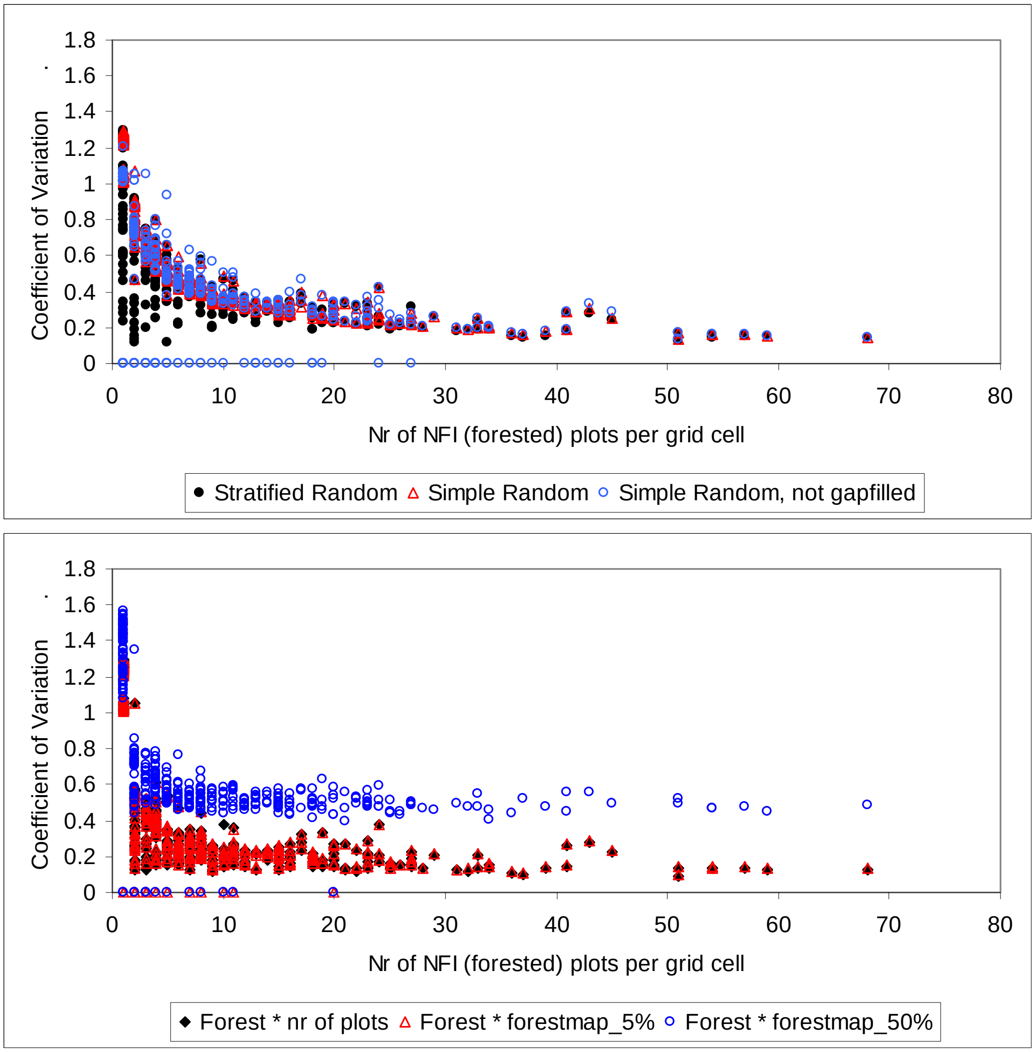

Figure 9-5 Coefficient of variation over cells with varying numbers of plot data

9.9.2. Lithuania

The procedure outlined in par. 0 will be illustrated by means of 744 NFI plots in Lithuania. The sampling pattern is given in Figure 9-6. Eurogrid cells are given as light blue10 × 10 km^2 cells, and NFI plots as dots. Although most plots are evenly distributed over the area, some gaps occur, particularly in the North and South-West. Also note that plots often occur in clusters of four (see inset at the lower left).

Carbon fluxes at plot scale have been simulated by sampling the multivariate parameter space of the carbon model. Figure 9-7 gives a dot plot representing one realization. A total of n = 100 equiprobable realizations have been generated, resembling parameter uncertainty. Figure 9-8 gives a histogram of carbon fluxes based on the entire ensemble. Note that this histogram is positively skewed.

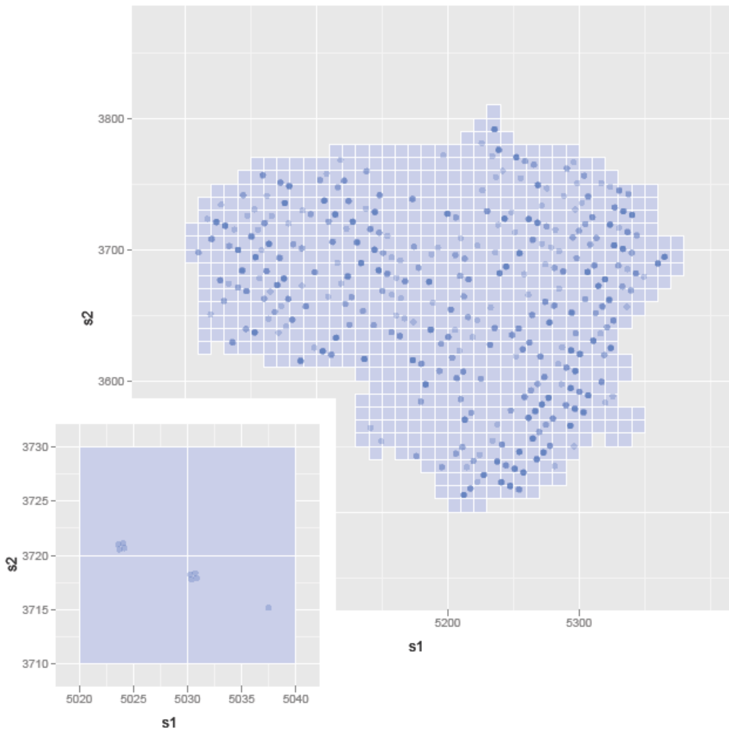

Figure 9-6 Distribution of (clustered) NFI sample plots with available data over Lithuania. 10 km x 10 km grid cells are given as white delimited blue squares

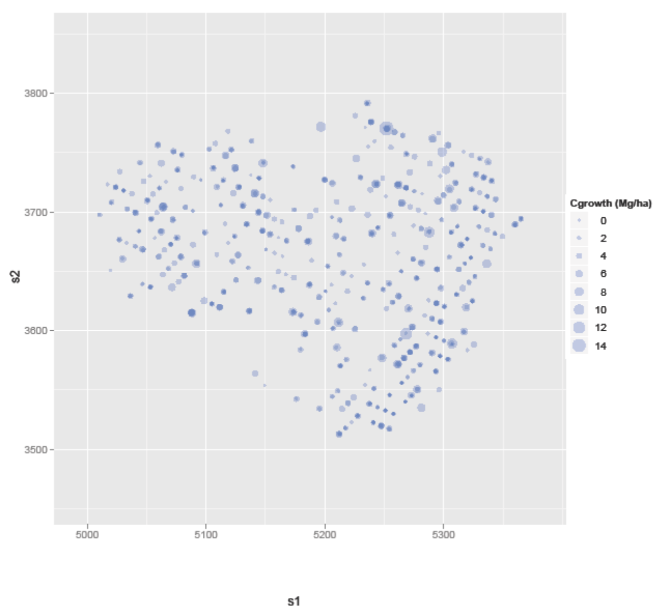

Figure 9-7 Example of a realization of the Monte Carlo analysis on plot level

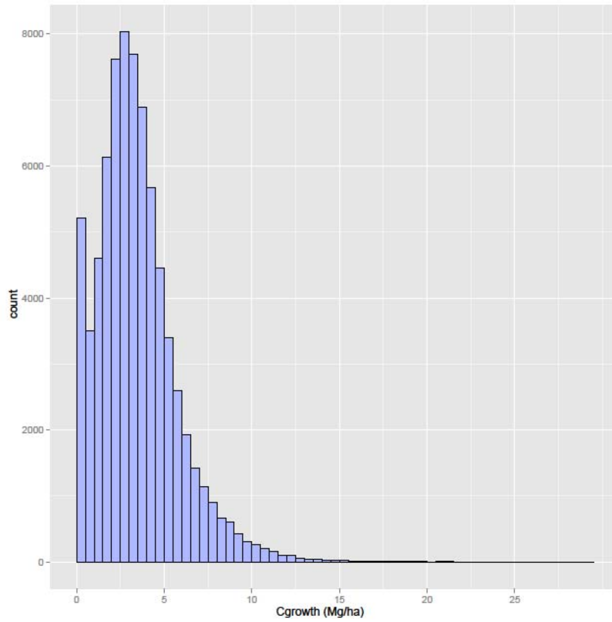

Figure 9-8 Histogram of C sink over all realizations and all plots

Carbon fluxes at NFI plot scale have been aggregated to 10 km x 10 km grid cells by means of a geostatistical procedure. Geostatistical procedures exploit information on spatial structure to reduce prediction error. Spatial structure is usually quantified by a semivariogram. For each realization obtained above, a semivariogram has been estimated and modelled. A total of three permissible models have been fitted to the sample semivariogram, i.e., a Spherical model, an Exponential model and a pure Nugget model. The model that fitted the sample semivariogram best in terms of the weighted sum of squared errors has been retained. The data set contained some clusters of plots (Figure 9-6, inset lower left) which provide valuable information on short distance variation. Figure 9-8 gives an example of a semivariogram. The low steepness and the high nugget suggest that the spatial structure of the C sink is limited. This variogram was quite typical over the simulations.

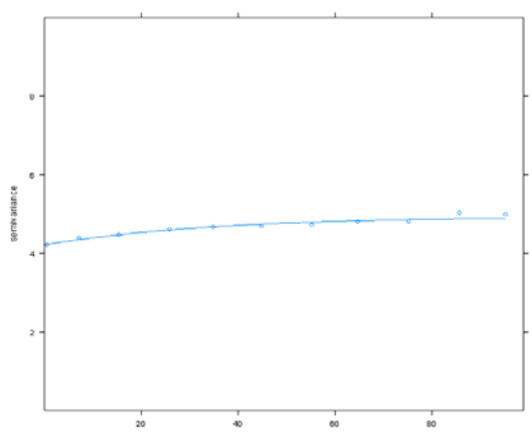

Figure 9-9 Example of a variogram for one realization (out of 100)

For each realization of carbon fluxes at plot scale, a total of m = 100 equiprobable realizations of carbon fluxes at Eurogrid scale has been simulated. Hence, the total number of 10 km x 10 km grid cell maps equals N × M = 10000. Each map has to be corrected for the fraction of forest (derived from Schuck et al., 2003).

At each grid cell, an ensemble of 10000 realizations of the carbon flux are thus available. These realizations can be used to estimate the distribution of the carbon flux for each cell. Each distribution reflects the uncertainty about the parameters of the carbon model, and the uncertainty due to spatial interpolation and aggregation. The carbon flux distributions for a selection of cells are given in Figure 9-10.

A map of the mean carbon flux (Mg/ha) can be obtained by averaging all maps. This is analogous to taking the mean of each carbon flux distribution. The result is given in Figure 9-11. Obviously, it shows resemblance to the forest fraction map in Figure 9-2. Likewise, the variance (Figure 9-13) or the 95%-prediction interval (Figure 9-14 & 9-15) can be derived, both quantifying the uncertainty about the true carbon fluxes.

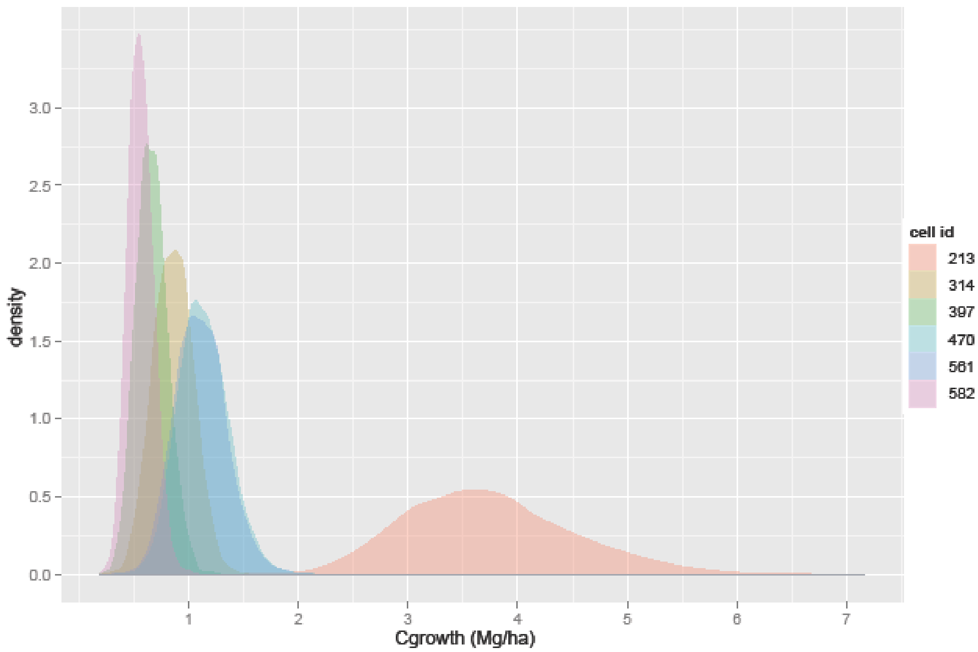

Figure 9-10 Examples of the distribution of C sink calculated for all 10000 realizations per 10 km x 10 km grid cell

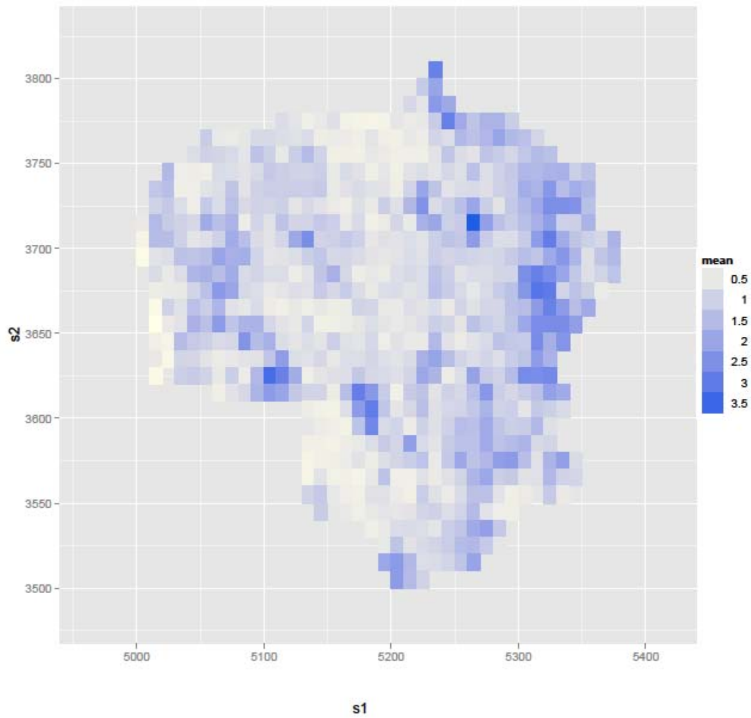

Figure 9-11 Mean of the grid cell total C sink over all MC realizations

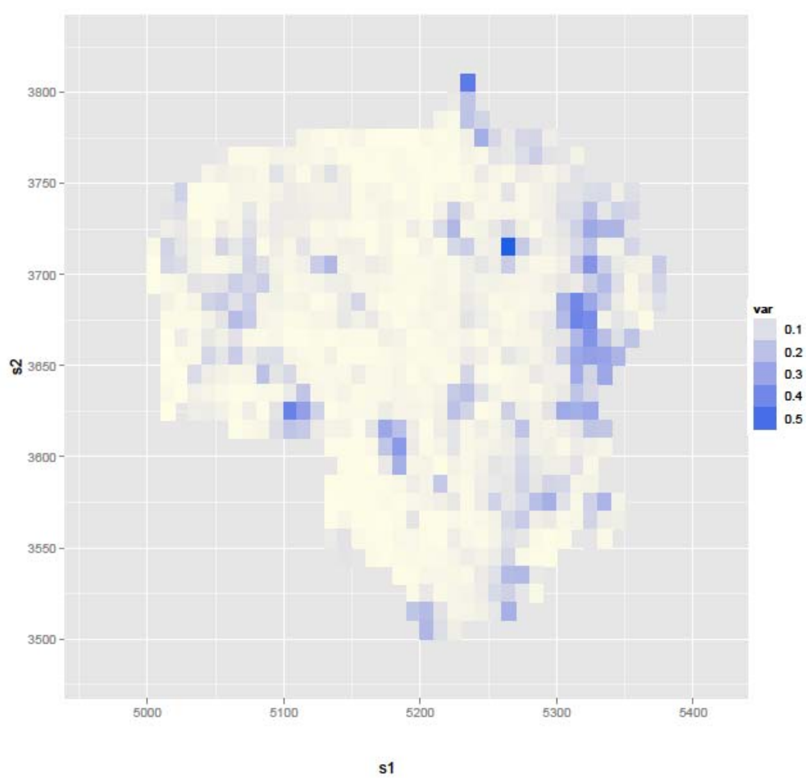

Figure 9-12 Variance of the grid cell total C sink over all MC realizations

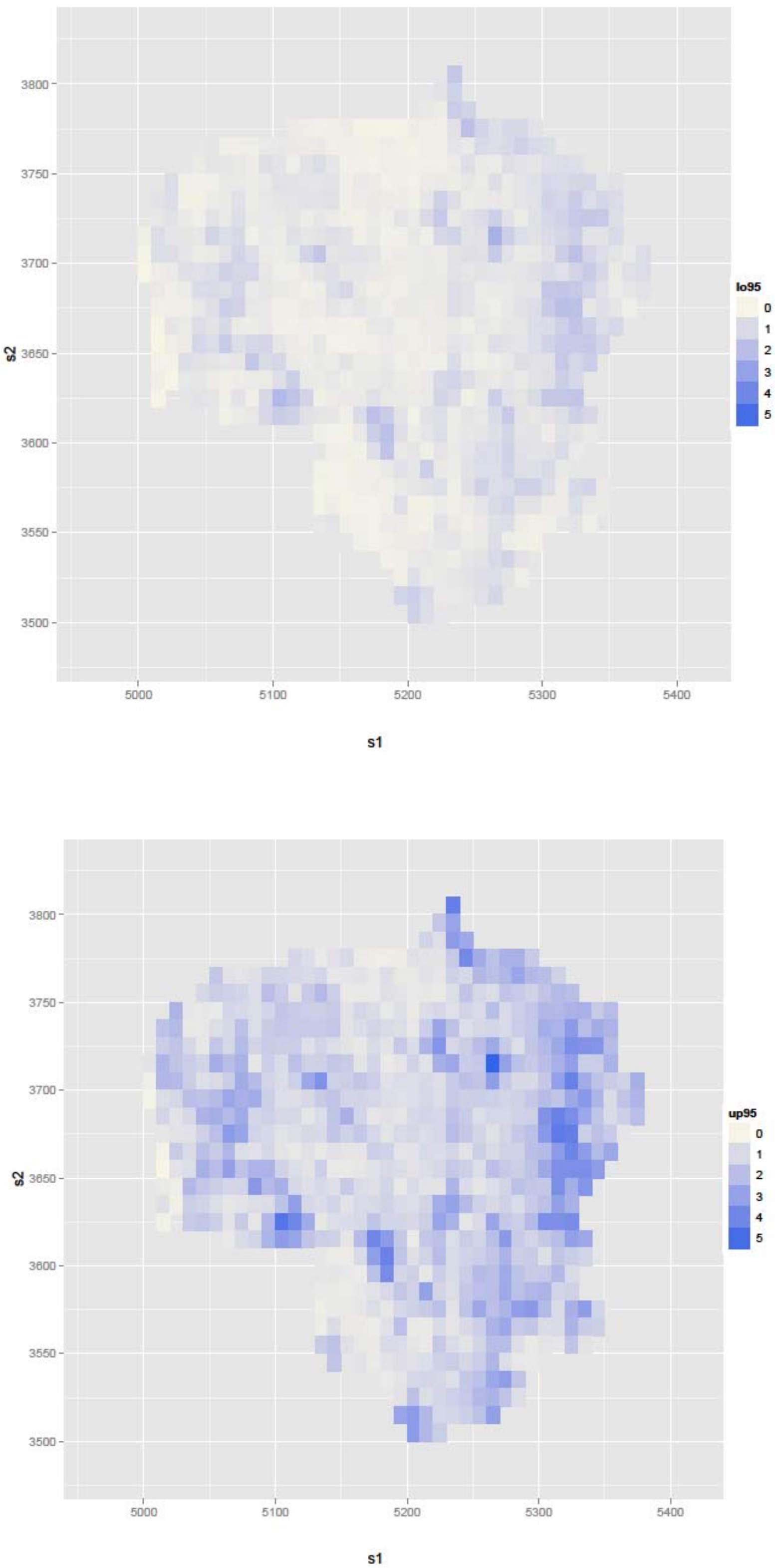

Figure 9-13: Lower and upper limits of the 95% confidence interval of the grid cell total C sink over all MC realizations

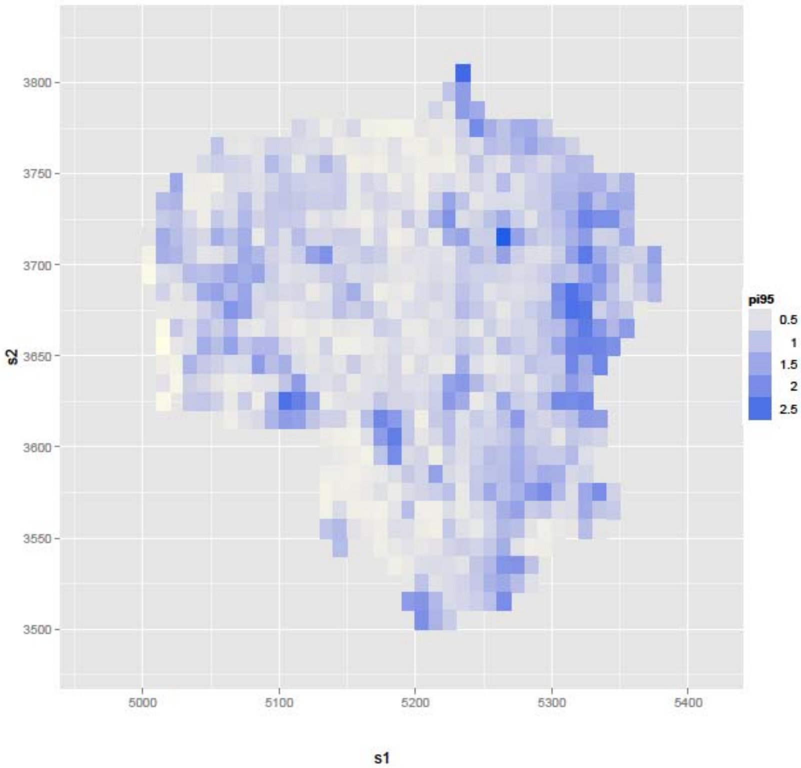

Figure 9-14: Width the 95% confidence interval of the grid cell total C sink over all MC realizations

The ensemble of N x M maps can be aggregated further without the need to apply the geostatistical procedure outlined above again. If the new aggregation areas are simply multiples of 10 km x 10 km grid cells, then simple arithmetic averaging of the grid cells of each realization suffices. As an example, the grid cells have been aggregated to NUTS 1 areas. The carbon flux distribution for each NUTS 1 area is given in Figure 9-15. Note that the uncertainty has been reduced due to aggregation.

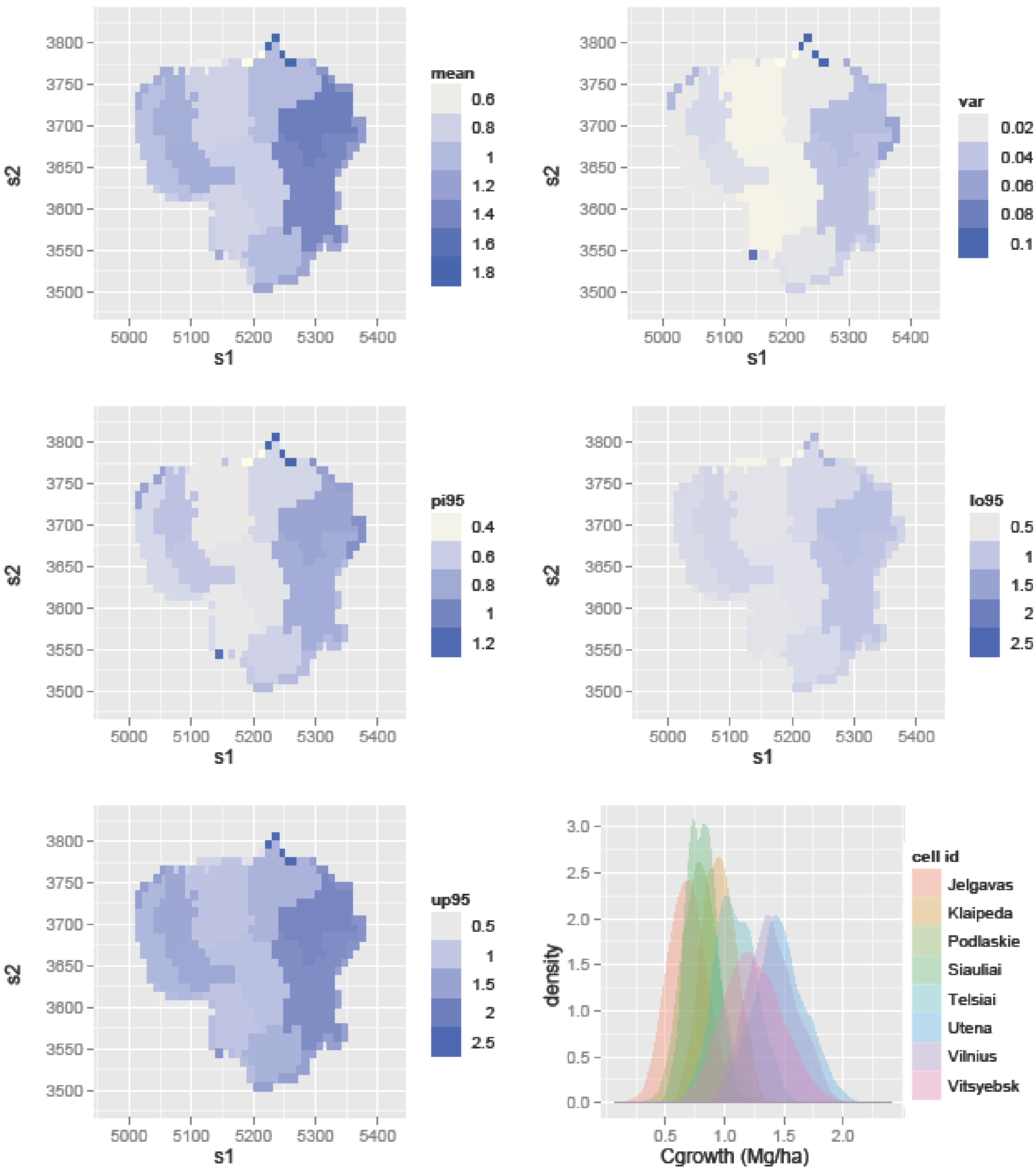

Figure 9-15 Summary of results aggregated to NUTS1 (from left to right and from above to below: mean, variance, width of 95% prediction interval, lower and upper limits of 95% prediction interval and distributions of NUTS1 aggregated results)

9.9.3. Umbria (Italy)

The uncertainty on grid cell scale and at regional (Umbria =NUTS1) scale was calculated assuming a triangular distribution for the input parameters with the (width between) minimum and maximum derived from GPG-LULUCF and the mean from the Italian NIR. Maps of the mean and variance of the individual grid cells are included in Annex E. Both relative and absolute uncertainty vary quite considerably (Annex E, Figure 9-16), but is not clear to what extent an edge effect is present at the outer limits of the province. It is clear, however, that the coefficient of variation, as a measure of relative grid scale uncertainty, was highly dependent on the number of NFI plots per grid cell (Figure 9-17) and stabilized around 15% (Figure 9-16). When (neighbouring) grid cells were aggregated the uncertainty in the prediction initially decreased rapidly, and stabilized between 12-15%.

As Umbria was already on NUTS1 level, and contained a limited number of plots, instead of aggregating to an administrative unit, the effect of aggregating larger units was tested by aggregating a cumulative number of neighbouring grid cells.

For the regional scale, i.e. for total of 107 grid cells with some (larger or smaller) part in Umbria, the coefficient of variation decreased to 13.7%. The total C sink is 512 Gg C and the calculated variance is 4933 (Gg C)^2. The total sink is an overestimate for Umbria, as it is based on the total forest area of all grid cells (i.e. 107 cells) with some part in Umbria.

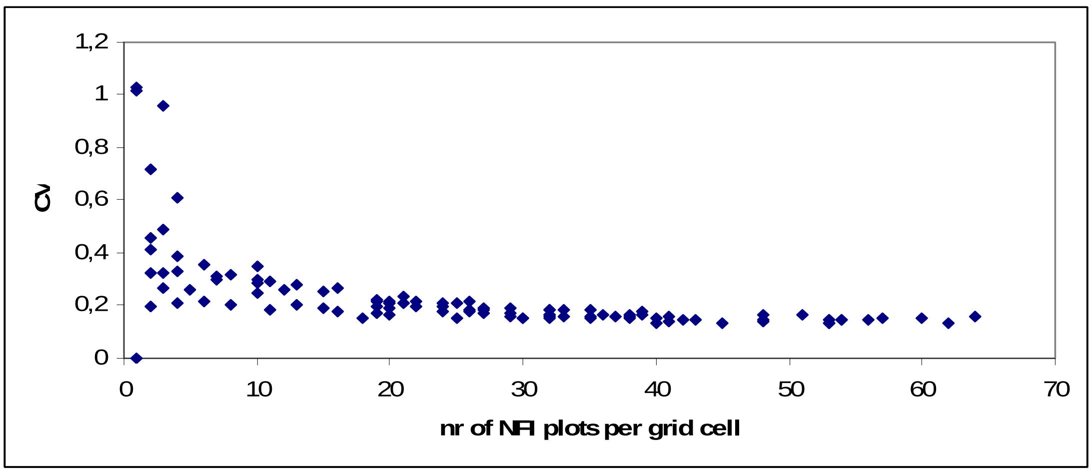

Figure 9-16 Coefficient of variation of the grid cell C sink related to the number of forested NFI plots in the grid cell

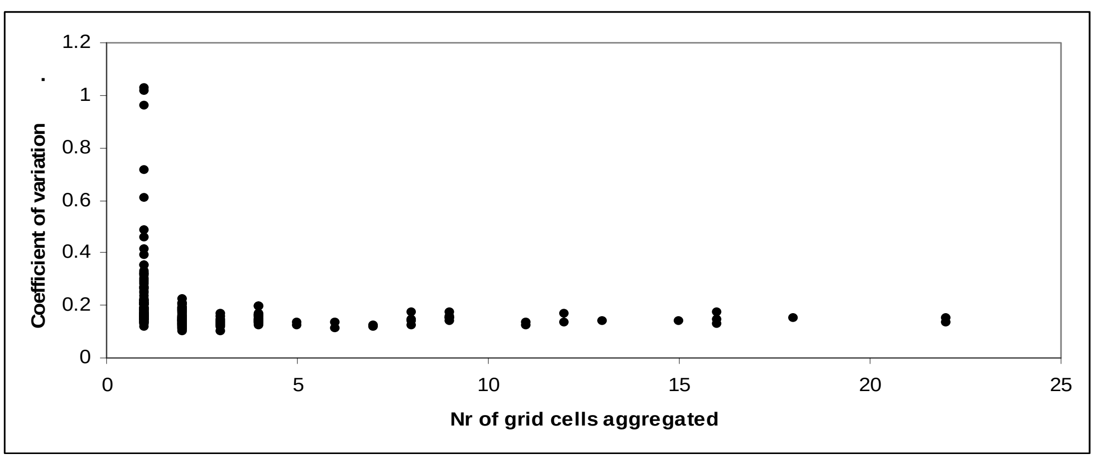

Figure 9-17 Coefficient of variation of the aggregated C sink dependent on the number of grid cells grouped from aggregation

9.9.4. Discussion

The foregoing analysis gives an estimate of the uncertainty at 10 x 10 km grid cell scale for the carbon sink from tree growth based on NFI plot data. This analysis includes several but certainly not all sources of error that affect the estimates of the mean, as discussed in par. 3. Some of the uncertainties that were left out are very difficult to catch quantitatively, other were considered not important enough to include in a proof of concept. The variance of the results over the different MC runs was used as the measure for (absolute) uncertainty, complemented with the coefficient of variation as a measure of relative uncertainty to compare across scales. There are other measures, like the 95% confidence interval calculated from the 2,5%-percentile and the 97,5 percentile, not assuming a specific type of distribution. However, adequately determining the tails of a distribution requires an even higher calculation effort than was required now, and was therefore not chosen.

The two regions that were aggregated using design based methods or approximations both had about 1 plot per square kilometre. For Umbria, only forested plots were actually available and grid cells with only few forested plots showed a high uncertainty of up to 100%. For The Netherlands however, though it was possible to include all of the original locations, also those where no forest was found, grid cells with few forested plots still showed a high relative uncertainty if aggregated according to a simple random design. If the plots are considered according to a stratified random, using a collapsed stratum design for approximation of variance, reducing the number of forested plots creates a scatter up and downwards rather than an increase in the coefficient of variation.

As the main source of the uncertainty is spatial heterogeneity (par 3) this reflects the increased uncertainty in sampling a sparse population of forest plots, rather than being an effect of running only a few plots with the model. Once there are about 20 forested plots in a grid cell, the relative uncertainty decreases only slightly with increasing number of plots. With a 1 km x 1 km grid, this means a forest cover of 20% or more. The 10 km x 10 km grid cells provide good estimates in forested areas with a dense measuring grid, but become quite uncertain if less than 10 forested plots are present. This would be the case for the less dense measuring grids of larger countries (e.g. Sweden, Lithuania).

Kriging could be a way to use information from a larger area than the 10 km x 10 km grid cell, and especially in large countries with low density measuring grids and homogeneous forests this seems appropriate. In these circumstances, clustering is often applied, allowing a good estimate of the nugget. However, the low spatial structure in the data seem to suggest that it is not crucial to have plots very close to one another. This may reflect the large effect of plot characteristics like age and management, which are not (necessarily) very closely related to the environment, have on the carbon sink. Only if the different plots of the cluster would fall in the same forest stand, would the small scale spatial correlation be high. This was indeed found for a small number of local variograms.

Aggregating to a larger scale decreases the uncertainty of the estimates. Though more than 10% of individual grid cells in the Netherlands have coefficients of variation higher than 100% for the stratified random, the national total has a coefficient of variation of only 25%. For Umbria, which has a similar initial plot density and a lower number of grid cells, but is more densely forested, the uncertainty of the regional total decreases even to less than 14%. In Lithuania, comparison of the plot scale histograms (examples only) and the NUTS1 scale histograms shows that not only does the uncertainty decrease, the differences between the plot or NUTS1 units also becomes smaller.

One very important aspect which was not incorporated in this exercise was the temporal uncertainty. It is common practice to collect NFI data over a time span of more than one year, and often there are gaps between cycles when no data at all are collected. In this study, no date or year was set to the estimates of the C sink. For actual application, however, this would become another issue to deal with. Another aspect arises when more than one country is involved in the aggregation and the harmonisation of the NFI data is concerned. However, much attention is already focussed on this topic and it is as such not considered in this (part of the) report.

9.10. *Summary and conclusions*

In this report we gave proof of concept of the calculation of a spatially explicit carbon sink, including an estimate of the uncertainty and error budgeting to identify the main sources of variance and possible gaps, at the 10 km x 10 km grid cell scale.

As a basic model the GPG-LULUCF equations were used, as well as the GPG-LULUCF default parameters if no country specific values were available. In case those were available but the uncertainty of the parameters was not, the latter was estimated from the standard deviation and minimum-maximum intervals provided in GPG-LULUCF. The model was applied at plot level to allow the use of species specific parameters. A series of N Monte Carlo runs was made, reflecting the full uncertainty matrix in input parameters using hypercube sampling. The same can be done for input data with their associated uncertainty.

For each of these N realisations, the plot level results were aggregated to 10 km x 10 km grid cells. This yielded N aggregated means with a sampling (design based) or model (model based) variance, reflecting the spatial heterogeneity calculated for each of the N realisations. Both model based and design based methods can be used for aggregation, depending on sampling design and plot density but also expected calculation time. Complicated designs can be approximated using simpler (simple random or stratified random / collapsed stratum) methods.

For each of these N realisations with associated distribution, M values are drawn from this distribution, representing the combined model and spatial uncertainty of the grid cell outcome. The distribution of the NxM values then reflects the grid cell outcome. If other input parameters than plot level data are used (e.g. a forest map), these can be drawn in a similar way for each of the M grid cell outcomes for each of the N plot level runs.

To use the uncertainty runs to identify gaps and prioritize between different sources of uncertainty, the same set of runs can be performed keeping one or a combination of model and/or input parameters constant. When all model and input parameters (i.e. also map information) is kept at its nominal value, the variance of the outcome reflects the spatial uncertainty.

This concept was applied in The Netherlands, in Lithuania (only the uncertainty calculations) and in Umbria. Design based methods were used in The Netherland and Umbria, where sampling density was high. Kriging was applied in Lithuania, where only few plots were available for these calculations. At grid cell scale, most uncertainty originated from spatial heterogeneity and –to a lesser extent- uncertainty in the forest cover, rather than from model parameters. No attempt was made to include pools other than carbon stock changes due to changes in biomass from growth. This could however easily be done using the same way, if input data, equations and input parameters are available. If these are completely lacking, a probable distribution can be created by experts. During the MC analysis, values can be drawn from this distribution and added to the total grid cell carbon source/sink. The effect of the missing pool on the total grid cell uncertainty can thus be estimated.

9.11. *References*

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Annex A: Propagation of measurement errors

Absolute error (AE) = largest possible error between actual and measured value (= unit of measurement)

Relative error (RE) = Absolute error / measured value

Calculation rules for propagation of measurement errors with M1 and M2 both measurements and C an exact value:

AE(C x M1) = C x AE(M1)

AE(M1 + M2) = AE(M1) + AE(M2)

AE(M1 - M2) = AE(M1) + AE(M2)

RE(M1 x M2) = RE(M1) x RE(M2)

RE(M1 / M2) = RE(M1) x RE(M2)

RE($M1^C$) = C x RE(M1)

Annex B: Equations & calculations for carbon emissions of Forests remaining forests

Following the IPCC report on Good Practice Guidance for LULUCF (IPCC 2003; further denoted as GPG-LULUCF) the total annual carbon source/sink functioning is approached as a change in carbon stocks over time. The total annual carbon stock change is expressed as a sum of three components:

$$\Delta C = \Delta C_{LB} + \Delta C_{DOM} + \Delta C_{Soil}$$

ΔC = annual change in carbon stock

ΔC_{LB} = annual change in carbon stock in living biomass

ΔC_{DOM} = annual change in carbon stock in dead organic matter

ΔC_{Soil} = annual change in carbon stock in forest soil

Change in carbon stocks in living biomass

The GPG-LULUCF default method to calculate change in carbon stocks in living biomass is subtracting biomass decrease due to losses from increase due to growth.

$$\Delta C_{LB} = \Delta C_G + \Delta C_L$$

ΔC_{LB} = annual change in carbon stock in living biomass

ΔC_G = annual increase in carbon stock in living biomass due to growth

ΔC_L = annual decrease in carbon stock in living biomass due to losses

An alternative method calculates change in carbon stock directly by taking the difference between carbon stocks on the same units at two points in time.

$$\Delta C_{LB} = \frac{C_{t_2} - C_{t_1}}{t_2 - t_1}$$

$$C = (V \cdot D \cdot BEF_2) \cdot (1 + R) \cdot CF$$

ΔC_{LB} = annual change in carbon stock in living biomass

C_{t_x} = carbon stock in living biomass at time x

CF = carbon fraction of dry matter

V = standing volume at time x

R = root-to-shoot ratio of dry matter increment

D = basic wood density

BEF_1 = biomass expansion factor for conversion of volume increment to above-ground dry matter increment

Carbon stock increase due to growth

The increase in carbon stock due to growth in the GPG-LULUCF default method is calculated from volume increment data converted to whole stand carbon stock changes using a set of conversion factors:

$$\Delta C_G = G_{TOTAL} \cdot CF$$

$$G_{TOTAL} = G_{AB}(1 + R)$$

$$G_{AB} = I_v \cdot D \cdot BEF_1$$

ΔC_G = annual increase in carbon stock in living biomass due to growth

G_{TOTAL} = annual dry matter increment in living biomass

CF = carbon fraction of dry matter

G_{AB} = annual dry matter increment in above-ground living biomass

R = root-to-shoot ratio of dry matter increment

D = basic wood density

BEF_1 = biomass expansion factor for conversion of volume increment to above-ground dry matter increment

Carbon stock decrease due to losses

The decrease in carbon stock due to losses in the GPG-LULUCF default method is calculated from volume changes due to harvest and disturbance data and converted to whole stand carbon stock changes using a set of conversion factors:

$$\Delta C_L = L_{Fellings} + L_{Fuelwood} + L_{OtherLosses}$$

$$L_{Fellings} = V_{Fellings} \cdot D \cdot BEF_2 \cdot (1 - f_{BL}) \cdot CF$$

$$L_{Fuelwood} = V_{Fuelwood} \cdot D \cdot BEF_2 \cdot CF$$

$$L_{OtherLosses} = A_{Disturbance} \cdot B_W \cdot (1 - f_{BL}) \cdot CF$$

ΔC_L = annual decrease in carbon stock in living biomass due to losses

$L_{Fellings}$ = annual decrease in carbon stock in living biomass due to fellings

$L_{Fuelwood}$ = annual decrease in carbon stock in living biomass due to fuelwood gathering

$L_{OtherLosses}$ = annual decrease in carbon stock in living biomass due to disturbances

$V_{Fellings}$ = annual volume harvested due to fellings

$V_{Fuelwood}$ = annual volume harvested due to fuelwood gathering

D = basic wood density

CF = carbon fraction of dry matter

BEF_1 = biomass expansion factor for conversion of standing volume to aboveground dry matter

f_{BL} = fraction of biomass left to decay in the forest

$A_{Disturbance}$ = area of forest affected by disturbances in one year

B_W = average standing biomass in the forest

Change in carbon stocks in dead organic matter

The change in carbon stock in dead organic matter in the GPG-LULUCF default method is the sum of the change in dead wood and the change in litter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

ΔC_{DOM} = annual change in carbon stock in dead organic matter

ΔC_{DW} = annual change in carbon stock in dead wood

ΔC_{LT} = annual change in carbon stock in litter

Carbon stock change in dead wood

The change in carbon stock in dead wood in the GPG-LULUCF default method is the difference between loss of dead wood due to decomposition and increase in dead wood due to mortality or management practices:

$$\Delta C_{DW} = A \cdot (B_{IN} - B_{OUT}) \cdot CF$$

ΔC_{DW} = annual change in carbon stock in dead wood

A = area of managed forest

B_{IN} = annual transfer of living to dead wood

B_{OUT} = annual transfer out of dead wood

CF = carbon fraction of dry matter

Carbon stock change in litter

The change in carbon stock in litter after a change in forest type in the GPG-LULUCF default method is calculated as a difference in reference or stable carbon stock in litter between forest types divided by the transition period (default 20 years):

$$\Delta C_{LT} = \frac{\sum_{i,j} \left[\left(C_j - C_i \right) \cdot A \right]}{T_{ij}}$$

ΔC_{LT} = annual change in carbon stock in litter

A = area of managed forest

C_i = stable litter carbon stock under previous state i

C_i = stable litter carbon stock under current state j

T_{ij} = time period of transition from state i to state j

Change in carbon stocks in forest soils

The change in carbon stock in soil after a change in forest type in the GPG-LULUCF default method is calculated as a difference in reference or stable soil carbon stock between forest types divided by the transition period (default 20 years):

$$\Delta C_{LT} = \frac{\sum_{i,j} \left[\left(SOC_j - SOC_i \right) \cdot A \right]}{T_{ij}}$$

ΔC_{LT} = annual change in carbon stock in litter

A = area of managed forest

SOC_i = stable soil organic carbon stock under previous state i

SOC_i = stable soil organic carbon stock under current state j

T_{ij} = time period of transition from state i to state j

Annex C: Input values for uncertainty calculation of carbon emissions of Forests remaining forests in Umbria

Table C-1: Calculated BEF1 values for Umbria used as input for uncertainty calculations

	Mean	*St. dev*	*Min*	*Max*
Coppice				
Carpinus betulus	1.10	0.07	1.00	1.30
Castanea sativa	1.14	0.07	1.00	1.30
Fagus sylvatica	1.17	0.08	1.00	1.30
Quercus cerris	1.06	0.07	1.00	1.30
Quercus sp. (deciduous)	1.20	0.08	1.00	1.30
Quercus sp. (evergreen)	1.28	0.08	1.00	1.30
Broadleaf	1.32	0.09	1.10	1.40
Needleleaf	1.21	0.08	1.00	1.30
High Stands				
Abies alba	1.18	0.08	1.00	1.30
Fagus sylvatica	1.17	0.08	1.00	1.30
Larix sp.	1.05	0.07	1.00	1.30
Picea abies	1.14	0.07	1.00	1.30
Pinus sp. (mountain pines)	1.17	0.08	1.00	1.30
Pinus sp. (mediterranean pines)	1.35	0.09	1.10	1.40
Quercus cerris	1.25	0.08	1.00	1.30
Quercus sp.	1.22	0.08	1.00	1.30
Broadleaf	1.26	0.08	1.10	1.40
Needleleaf	1.21	0.08	1.00	1.30
Eucalyptus globulus	1.17	0.08	1.00	1.30

Table C-2: Wood density values for Umbria used as input for uncertainty calculations

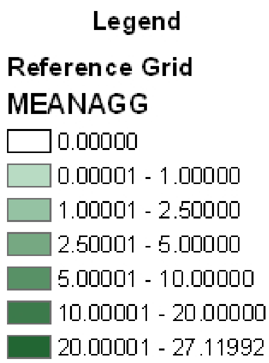
	Mean	*St. dev*	*Min*	*Max*
Coppice				
Carpinus betulus	0.66	0.10	0.55	0.83
Castanea sativa	0.49	0.07	0.38	0.66
Fagus sylvatica	0.61	0.09	0.50	0.78
Quercus cerris	0.69	0.10	0.58	0.86
Quercus sp. (deciduous)	0.65	0.10	0.54	0.82
Quercus sp. (evergreen)	0.72	0.11	0.61	0.89
Broadleaf	0.53	0.08	0.42	0.70
Needleleaf	0.43	0.06	0.32	0.60
High stands				
Abies alba	0.38	0.06	0.27	0.55
Broadleaf	0.53	0.08	0.42	0.70
Fagus sylvatica	0.61	0.09	0.50	0.78
Larix sp.	0.56	0.08	0.45	0.73

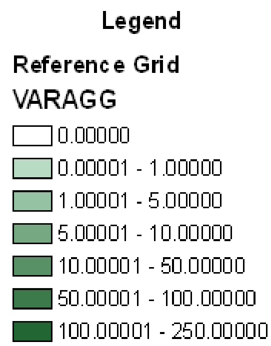
Needleleaf	0.43	0.06	0.32	0.60
Picea abies	0.38	0.06	0.27	0.55
Pinus sp. (mountain pines)	0.47	0.07	0.36	0.64
Pinus sp. (Mediterranean pines)	0.53	0.08	0.42	0.70
Quercus cerris	0.69	0.10	0.58	0.86
Quercus sp.	0.67	0.10	0.56	0.84
Eucalyptus globulus	0.54	0.08	0.43	0.71

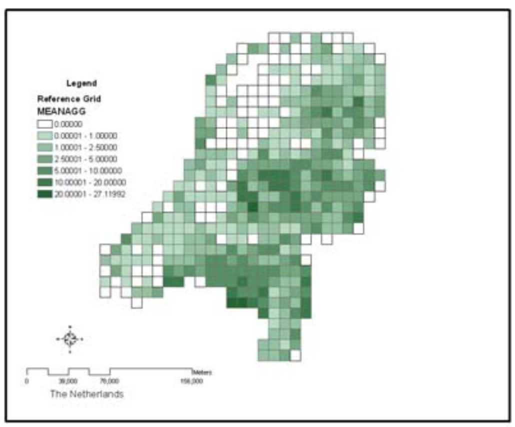
Table C-3: Root-to-shoot values for Umbria used as input for uncertainty calculations

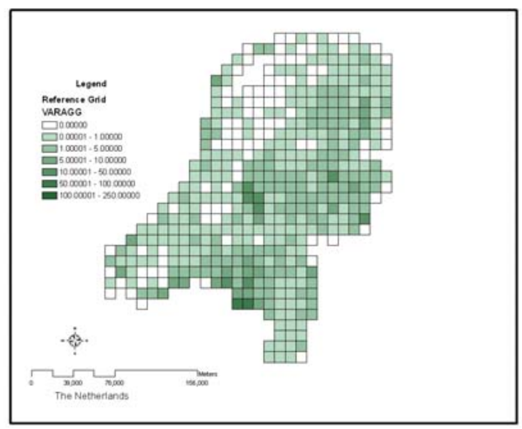
	Mean	*St. dev*	*Min*	*Max*
Coppice				
Carpinus betulus	0.26	0.10	0.13	0.52
Castanea sativa	0.28	0.10	0.14	0.56
Fagus sylvatica	0.20	0.07	0.10	0.40
Quercus cerris	0.24	0.09	0.12	0.48
Quercus sp.(evergreen)	1.00	0.37	0.50	2.00
Quercus sp.(deciduous)	0.20	0.07	0.10	0.40
Broadleaf	0.24	0.09	0.12	0.48
Needleleaf	0.29	0.11	0.15	0.58
High Stands				
Abies alba	0.28	0.10	0.14	0.56
Fagus sylvatica	0.20	0.07	0.10	0.40
Larix sp.	0.29	0.11	0.15	0.58
Picea abies	0.29	0.11	0.15	0.58
Pinus sp. (mountain pines)	0.36	0.13	0.18	0.72
Pinus sp. (Mediterranean pines)	0.33	0.12	0.17	0.66
Quercus cerris	0.24	0.09	0.12	0.48
Quercus sp.	0.20	0.07	0.10	0.40
Broadleaf	0.24	0.09	0.12	0.48
Needleleaf	0.29	0.11	0.15	0.58
Eucalyptus globulus	0.43	0.16	0.22	0.86

Annex D: Maps with grid cell total carbon sinks and carbon sink variance for The Netherlands

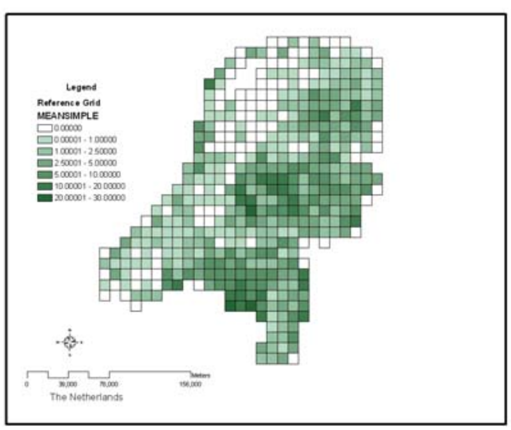


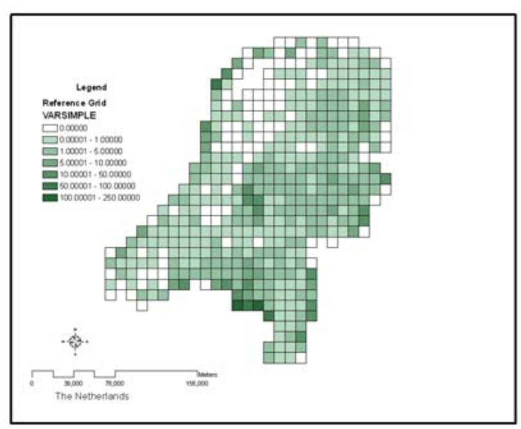




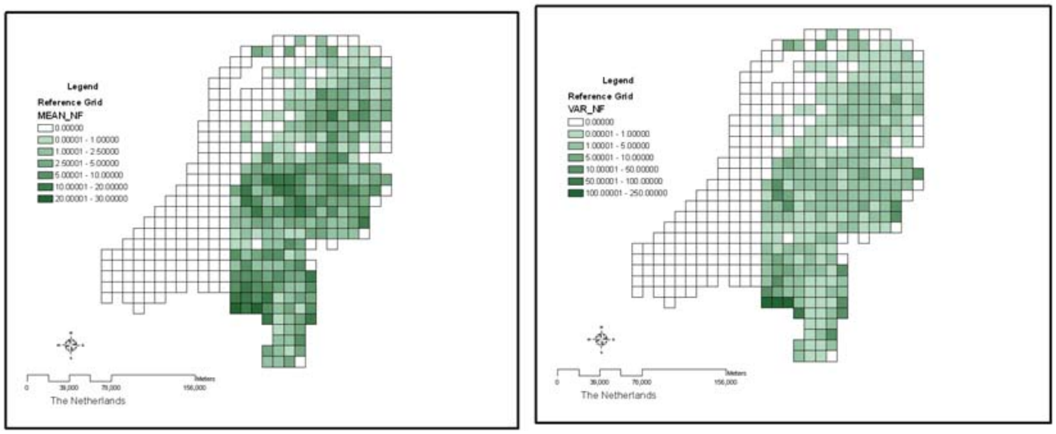


Aggregation according to stratified random.

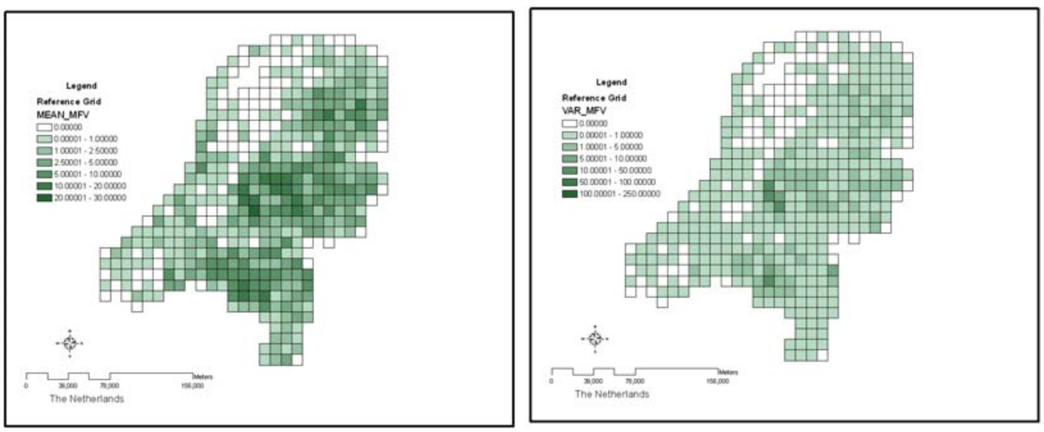




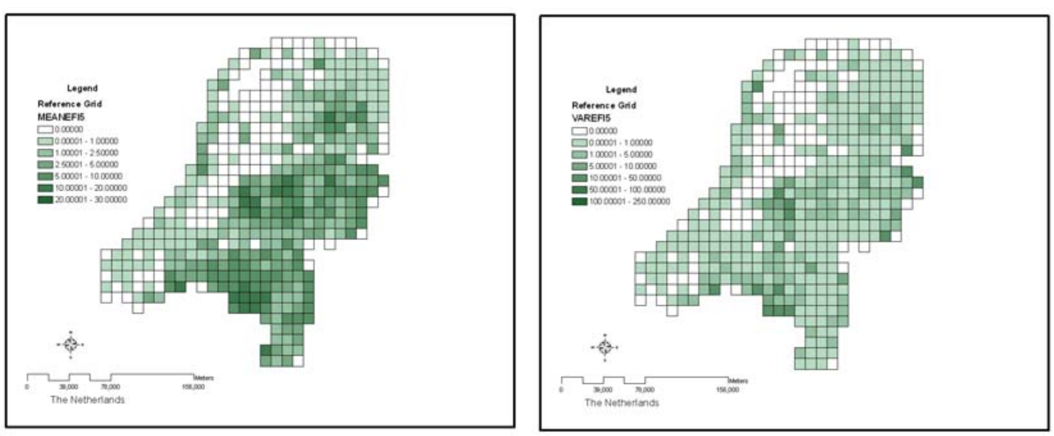
Aggregation according to simple random.



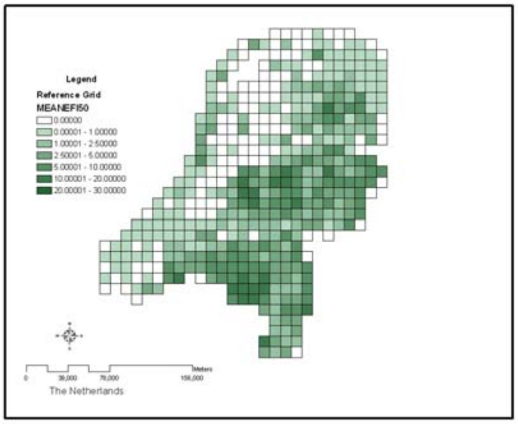
Aggregation according to simple random, plots with missing values excluded

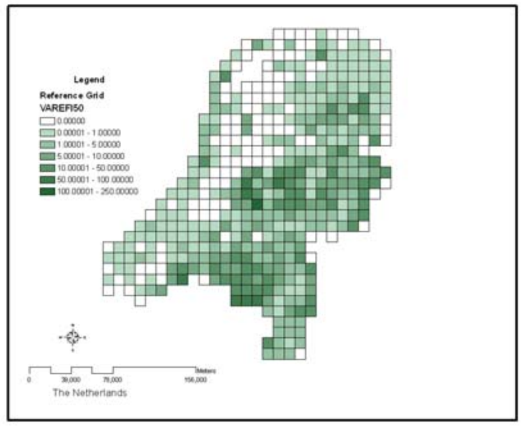


Aggregation of forested plots and forest cover derived from nr of plots



Aggregation of forested plots and forest cover derived from forest map (assuming 5% uncertainty)

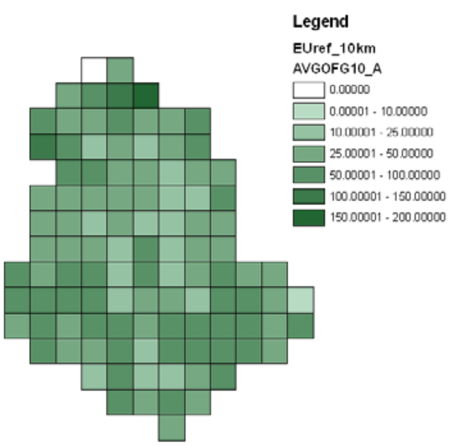




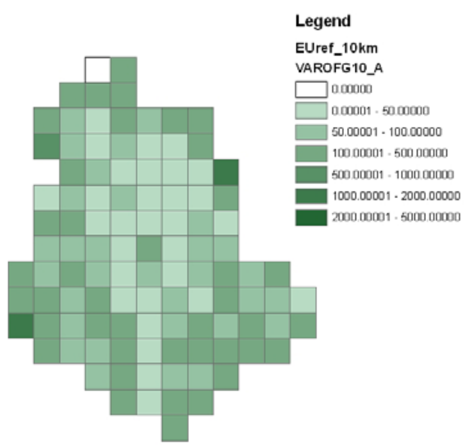
Aggregation of forested plots and forest cover derived from forest map (assuming 50% uncertainty)

Annex E: Maps with grid cell total carbon sinks and carbon sink variance for Umbria (Italy)

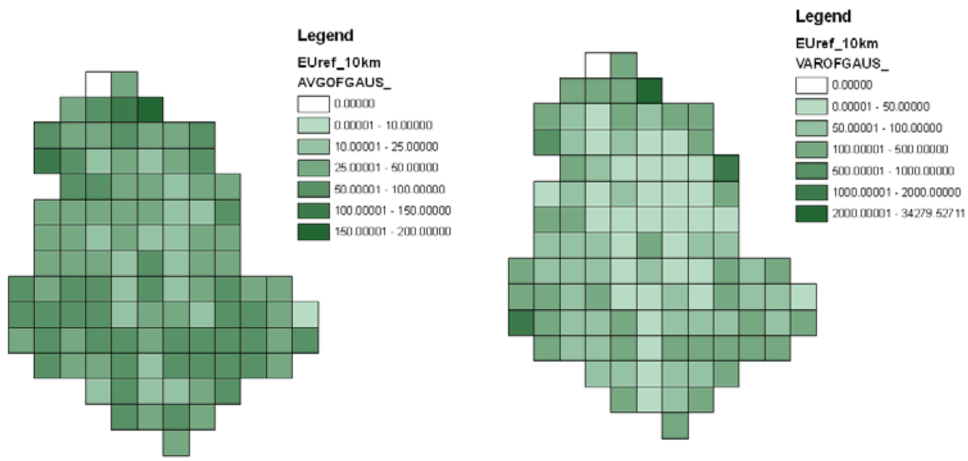
Total carbon sink
(=average over MC runs)



Total grid cell uncertainty
(=variance over MC runs)



Uncertainty of input parameters were assumed to be normally distributed and standard deviations were set at 10% of the mean values.



Uncertainty of input parameters were assumed to be normally distributed and standard deviations were based on the errors and intervals given in the GPG-LULUCF.

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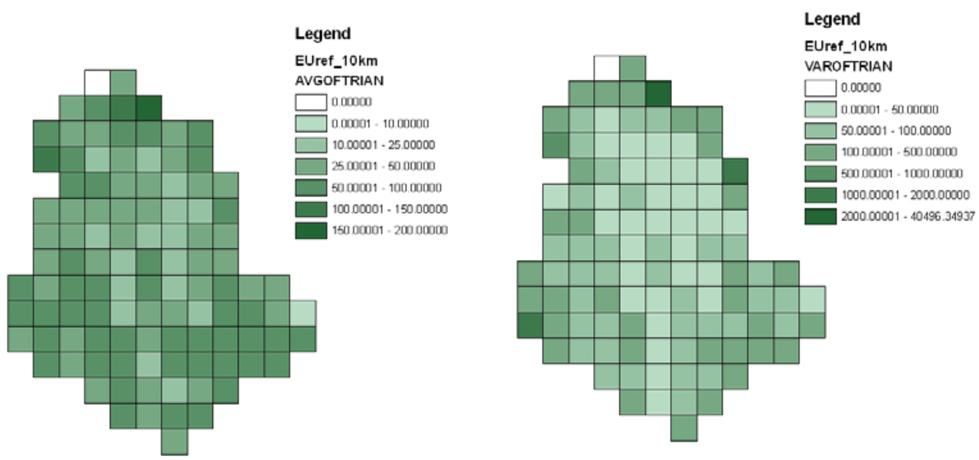

For uncertainty of input parameters no assumption of normality was made as some intervals showed clear asymmetry around the mean, and a triangular distribution defined by a minimum, a mean and a maximum was used

Annex F: Total C sinks in forest per province (NUTS1) in The Netherlands

	Stratified	*Simple*	*Forest * nr*	*Forest **	*Forest **
Total over province (mean value over runs in Gg C)					
Drenthe	104	103	102	89	94
Flevoland	41	41	41	13	14
Friesland	31	31	31	23	24
Gelderland	238	239	235	231	237
Groningen	29	29	27	11	11
Limburg	86	85	73	84	86
Noord-Brabant	223	221	215	221	229
Noord-Holland	27	27	26	33	34
Overijssel	121	122	119	130	131
Utrecht	77	78	78	79	80
Zeeland	9	9	8	9	9
Zuid-Holland	34	34	32	19	19
Variance of total over province (in (Gg C)^2)					
Drenthe	924	991	356	278	390
Flevoland	144	187	56	25	38
Friesland	180	187	61	71	85
Gelderland	2596	3145	945	1129	1494
Groningen	259	300	90	24	23
Limburg	436	609	127	189	247
Noord-Brabant	3564	3803	1166	1405	1813
Noord-Holland	147	163	45	139	179
Overijssel	1430	1577	448	554	686
Utrecht	400	460	281	341	576
Zeeland	43	46	19	25	30
Zuid-Holland	303	324	101	90	101
Coefficient of variation					
Drenthe	0,29	0,31	0,18	0,19	0,21
Flevoland	0,29	0,33	0,18	0,38	0,46
Friesland	0,44	0,44	0,25	0,37	0,39
Gelderland	0,21	0,24	0,13	0,15	0,16
Groningen	0,56	0,59	0,34	0,45	0,44
Limburg	0,24	0,29	0,15	0,16	0,18
Noord-Brabant	0,27	0,28	0,16	0,17	0,19
Noord-Holland	0,45	0,47	0,25	0,36	0,40
Overijssel	0,31	0,33	0,18	0,18	0,20
Utrecht	0,26	0,28	0,22	0,23	0,30
Zeeland	0,70	0,77	0,58	0,57	0,60
Zuid-Holland	0,51	0,53	0,31	0,50	0,52

Annex G: Decision trees for aggregation methods

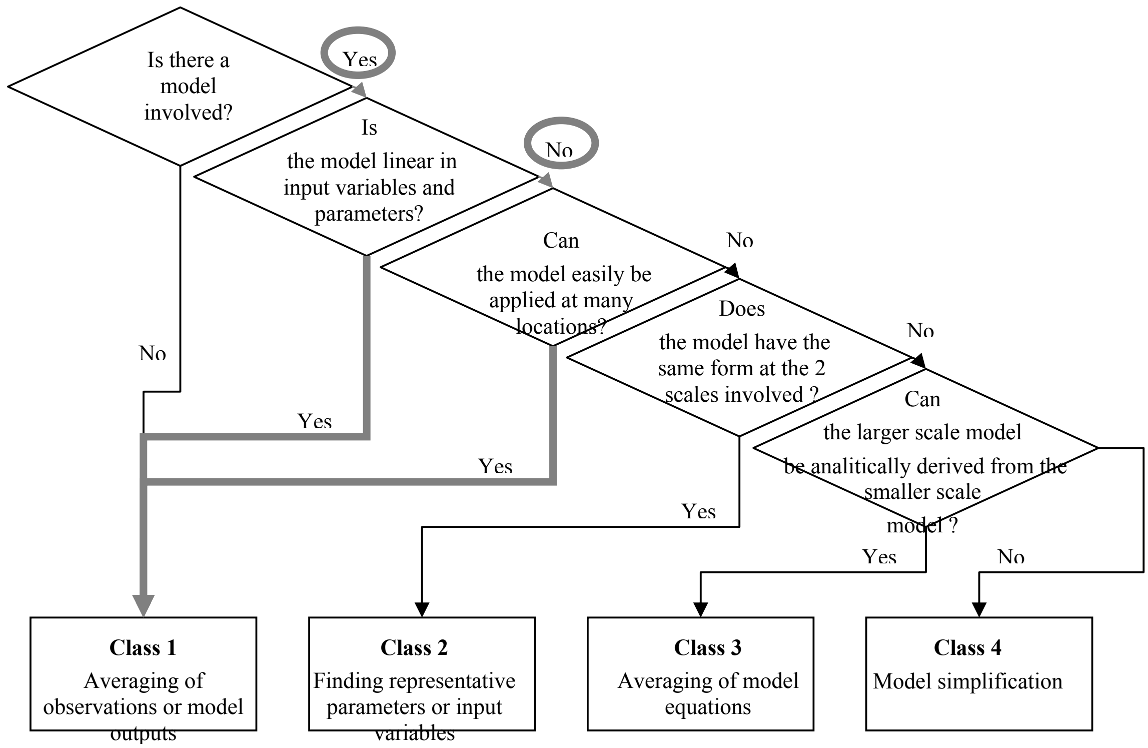

Figure G-1: Decision tree to four major classes of upscaling methods (Bierkens, 2000)

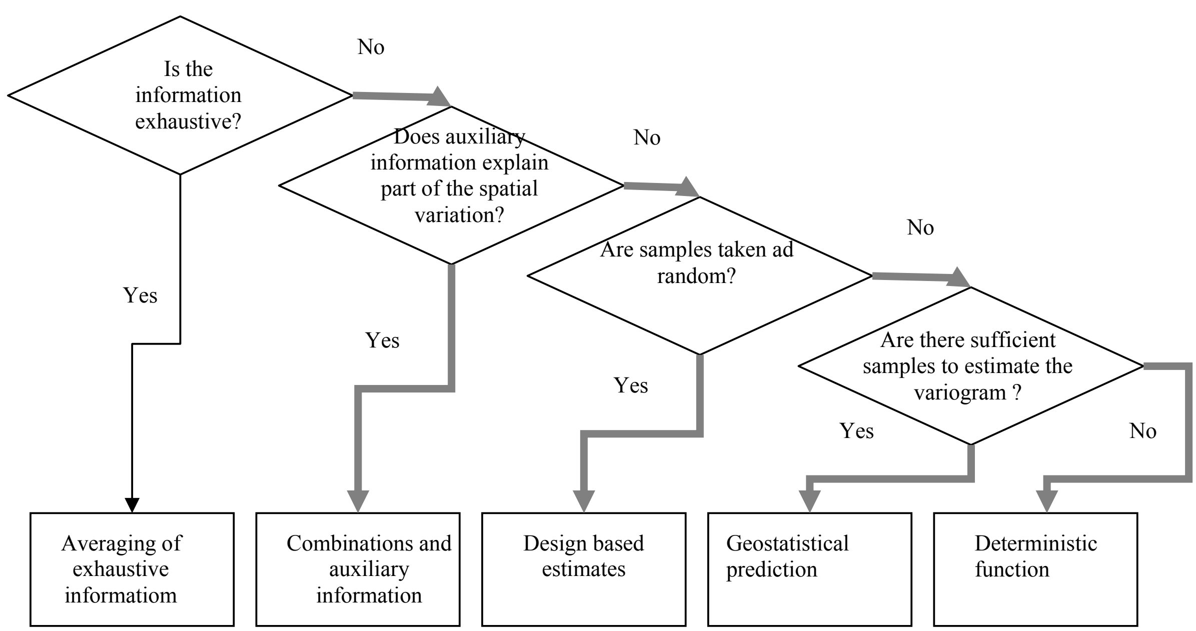

Figure G-2: Decision tree to five subclasses of Class I upscaling methods (Bierkens, 2000)

10. Assessment of Data Availability for LULUCF - sector Reporting in MASCAREF Test Countries

Emil Cienciala and **Zuzana Exnerova**
IFER - Institute of Forest Ecosystem Research, Ltd., Czech Republic
Email: emil.cienciala@ifer.cz and zuzana.exnerova@ifer.cz

Kestutis Armolaitis
Lithuanian Forest Research Institute, Lithuania
Email: k.armolaitis@mi.lt

Olivier Bouriaud
Forest Research and Management Institute, Romania
Email: obouriaud@gmail.com

Giorgio Matteucci
National Research Council, Institute of Agro-Environmental and Forest Biology, Italy
Email: giorgio.matteucci@isafom.cs.cnr.it

Kalliopi Radoglou
Forest Research Institute, National Agricultural Research Foundation, Greece
Email: radoglou@fri.gr

Tibor Priwitzer
National Forest Centre, Slovakia
Email: priwitzer@nlcsk.org

Rainer Baritz
Federal Institute for Geosciences and Natural Resources (BGR), Germany
Email: Rbaritz@pop3.bgr.de

Göran Ståhl
Swedish University of Agricultural Sciences, Sweden
E-mail: Goran.Stahl@srh.slu.se

Abstract

Reflecting the heterogeneity in land use, natural conditions and monitoring data availability, there is a wide variety in greenhouse gas reporting practices within the European Community. The MASCAREF project aims to contribute to a further harmonization and strengthening of the existing national systems to better meet international reporting requirements for LULUCF, as well as improve comparability, transparency and accuracy of the national inventory reports for LULUCF of EU Member States. It will do this based on available data from regional, national and EU-wide projects and activities that took place over the last decade, data from which are often currently not readily available for reporting improvements on national scale. The integrative work in MASCAREF is focused on five selected test areas, for each of which one specific thematic pilot study will be conducted. Four countries (Greece, Lithuania, Romania, Slovakia) and one region within a country (Umbria in Italy) were selected for this work. This report introduces the forestry sector in the test areas and summarizes the main issues related to current LULUCF reporting practice. The current National Forest Inventories in place are described, as well as the availability of data from other (European) projects. The report concludes with a description of the main focus for the respective pilot studies in MASCAREF.

10.1. *Introduction*

The European Community represents a widely heterogeneous mosaic of countries with different natural conditions and different land use. The emission inventory of the Land Use, Land-Use Change and Forestry (LULUCF) sector under the United Nations' Framework Convention on Climate Change (UNFCCC) must consider many different definitions, factors, sampling strategies and methodological approaches. The selection of suitable methods is naturally also affected by availability of suitable source data. These issues make the effort of compiling harmonized and comparable estimates from different countries extremely challenging. In this respect, tremendous credit must be given to IPCC for producing the Good Practice Guidance for LULUCF (IPCC 2003; further denoted as GPG-LULUCF. GPG-LULUCF reflects the wide heterogeneity and conditions of different countries offering a Tier-structured approaches and detailed methodological guidance to emission inventory of the LULUCF sector. The effect of GPG-LULUCF implementation is a progressing consolidation of LULUCF inventories of Annex I countries. On the other hand, many methodological issues of LULUCF inventories remain problematic and should be further developed. The MASCAREF project contributes to this effort. Using five European regions as test cases, it addresses methodological issues that may aid and improve the local LULUCF emission estimates.

The aim of this report is to introduce the selected test areas, data availability in those areas and specification of the thematic focus for each case, i.e., region or country study (described below). It will serve as an introductory text to the specific thematic studies performed in the selected regions, which is the main aim of the MASCAREF project (i.e. Task 6 on case studies is intended to build on the results from Tasks 1 to 5). Due to the limited resources available, for each of the individual test areas characterized by different conditions regarding bioclimatic conditions, forest types, species composition, history and presence/absence of NFI programs and other monitoring networks, one specific pilot study will be conducted exemplifying approaches of aiding and/or improving the LULUCF emission estimates.

10.2. *Forests, Forestry and Geographical Information*

10.2.1. Romania

Romania's continental and rather dry climate of the plains is interrupted by moist temperate and alpine conditions in the Carpathian Mountains. Of the 6.4 million ha of forest (mostly in the mountains), less than half is managed as Group II forests – 'forests with productive and protective functions' (Milescu 1999). The rest has mainly protective functions. Still, UN-ECE/FAO (2000) reports 5.6 million ha as 'available for wood supply. Beech and Norway spruce are the main tree species. About 39% of the forest is in private or local public ownership. The remaining 61% are state forests and are administrated by the National Forest Administration-Romsilva, which is the main timber provider for the market. Problems facing the forestry sector include: a very low accessibility of forest, a low investment level and endemic illegal logging. Table 10-1 summarizes some of the main forestry statistics of Romania (www.fao.org/forestry).

Table 10-1 Forest area and growing stock statistics for Romania (www.fao.org/forestry)

	Forest		*OWL*	
	1990	***2005***	***1990***	***2005***
Total Area (x 1000 ha)	6371	6370	314	258
Primary	*233*	*233*	-	-
Modified natural	*651*	*651*	-	-
Semi-natural	*5339*	*5339*	-	-
Productive plantation	*92*	*92*	-	-
Protective plantation	*57*	*57*	-	-
Total Area (% of land area)	27.8	27.7	1.4	1.1
Volume Growing Stock (million m^3 over bark)	1348	1347	-	-
Removals (x1000 m^3 over bark)	17218	17300	-	-
Industrial	*11364*	*11418*	-	-
Woodfuel	*5854*	*5882*	-	-
Biomass (million tonnes DM)	1313	1314	-	-
Living	*1133*	*1133*	-	-
Dead	*180*	*181*	-	-
Carbon (million tonnes C)	1438	1439	-	-
Living	*567*	*567*	-	-
Dead + litter	*149*	*150*	-	-
Soil	*723*	*723*	-	-

10.2.2. Slovakia

Much of the Slovakian forests are situated in the western part of the Carpathians. In total forests cover 41% of the land area of Slovakia. Of the 2 million ha, 43% is state owned, and 21% community owned, most of the remainder is privately owned (UN-ECE/FAO 2000). Coniferous, broadleaved and mixed forests each comprise about one-third of the total forest area (Scheer and Longauer 1999). Forest health remains a concern in Slovakian forestry. About half of the total fellings in Slovakia (7.4 million m^3/yr) still consists of salvaged wood. Much of the harvesting is carried out in a small-scale shelterwood system. This will probably increase under the envisaged increase in nature-oriented forest management. The forest sector is important to the Slovakian economy with a contribution of 7.4% to the GDP. Table 10-2 summarizes some of the main forestry statistics of Slovakia (www.fao.org/forestry).

Table 10-2 Forest area and growing stock statistics for Slovakia (www.fao.org/forestry)

	Forest		***OWL***	
	1990	***2005***	***1990***	***2005***
Total Area (x 1000 ha)	1922	1929	-	-
Primary	*24*	*24*	-	-
Modified natural	*938*	*946*	-	-
Semi-natural	*937*	*940*	-	-
Productive plantation	*21*	*17*	-	-
Protective plantation	*2*	*2*	-	-
Total Area (% of land area)	40.0	40.1	-	-
Volume Growing Stock (million m^3 over bark)	402	494	-	-
Removals (x1000 m^3 over bark)	5545	6732	-	-
Industrial	*5073*	*6372*	-	-
Woodfuel	*472*	*360*	-	-
Biomass (million tonnes DM)	354	438	-	-
Living	*328*	*407*	-	-
Dead	*25*	*32*	-	-
Carbon (million tonnes C)	462	510	-	-
Living	*163*	*203*	-	-
Dead + litter	*29*	*36*	-	-
Soil	*270*	*270*	-	-

10.2.3. Greece

The undulating landscape of Greece in combination with the Mediterranean climate and considerable rainfall provide very favourable conditions for forest growth but is many cases the soil dept limit this potential due to previous erosion phenomena. Only the summer drought limits the forest development and makes it susceptible to fires. About half of the country's total area is covered by forest and other wooded land. Much of the forest and other wooded land (6.6 million ha in total) consists of a shrub-like, grazed vegetation (UN-ECE/FAO 2000). The species richness is very high in Greek forests and other wooded land (OWL). Some 3 million ha are seen as forest available for wood supply, and of that almost half is managed as coppice (Smiris 1999). Some 49 000 ha of forest and other wooded land burned annually between 1989 and 1998, mainly due to human causes. The annual fellings are low, and mainly consist of fuelwood. The forestry sector contributes only 0.17% to the GDP. However, the externalities from tourism (partly for forests and landscape) contribute much more. Table 10-3 summarizes some of the main forestry statistics for Greece (www.fao.org/forestry).

Table 10-3 Forest area and growing stock statistics for Greece (www.fao.org/forestry)

	Forest		***OWL***	
	1990	***2005***	***1990***	***2005***
Total Area (x 1000 ha)	3299	3752	3212	2780
Primary	*0*	*0*	*0*	*0*
Modified natural	*3181*	*3618*	*3212*	*2780*
Semi-natural	*0*	*0*	*0*	*0*
Productive plantation	*0*	*0*	*0*	*0*
Protective plantation	*118*	*134*	*0*	*0*
Total Area (% of land area)	25.6	29.1	24.9	21.6
Volume Growing Stock (million m^3 over bark)	156	177	0	0
Removals (x1000 m^3 over bark)	2979	1842	-	-
Industrial	*1168*	*438*	-	-
Woodfuel	*1811*	*1404*	-	
Biomass (million tonnes DM)			-	
Living	*103*	*117*	-	-
Dead	-	-	-	-
Carbon (million tonnes C)			-	-
Living	*52*	*59*	-	-
Dead + litter	-	-	-	-
Soil	-	-	-	-

10.2.4. Italy

For its geographical position and shape, Italy is characterised by a large variation of environmental conditions, ranging from Alpine to temperate to typical Mediterranean climatic types. Two mountain ranges shape the Italian territory: the Alps surround the country in the north with in east-to-west arc and the Apennines that stretch the peninsula from north to south. Forests are mostly concentrated in these mountain ranges and in their proximity. Growth conditions for forests can span from good/mesic to dry/xeric in some areas. The rich biological diversity, the attractiveness of the environment and the production potential in some environmental conditions, are strengths of Italian forestry. Stand conditions can span from stable, biodiverse mixed forests to stands with reduced biodiversity. Forest structures vary from high stands to coppice stands. The most recent Global Forest Resource Assessment (FAO, 2005) reports 9.98 milllion ha of forests (34% of total land area) and 1.05 Mha of other woodlands (3.6% of land area). Two-thirds of forest area is privately owned. At national level, coppice and high stands management systems are equally distributed, with the former system preferred among the private owners (Colpi et al. 1999). However, the conversion from coppice to high forest is more and more applied, either intentionally or by natural ageing. The forest available for wood supply is 6 million ha. Most of the high stands are managed by shelterwood or selective management systems, the latter most common in the Alps.

Table 10-4 Forest area and growing stock statistics for Italy (www.fao.org/forestry)

	Forest		***OWL***	
	1990	***2005***	***1990***	***2005***
Total Area (x 1000 ha)	8383	9979	880	1047
Primary	-	-	-	-
Modified natural	-	-	-	-
Semi-natural	-	-	-	-
Productive plantation	-	-	-	-
Protective plantation	-	-	-	-
Total Area (% of land area)	28.5	33.9	3.0	3.6
Volume Growing Stock (million m^3 over bark)	1051	1447	57	97
Removals (x1000 m^3 over bark)	9877	9600	-	-
Industrial	*4982*	*3800*	-	-
Woodfuel	*4895*	*5800*	-	-
Biomass (million tonnes DM)	959	1431	81	137
Living	*853*	*1272*	*74*	*125*
Dead	*106*	*159*	*7*	*12*
Carbon (million tonnes C)	1179	1608	148	204
Living	*423*	*636*	*37*	*62*
Dead + litter	*105*	*147*	*9*	*14*
Soil	*650*	*825*	*102*	*128*

Italian forests are amongst the most diversified and richest semi-natural forests in Europe. However, the interests of forest owners are also extremely diverse, and this has led to a situation where Italy has both a large and rapidly increasing growing stock, but where it is also one of the larger net importers of wood products in Europe. Table 10-4 summarizes some of the main forestry statistics for Italy (www.fao.org/forestry).

10.2.5. Lithuania

Lithuania is a low lying country with most of the country below 200 m in elevation. The central lowlands rise slightly to a hilly region in the west, where the climate is moderated by maritime influences. With roughly 2 million ha of forests, they cover about one third of the country. Most of these forests are concentrated in the highlands in the east and south-east with a more continental climate. Main tree species are *Pinus sylvestris* (35 – 36%, according to the Lithuanian Statistical Yearbook of Forestry, 2006 and 2007), *Picea abies* (20 – 21%)or *Betula sp*. (*B. pendula* and *B. pubescens*) (21 – 22%).

Table 10-5 Forest area and growing stock statistics for Lithuania (www.fao.org/forestry)

	Forest		***OWL***	
	1990	***2005***	***1990***	***2005***
Total Area (x 1000 ha)	1945	2099	80	77
Primary	*20*	*26*	-	-
Modified natural	*1493*	*1548*	*80*	*77*
Semi-natural	*308*	*384*	-	-
Productive plantation	*84*	*100*	-	-
Protective plantation	*40*	*41*	-	-
Total Area (% of land area)	31.0	33.5	1.3	1.2
Volume Growing Stock (million m^3 over bark)	320	400	2	2
Removals (x1000 m^3 over bark)	3651	7727	-	-
Industrial	*2779*	*5881*	-	-
Woodfuel	*872*	*1846*	-	-
Biomass (million tonnes DM)	226	279	2	2
Living	*206*	*258*	*2*	*2*
Dead	*20*	*21*	-	-
Carbon (million tonnes C)	299	341	9	9
Living	*103*	*129*	*1*	*1*
Dead + litter	*56*	*61*	*2*	*2*
Soil	*140*	*151*	*6*	*6*

About 70% of all forests have as main function wood production, and in 2005 almost 8 million m^3 of wood were harvested (www.fao.org). Wood products and paper are among Lithuania's oldest industries, while current main activities of the forestry sector include chemical timber processing, and the production of furniture, pulp, paper, wood fiber, wood chips, joinery articles, and cardboard. Exports of forest products amounted to $200.9 million in 2000. (http://www.nationsencyclopedia.com/Europe/Lithuania-FORESTRY.html). Table 10-5 summarizes some forestry statistics of Lithuania (www.fao.org/forestry).

10.3. *State of Current Emission Reporting Practices*

There are a few important decisions that a Party must make for reporting the emissions and removals by land-use, land-use change and forestry (LULUCF) in the national inventory. These are:

1. What are the country's definition of land use;
2. Which forest carbon pools are included in the inventory;
3. What is the level of reporting (tier) for each pool within the inventory; and
4. What is the significance of each land use and land-use change category.

Of these, the middle two items determine the completeness and level of uncertainty in the inventory and it is considered good practice to adopt progressively more complete and higher levels of reporting with time for categories that are significant. In this section we will briefly describe the options and terminology for each of these four items.

10.3.1. Land Use Definitions

Countries may use their own definitions of these categories. These should refer to internationally accepted definitions, such as those by FAO, Ramsar, etc.

- **a) Forest land**: includes all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, sub-divided into managed and unmanaged. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category. Countries must also specify a forest definition under the Kyoto Protocol. This definition is based on area (0.05 – 1.0 ha); canopy closure (10% - 30%) and tree height (2 – 5 m).
- **b) Cropland:** includes arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category.
- **c) Grassland:** includes rangelands and pasture land that are not considered as cropland and where the vegetation that fall below the threshold used in the forest land category.
- **d) Wetlands** include land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, grassland or settlements categories.
- **e) Settlements:** includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories.
- **f) Other land**: includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories.

10.3.2. Forest Carbon Pools

There are five pools considered in the national inventory:

- **a) Aboveground biomass:** All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage.
- **b) Belowground biomass:** All living biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.
- **c) Dead wood:** Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.
- **d) Litter:** Includes all non-living biomass with a diameter less than a minimum diameter chosen by the country (for example 10 cm), lying dead, in various states of decomposition above the mineral or organic soil. This includes the litter, fumic, and humic layers. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.
- **e) Soil organic matter** Includes organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included with soil organic matter where they cannot be distinguished from it empirically.

10.3.3. Reporting Tiers

Reporting tiers refer to the level of complexity for a methodology used to calculate the emissions and removals from a carbon pool in a given land use or land-use change category.

The **Tier 1** approach employs the basic method and default emission factors provided in the *GPG-LULUCF*. Tier 1 methodologies usually use activity data that are spatially coarse, such as nationally or globally available estimates of deforestation rates, agricultural production statistics, and global land cover maps.

Tier 2 can use the same methodological approach as Tier 1 but applies emission factors and activity data which are country specific for the most important land uses/activities. Tier 2 can also apply stock change methodologies based on country-specific data. Country-defined emission factors/activity data are more appropriate for the climatic regions and land use systems in that country. Higher resolution activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialised land-use categories.

At **Tier 3**, models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national to fine grid scales. Tier 3 provides estimates of greater certainty than Tier 1 or Tier 2. Tier 3 generally includes biomass and soil dynamics.

10.3.4. Key Categories

The concept of *key source categories* was introduced in the *GPG2000* and in the *GPG-LULUCF* is extended to include both sources and sinks. In the *GPG2000* a key category is defined as:

> *"one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both"*

For the LULUCF sector, a key category analysis is required to identify:

- which land-use and management activities are significant;
- which land-use or livestock (sub)category is significant;
- which CO_2 emissions or removals by sinks from various carbon pools are significant; and
- which non-CO_2 gases and from what categories are significant.

Key categories should progressively move to higher reporting Tiers with time.

10.4. *Greece*

10.4.1. Forest Definition

The definition of forest land used until today in the Inventory of GHG under the UNFCCC is the definition used in the 1st National Forest Inventory (GSFNE 1992):

Forest Land includes*: (a) areas larger than 0.5 ha or strips more than 30 m wide with tree crown cover (stand density) of more than 10% of the area, or areas with 250 trees of reproductive age per hectare, able to produce wood or other products or services and are not used for any other land-use (b) areas where trees are removed to below 10% of stand density and are not given for other land-use (c) reforested areas and (d) scrublands (areas covered by broadleaved evergreens).*

Forest Land is divided into Forests and Other Wooded Lands: Forests are characterised by forest trees (high and coppice forests) that produce or are able to produce at least 1 m^3 of commercial timber per hectare per year. Other Wooded Lands are characterised by branchy dwarf trees and scrubs (usually broadleaved evergreens), do not currently produce commercial timber and are valuable mainly for providing protection, forage and fuelwood.

Cropland includes *all annual and perennial crops as well as temporary fallow land.*

Grassland includes *rangeland and pasture with vegetation that falls below the threshold of forest definition and are not expected to exceed without human intervention. Pastures that have been fertilised or sown are considered as cropland.*

Wetlands include *land that is covered or saturated by water for all or the greatest part of the year (e.g. lakes, reservoirs, marshes), as well as river bed (including torrent beds) and that does not fall into the forest land, cropland, grassland or settlements categories.*

Settlements include *all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories.*

Other land includes *all land areas that do not fall into any of other land-use categories (e.g. rocky areas, bare soil, mine and quarry land).*

10.4.2. Pools and Tiers

A summary of the carbon pools and reporting tiers use by Greece is shown in Table 10-6. The country is using Tier 2 for some aspects of *Forest Land remaining forest land* and *Cropland remaining cropland*, but in the majority of cases, Tier 1 reporting is used.

Table 10-6 Greece – carbon pools and reporting tiers

	Carbon Pools				
	Aboveground Biomass	Belowground Biomass	Dead Wood	Litter	Soil Organic Matter
Forest land ⇨ Forest Land	T2, T3	T2	T1 (forests not affected by wildfires) T2 (forests affected by wildfires)	T1	T1
Non-forest land ⇨ Forest Land	T1, T2	T1, T2	T1, T2	T1	See Cropland ⇨ Cropland
Cropland ⇨ Cropland	T2	T2			T1
Grassland ⇨ Grassland	T1	T1	T1	T1	T1
All Land ⇨ Grassland	T1	T1			See Cropland ⇨ Cropland
Wetlands	Not reported				
Settlements	Not reported				
Other land	Not reported				

*** T1, T2: IPCC methodology Tier 1 and Tier 2 respectively**

10.4.3. Key Category Analysis and Uncertainties

The determination of the key categories[1] for the Greek inventory system is based on the application of the Tier 1 methodology described in the *GPG-LULUCF*. As one would have expected using mostly Tier 1 and some Tier 2 reporting techniques and age-constant, species dependent BEFs and R-to-S, the estimate uncertainties in the Greek NIR from LULUCF are relatively high (Table 10-7)

Table 10-7 Greece – key categories and uncertainties in LULUCF

[1] Key categories are those which, when summed together in descending order of magnitude, add up to over 95% of total emissions (level assessment) or the trend of the inventory in absolute terms.

Category	Key	Uncertainty
Forest land ⇨ Forest Land	Level & Trend	79%
Cropland ⇨ Cropland	Level & Trend	67%
Non-forest land ⇨ Forest Land	Trend	113%
Total		
LULUCF contribution to total emissions		

10.4.4. Kyoto Protocol Reporting Options

Table 10-8 Greece - key decisions under the Kyoto Protocol illustrates Greece's choice of parameters for forest definition as well as its elections for Article 3, paragraph 3 and 4, activities in accordance with decision 16/CMP.1.

The described forest parameters values are within the ranges prescribed in paragraph 1 (a) of the annex to decision 16/CMP.1, **but they differ from the definition used in the NIR**. Greece used different single minimum values compared to those used in the Inventory Report under the UNFCCC and traditionally used in the FAO reports in order to ensure consistency with the new national legislation. The new law about forest definition was introduced in 2003 but it was contested to the Council of State and the decision is still pending.

Table 10-8 Greece - key decisions under the Kyoto Protocol

Item	**Description**
Forest definition	- Min tree cover: 25 % - min land area: 0.3 ha - min tree height: 2 m
Forest management	Elected /accounting period: commitment period
Cropland management	Not elected
Grazing land management	Not elected
Revegetation	Not elected

10.4.5. Comments from the Inventory Review Report (IRR)

Greece's national inventory report (NIR) is evolving. In the 2005 NIR, the country improved its reporting by using IPCC *GPG-LULUCF*. Nevertheless the IRR expressed concerns as to the annual variability in emissions from various categories and lack of reporting on others, and overall high level of uncertainties. The IRR suggested that Greece should focus on improving its monitoring of fire disturbances.

10.5. *Italy*

10.5.1. Forest Definition

Italy's definition of forest was not specified in the latest NIR but, according to the Report on the determination of Italy's assigned amount under Article 7, paragraph 4, of the Kyoto Protocol, the definition adopted by Italy agrees with the Food and Agriculture Organization of the United Nations definitions, with a minimum area of land of 0.5 hectares, tree crown cover of 10 per cent and minimum tree height at maturity of 5 meters

10.5.2. Pools and Tiers

A summary of the carbon pools and reporting tiers use by Italy is shown in Table 10-9. Generally, a combination of tier 1 and tier 2 methods are adopted for the inventory estimation, except for the category forest land, where a growth model was applied to forest. In other land uses, Tier 1 reporting is used.

Table 10-9 Italy - carbon pools and reporting tiers

	Carbon Pools				
	Aboveground Biomass	Belowground Biomass	Dead Wood	Litter	Soil Organic Matter
Forest land ⇨ Forest Land	T1; T2*; growth model				
Non-forest land ⇨ Forest Land	Not reported				
Cropland ⇨ Cropland	T1				
Non-cropland ⇨ Cropland	T1				
Grassland ⇨ Grassland	T1	T1	NA**	NA	
Non-grassland ⇨ Grassland	T1				
Wetlands	Not reported				
Settlements ⇨ Settlements	T1				
Non-settlements ⇨ Settlements	T1				
Other land	Not reported				

* T1, T2: IPCC methodology Tier 1 and Tier 2 respectively. NA: no available information

10.5.3. Key Category Analysis and Uncertainties

The determination of the key categories for the Italian inventory system is based on the application of the Tier 1 and Tier 2 approaches described in the *GPG-LULUCF* (Table 10-10).

Table 10-10 Italy – key categories and uncertainties in LULUCF

Category	**Key**	**Uncertainty**
Forest land ⇨ Forest Land	Level & Trend	86 %
Cropland ⇨ Cropland	Level & Trend	
Non-forest land ⇨ Forest Land	Level & Trend	
Other land ⇨ Cropland	Trend	
Other land ⇨ Settlement	Level & Trend	
Total		
LULUCF contribution to total emissions		56%

The overall uncertainties for dominant forest land category are estimated to be 86% for the period of 1990-2005. The overall uncertainty of the LULUCF sector is estimated to be 56%. In addition, the forest sector affects the overall uncertainty of the total GHG inventory, being 3.3% in 2004 without LULUCF and 8.3% with LULUCF.

10.5.4. Kyoto Protocol Reporting Options

The forest definition adopted by Italy agrees with the Food and Agriculture Organization of the United Nations definitions, therefore the threshold values for tree crown cover, land area and tree height are applied as shown in Table 10-11.

Under SBSTA conclusion FCCC/SBSTA/2006/L.6 and related draft COP/MOP2 decision (FCCC/SBSTA/2006/L.6/Add.1), credits from forest management are capped, in the first commitment period, to 2.78 Mt C per year times fives. Italy will elect forest management as an activity under Article 3.4.

Table 10-11 Italy - key decisions under the Kyoto Protocol

Item	Description
Forest definition	– tree crown cover:10 % – min. area of land: 0.5 hectares; – min. tree height: 5 meters.
Forest management	Elected/ accounting period: commitment period
Cropland management	Not elected
Grazing land management	Not elected
Revegetation	Not elected

10.5.5. Comments from the Inventory Review Report

For what concern LULUCF, the 2006 Inventory Review Report (IRR) complimented Italy for successful and full adoption of GPG-LULUCF. However various shortcomings were highlighted such as high level of uncertainties, unreliable values of soil carbon in the conversion to forest land and lack of data concerning certain important categories like flooded land. The Expert Review Team suggested validation of modelled growing stock estimates based on sample measurements for at least the dominant forest types, at least until the estimates from new forest inventory become available, which may lead to recalculations of the growing stock and carbon increment estimates. These values are important since estimates for below-ground biomass, dead organic matter and soil carbon are derived as a function of above-ground biomass. The uncertainty for soil carbon is estimated to be high at 150 per cent and Italy was encouraged to generate data from field studies for different forest types to reduce uncertainty for its next submission.

10.6. *Lithuania*

10.6.1. Forest Definition

Lithuania did not specify a forest definition of forest in the latest NIR.

10.6.2. Pools and Tiers

A summary of the carbon pools and reporting tiers use by Lithuania are shown in Table 10-12. Grassland, Settlement, and Other categories are reported by Lithuania as changes within these categories are insignificant or reliable data are not available and therefore not considered in the NIR. The country is using only Tier 1 for the categories that are reported.

Table 10-12 Lithuania - carbon pools and reporting tiers

	Carbon Pools				
	Aboveground Biomass	Belowground Biomass	Dead Wood	Litter	Soil Organic Matter
Forest land ⇨ Forest Land	T1	T1	T1	T1	T1
Non-forest land ⇨ Forest Land	Not reported				
Cropland ⇨ Cropland	T1	T1			T1
Grassland ⇨ Grassland	Not reported				
All Land ⇨ Grassland	Not reported				
Wetlands	Not reported				
Settlements	Not reported				
Other land	Not reported				
Agricultural lime applications	T2				

*** T1, T2: IPCC methodology Tier 1 and Tier 2 respectively**

10.6.3. Key Category Analysis and Uncertainties

There is no complete key category analysis provided by the Lithuanian NIR for 2006. NIR has identified only two key categories: forest land remaining forest land and land converted to forest land (Table 10-13). Furthermore, quantitative uncertainty analysis is carried out for all categories except LULUCF.

Table 10-13 Lithuania – key categories and uncertainties in LULUCF

Category	**Key**	**Uncertainty**
Forest land ⇨ Forest Land	Key	
Cropland ⇨ Cropland		
Non-forest land ⇨ Forest Land	Key	
Total		
LULUCF contribution to total emissions		

10.6.4. Kyoto Protocol Reporting Options

Table 10-14 shows the Party’s choice of parameters for forest definition as well as elections for Article 3, paragraphs 3 and 4, activities in accordance with decision 16/CMP.1. Lithuania’s choice of the parameters to define forest is within the range specified by decision 16/CMP.1. In addition, the country has adopted a minimum width of 10 metres to define its forests, following the IPCC good practice guidance for LULUCF. The values of minimum land area, minimum tree height and minimum forest width are defined in accordance with the Lithuanian Forestry Law.

Table 10-14 Lithuania – key decisions under the Kyoto Protocol

Item	Description
Forest definition	- min tree cover: 30 % - min land area: 0.1 ha - min tree height: 5 m
Forest width	Min: 10 m
Forest management	Elected /accounting period: commitment period
Cropland management	Not elected
Grazing land management	Not elected
Revegetation	Not elected

10.6.5. Comments from the Inventory Review Report

The main concerns defined in IRR in 2005 regarding NIR are insufficient transparency in the report, lack of detailed information for categories and emissions estimations. The IRR recommends providing information on the land use definitions as well as improvements in the emission estimations for carbon storage.

10.7. *Romania*

10.7.1. Forest Definition

Romania has reported the following parameters defining "forest":

"Forest Land *includes a land of minimum 0.25 hectares with a tree crown cover of more than 10 per cent of the area. Tree's minimum height must be 5 m in mature stage in natural sites. The definition includes also: forest nurseries, trees genetic trials within the forest land, forest pathways and roads, meadows, glades and other forest gaps, forest ecosystems within the national and natural parks, natural protected areas and other protected forest areas, protection forest belts with an area larger than 0.5 ha and a minimum width of 20 m, as well as Pinus mugo shrubs in alpine areas*"

10.7.2. Pools and Tiers

A summary of the carbon pools and reporting tiers used by Romania are shown in Table 10-15. Due to lack of specific information, under Forest land related to Forest land remaining Forest both Tier 1 and Tier 2 are used.

Table 10-15 Romania – carbon pools and reporting tiers

	Carbon Pools				
	Aboveground Biomass	Belowground Biomass	Dead Wood	Litter	Soil Organic Matter
Forest land ⇨ Forest Land	T2	T1	T1	T1	T1
Non-forest land ⇨ Forest Land	Not reported				
Cropland ⇨ Cropland	Not reported				
Grassland ⇨ Grassland	Not reported				
All Land ⇨ Grassland	Not reported				
Wetlands	Not reported				
Settlements	Not reported				
Other land	Not reported				

*** T1, T2: IPCC methodology Tier 1 and Tier 2 respectively**

10.7.3. Key Category Analysis and Uncertainties

There is no information regarding the key categories provided in the NIR.

Furthermore, Romania has not done a full quantitative estimate of uncertainty as described in the "IPCC Good Practice Guidance". IPCC GPG 2000 reports some uncertainty estimates associated with emission factors, but those associated with activity data are not estimated since the official statistics have not provided any uncertainty values.

10.7.4. Kyoto Protocol Reporting Options

Considering Article 3.4 of the Kyoto Protocol and the Decision 16/CMP.1, Romania as an Annex I Party, has chosen revegetation and forest management (Table 10-16).

Table 10-16 Romania - key decisions under the Kyoto Protocol

Item	**Description**
Forest definition	- min tree cover: 10 % - min land area: 0.25 ha - min tree height: 5 m
Forest width	min 20 m
Forest management	Elected /accounting period: commitment period
Cropland management	Not elected
Grazing land management	Not elected
Revegetation	Elected /accounting period: commitment period

10.7.5. Comments from the Inventory Review Report

The Inventory Review Report 2005 (IRR) of Romania has defined a lot of improvements that should be implemented. First of all and very important is to provide CO2 emission/removals in all categories. It is recommended to give more supporting background and clearness regarding some of the estimations. Furthermore, it is recommended to harmonise the used magnitudes or report why different ones are used.

10.8. *Slovakia*

10.8.1. Forest Definition

Slovakia has reported the following parameters defining "forest": **Forest Land** *includes: land with minimum tree crown cover of 20 % for trees capable to reach minimum height of 5 m in situ. The minimum area for forest is 0.3 ha. Temporarily unstocked areas are included (forest regeneration areas). For linear formations, a minimum width of 20 m is applied.*

10.8.2. Pools and Tiers

Results of calculations were obtained by using the IPCC Methodology (IPCC, 2003) and the national data on wood volume increments for individual forest tree species, and results of a roundwood harvest inventory. No further specific data on the used methodology is available.

10.8.3. Kyoto Protocol Reporting Options

Table 10-17 illustrates Slovakia's choice of parameters for forest definition as well as its elections for Article 3, paragraph 3 and 4 activities in accordance with decision 16/CMP.1.

Table 10-17 Slovakia - key decisions under the Kyoto Protocol

Item	**Description**
Forest definition	- min tree cover: 20 % - min land area: 0.3 ha - min tree height: 5 m
Forest width	Min: 20 m
Forest management	Elected /accounting period: commitment period
Cropland management	Elected /accounting period: commitment period
Grazing land management	Elected /accounting period: commitment period
Revegetation	Elected /accounting period: commitment period

10.8.4. Comments from the Inventory Review Report

As revealed in the Slovakian Inventory Review Report (IRR) for 2005, there were many shortcomings in NIR. Great fluctuation in the LULUCF sink during the years, no complete implementation of the GPG LULUCF, no key category analysis, lack of transparency, no uncertainty estimations, unclear definitions, lack of supporting explanation regarding certain estimations are some of the main gaps in Slovakian NIR.

10.9. *State of Data Availability*

10.9.1. Monitoring systems

The metadata of European monitoring projects with data relevant for MASCAREF test countries is summarized in Table 10-18.

Table 10-18 Metadata of European scale forest monitoring projects relevant for MASCAREF

		GREECE	ITALY	LITHUANIA	ROMANIA	SLOVAKIA
Level I	general	N=15, 4 subsamples per plot monitor forest health on acidic soils 1993, 1994	1995-96: for soils: N=50 from total Level I N= 265 2006-7: BioSoil survey on all plots (N=234)	Forest soils: initial n=74 (16x16 km, 1992) from total Level I n=963 (4x4 km). Re-sampled in 1998 (n=67).	Total Level I: N=242 Soil data from N=233	N=112 1. 1993. re-sampled 1998 (selected parameters) **2.** 2006-7 **BioSoil** complete survey
	O layer	L removed, F+H sampled together; no sampling by cylinder	Separated and analysed (see under BioSoil for 2006-7)	L mixed with F and H. 1 composite sample from 12 subsamples (round metal frame, 0.1 m2)	Separated L, F, H	1. L mixed with F and H, 20 (10) subsamples 2. L, F+H 5 subsamples
	Mineral soil	0-10 cm and 10-20 cm; If the stone content was high, sampling took place in an adjacent area	0-10, 10-20, composite from 3 subsamples (see under BioSoil for 2006-7)	0-5, 5-10, and 10-20 cm (1992) and 0-10 and 10-20 cm in 1998. Composite sample from 12 subsamples:4 transects from the central tree with 3 subsamples at each transect	0-10, 10-20 cm.	1. 0-10 and 10-20 cm (20 soil pits ("shallow pit method"), composite sample 2. 0-10, 10-20, 20-40, 40-80 cm, 5 subsamples
	C analysis	wet digestion (cold oxidation) by means of K2Cr2O7 In our 15 plots there was no CaCO3 detectable	Dry combustion	Dry combustion (900°C)	Dry combustion	1. C_{ox}. (Tyurin) 2. wet digescion (LECO)
	Bulk density	No data, but bulk density can be calculated from equations taking into account texture and organic C analysis	Not measured	Not measured	Measured	1. 20% of the sites – measured, 80% estimated 2. measured on all plots, at least to 20 cm
	stones	Visual assessment	Visual assessment	Not measured	Visual assessment	Visual judgement
	classification	Humus forms acc. to Pritchet and Fisher 1987 Soil type: FAO, Unesco 1974	No classification performed on level I in 1995-96 (see under BioSoil for 2006-7)	Soil types: FAO/WRB but without mandatory chemical analyses	Soil types: National classification transformed to FAO classification	1. Mull, Moder, Mor ("rough" approach) Soil: National Classification, transformed to FAO 2. WRB 2006, not yet completed

		GREECE	ITALY	LITHUANIA	ROMANIA	SLOVAKIA
Level II	general	N=4 1995 evergreen oaks, deciduous oaks, beech and fir	Soil data from N=20 from a total of N=31 beech, norway spruce, turkey oaks, holm oaks, other deciduous oaks, mixed deciduous, larch	N=9, in 1995 (*Pinus sylvestris* – n=3; *Picea abies* - n= 2; *Fraxinus exelsior* – n=1*; Betula pendula* – n=1*;Querqus robur* – n=1; *Alnus glutinosa* – n=1)	Total Level II: N=13 Soil data from N=13	1. n=8 plots (no subplots) 1995 – 1998 2. BioSoil, in 2007
	O-layer	See level I	Separated and analysed (see under BioSoil for 2006-7)	See Level I	Separated L, F, H	See Level I
	Mineral soil	0-10 cm, 10-20, 20-40 cm and 40-80 cm; design as with Level I	0-10, 10-20, 20-40, 40-80 composite from 5 subsamples 1 soil pit	0-10; 10-20; 20-40, and 40-80 cm 1 soil pit	0-10, 10-20, 20-40, 40-80 cm.	1. Sampling depth classes (0-10 cm, 10-20 cm, 20-40 cm, 40-80 cm) with some respect to horizon boundaries in case of sharp boundaries 20 soil spots – augeringin the buffer zone (periphery of the square-plot) 2. 0-10 cm, 10-20 cm, 20-40 cm, 40-80 cm 2. 5 composite samples (4x6 subsamples augering), + deep soil pit
	Bulk density	Measured	Not measured	Not measured	Measured	Measured
	Stones	See level I	Visual assessment	Very few stones	Visual assessment	See Level I
	Litter Fall	N=2 sites There was no distinction between the various litterfall parts	N=20 sites. Measured only for three years. Interuppted in 1998. Methods according to ICP Manual	N=3 plots (1 - since 2000: 1 – since 2005, and 1 – since 2008). 10 traps per plot: needles, fine woody debris and cones are separated.	N=4 sites, 25 traps per stand, dry mass of leaves and fine woody debris, leaves area index.	N=4 sites; 10 traps per stand, dry mass of leaves, wood and the rest of samples
	DOC	Not measured	N=2 sites since 1999; N=4 sites since 2005; N=8 sites since 2006 0 tension lysimeters, litter layer (4 sites); suction lysimeters from three depths, all sites. Depth change from ite to site (horizons)	Not measured	Not measured	Not measured
	Fluxes	Not measured	Three sites with eddy covariance towers (ecosystem CO_2 net fluxes)	Not measured	Not measured	Not measured

		GREECE	ITALY	LITHUANIA	ROMANIA	SLOVAKIA
	Forest structure, species compositio n, increments	Ground vegetation was assessed approximately every two years. Increment every 5 years. Breast diameter and tree height was measured for all trees in the 4 plots	N=31 Tree species, structure and increments every 5 years. N=15 Species composition of understory, annually	Species composition and increment are measured since 1995 every 5 years according to ICP-Forest Manual	N=12 sites, every 5 years period for forest structure, species composition and increment	Forest structure and species composition- 7 plots, every 5 years Radial Increment- on 6 plots, once per year, by band dendrometer Diameter increment on 5 plots, in two-week intervals by micro-dendrometers
Other research plots	Type of inventory / monitoring	Land Resource Survey of Greece N>2000 plots 1980-1998 One pit; genetic hoizons	CarboItaly: 13 forest sites with ecosystem canopy fluxes and ecological measurements, including soils LTER: several level II plots are part of the LTER network. Two more forest stations (not level II) are also included Several research plots for forest structure and management	No other research plots	No other research plots	No other research plots
	Information relevent to soil and Litter carbon (see structure of Level I)		A soil map of Italy 1:250000 is available.			No relevant information

		GREECE	ITALY	LITHUANIA	ROMANIA	SLOVAKIA
BioSoil	What is different as to Level I (e.g. the biomass assessment, analysis of soil physical parameters?)	The biosoil project was carried out for the 4 Level II plots. Soil porosity was measured The analyses are still being carried out. The bulk densities of soil profiles have been measured	Performed in 2006-07: Level I (n=234) and Level II (n=1, other 20 sampled in 1996). Soil, **level I and II**: organic layer L separated, F and H separated only if singularly present unless sampled and analysed as FH; mineral soil – 0-10, 10-20, 20-40 and 40-80 cm (the latter two when present). 1 soil pit at all plots Sampling design: **Level I** – organic layer 1 composite sample from 5 subsamples; mineral soil – 1 composite sample from 5 subsample (more often minipits); **Level II** – 3 composite samples from 24 subsamples (all samples). Bulk density: measured (cylinders). Ston content evaluated from soil pit. Soil classification according to the FAO/WRB. Forest structure and typology, dead wood at all plots. Biodiversity of, shrubs and groud vegetation on a subset of plots	It was performed in 2007: Level I (n=62) and Level II (n=2). Sampling: organic layer – L, F and H separate ; mineral or organogenic soil – 0-10, 10-20, 20-30, 30-40 and 40-80 cm. Sampling design: **Level I**– L, F and H separate, - 1 composite sample from 8 subsamples; mineral soil – 1 composite sample from 12 subsamples; **Level II** – 3 composite samples from 8 subsamples (all samples). Bulk density and stones (method of penetratio) are measured. Soil classification according to the FAO/WRB. Laying dead wood and biodiversity of trees, shrubs and groud vegetation were assessed	Not implemented	The same plots as level I Information see above
ForestBiota	general		8 sites	Not implemented	Not implemented	
	Details regarding dead organic matter; link with soils and forest biomass?		Deadwood sampled according to ForestBiota protocol. Link to forest structure			ForestBIOTA manual

10.9.2. National Forest Inventory

Greece

The first National Forest Inventory (NFI) was conducted during 1963-1985 and was issued in 1992.

A second NFI is not scheduled by Greece for the near future. For this reason, a national system for the estimation and reporting of GHG emissions and removals for reporting under the UNFCCC and the Kyoto Protocol is under development. This system comprise a LULUC monitoring programme and programmes to estimate C stock changes in different carbon pools, designed specifically to meet the technical needs for reporting under the UNFCCC and the Kyoto Protocol.

Italy

The history of NFI in Italy is relatively recent. Italy performed its first NFI in 1985, using a single-phase statistical sampling on a 3 km x 3 km grid. The inventory was designed to provide data at national level, although the extraction of some regional data was feasible. In 1985, for biomass parameters, only aboveground volume (biomass) of stem (all species) and main branches (broadleaved species) and its growth was estimated.

Italy has recently finished the second National Forest Inventory that has been significantly called National Inventory of Forests and Carbon (INFC, http://www.infc.it). The inventory protocol and design have been completely revised with respect to the NFI of 1985. In 2003-2005 (reference year for forest area: 2005), the INFC was designed using a “double sampling for stratification” schemes in three phases (Fattorini et al, 2006; http://www.infc.it; INFC, 2005): the first phase was devoted to land use/land cover classification and was performed “on screen” by photointepretation of approximately 301000 points on a 1 km x 1 km grid. The point was randomly located within the grid square. In the second phase, a subset (~ 30000) of the points classified as forests, low density forests, areas temporarily without forest cover or plantation was selected and visited to verify and refine land use/cover, to determine geographical position and to assess a number of basic parameters (forest type, site basic data, administrative data). The plots were permanently marked by burying a metal plate in the center of the plot.

The third phase has been devoted the measurements of forest quantitative parameters and was performed on a subset of plots assigned to forest according to FAO definition (6865 plots). Plots were stratified following the results of phase 2. The third phase will allow the estimation of aboveground volume, biomass and growth, features of understory vegetation, dead wood, forest health status and other additional parameters. Nearly 2000 trees of different species were harvested in order to derive updated allometric relationship. In 2008-2009, a special survey will be performed on 1600 plots to assess soil and litter carbon and all the parameters of phase 2. Data coming from the elaboration of Phase 1 and 2 are already available (http://www.infc.it; INFC, 2005) while the data of Phase 3 will be available in 2008. INFC (2005) has been designed to provide data at regional level. Hence, it is highly probable that the regions, in the future, will use INFC 2005 as the basis for assessment of regional forest resources. Ideally, Regions can, on a voluntary basis, increase the density of second and third phases’ plots in order to refine estimates. The overall plan is to repeat NFI every 5 years

The number of points of the three Phases of INFC 2005 in Umbria, the region interested by the proof of concept study are 8442, 1094 and 332 for Phase 1, 2 and 3, respectively.

Currently, UNFCCC reporting of LULUCF category Forest Land is based on NFI data of 1985 . A growth model is used to recalculate annual growing stocks year by year to which harvested wood is subtracted (details are available in 2006 and 2007 NIR). From aboveground volume, BEFs and Root-Shoot ratios are applied to estimate aboveground and belowground biomass. Deadwood is estimated by using a fixed ratio to aboveground biomass, while litter and soil pools are derived from aboveground biomass using linear functions versus published literature (litter) or level II data (soil). When the complete data set of NFI 2005 will be available, the data series will be revised according to new specific forest area, biomass, litter and soil data.

Lithuania

The continuous Lithuanian National Forest Inventory began in 1998 (1998-2002) and the first re-inventory of the permanent sample plots occurred 2003-2007. Thereafter a five-year invent cycle is planned. In addition to the permanent sample plots, temporary sample plots are inventoried but with a lower sampling intensity (intensity three to one). In total the inventory comprises about 5600 permanent sample plots. The field inventory covers Forest land, and in the case of afforestation/deforestation Grassland and Wetlands as well. Areas of remaining land use classes (Settlements, Cropland and Other land) are complemented by information from land use maps.

Information on living and standing and laying dead trees is inventoried. For a sub-sample of living trees, their position, height, crown height, age and increment are monitored. Some stand and site variables, including soil related variables (thickness of organic layer and mineral horizons, soil texture by finger test, depths of carbonates, peat and parent material) are also surveyed.

NFI data provide input for reporting changes in the carbon pools aboveground living biomass, dead wood, litter and soil organic carbon. Belowground living biomass might be estimated by root to shoot ratios but below ground dead wood is not inventoried. For below ground living biomass all trees sizes are covered (species constituting ca 10% of volume are not excluded). The aboveground dead wood (including the stumps) is completely covered and the litter and soil organic pools are modeled.

Romania

Romanian forests have known successive and brutal changes, being State owned until 1990 as a consequence of the 1948 nationalisation, while the restitution process is still ongoing nowadays, that contribute to making a complex context for the forest inventory. National inventories of the forestry fund were elaborated in 1965, 1973, 1980 and 1984 based on the information contained by the forest management plans. An inventory system based on permanent sample plots has been experimented between 1983 and 1989. This system was implemented in 1990 over the entire forestry fund and was combined with the national forest monitoring system. The forest inventory currently relies on annually reported forest statistics aggregated at country level. The last full inventory was made in 1985.

The Romanian National Forest Inventory is designed as a continuous forest inventory (CFI) with a five-years inventory cycle. It is based on a systematically sampling, combine repeated measurements of permanent plots with measurements of temporary plots and it is a two stage NFI (aerial photos and field forest measurements and assessment). The Romanian NFI covers the entire country territory and is based on a 4x4 km grid. The density of grid is higher in plain area (2x2 km) because of a very low forest cover. In the south-west corner of a 4x4 (2x2) km grid is located a tract of 250x250m with 4 sample plots on the corners. The field forest inventory comprises about 24000 permanent and 5000 temporary sample plots.

A systematically grid of 500x500m covering the entire country territory is used for determine land use (and land use change) categories on orthophotograps. The first Romanian NFI started in 2007 with a pilot inventory and it is estimated to be finished in 2011. It covers forests, other wooded lands and trees outside forest.

The NFI data collected on field survey mainly refer to:

- living trees (species, tree position, DBH, height, age, crown condition, increment, damages etc.);
- forest stand (forest type, silvicultural system, tree species composition, vertical structure, canopy cover, age, stage of development, damages etc.);
- forest regeneration (species, origin, age, height, diameter, damages etc.);
- dead wood: standing and lying deadwood, stump (diameter, height or length, decay etc);
- forest site (relief, terrain, slope, exposure, shrubs and herbs cover etc);
- forest soil (soil type, soil layers, depth, humus, texture, soil skeleton, moisture, soil chemistry etc.).

Start date of this new inventory was 2006 for the prototype 'pilot' run. The first round is expected to be completed by 2010. The pilot inventory that covers the entire country, could provide usable data already by 2008.

The Romanian reporting systems on LULUCF activities under the Kyoto Protocol and AFOLU under UNFCCC are not yet based on NFI information, but the Romanian NFI was designed for providing information needs precisely for this purpose. It will provide inputs and statistics assessments for reporting the carbon sequestration in forests and changes in the aboveground living biomass, dead wood and soil organic carbon pools. It should be underlined that the reference definitions would therefore be used for most classification and core variables (coverage, volume of growing stock, annual increment, annual drain, volume of dead wood, etc.) as is, or in paralel with the national definitions. Meanwhile, the national system for estimating emission has been set and is under development.

Slovakia

The first cycle of Slovak NFI was performed during 2005 and 2006. The NFI is based on combined ground-photo method with systematic allocation of sampling units on the whole territory of the country in the network 4x4 km. In total the ground inventory comprises about 1 422 permanent sample plots. This network density (one inventory plot with the area of 500 m2 represents about 1,600 ha of the territory). In ground inventory, which is the basis of the whole reconnaissance, four kinds of experimental plots represent sampling units. They are namely A – constant circle with diameter r = 12.62 m for detection of site, stand and ecological characteristics, and for the inventory of dead lying wood and stumps, B – two concentric circles (r = 3 m and 12.62 m) for detection of tree characteristics with the diameter $d_{1,3}$ = 7-12 cm a ≥12 cm, C – variable circle for small trees with $d_{1,3}$ <7 cm (its diameter r = 1.0, resp. 1.41, resp. 2,0 m) is chosen according to concrete density of individuals, D – extended constant circle with r = 25 m for the inventory of forest borders, roads and water resources. They were chosen in a way to adapt optimally to the characteristics of information spectrum, which is very broad and comprises more than 100 attributes and parameters. Photo inventory was carried out on orthophotograps of Slovakia in the network 2x2 km. Sampling units were in total 12,268 interpretation plots each with the area of 2,500 m^2. It was used mainly for identification of forest and non-forest lands. The field inventory covers Forest land and Other land with tree cover. Areas of remaining land use classes (Grassland, Cropland, Wetland Settlements, and Other land) are complemented by information from land use database.

Whole spectrum of information on tree level or stand level is inventoried. For example on tree level: qualitative and quantitative characteristics (tree diameter $d_{1,3}$, height of tree, height of live crown, crown width, stem diameter $d_{0,3}$ in 30% of the height of tree and stem diameter d_0 on the level of tree foot or also on the level of potential height of stump = $0.5.d_{1,3}$) On stand level following information are evaluated: Stand characteristics (forest form, silvicultural system, tree species composition, vertical structure of stand, canopy, age of tree, growth (development), Forest regeneration (presence of natural seeding, origin and proportion of regeneration, mean height, mean diameter, age and quality of individuals), Site characteristics (terrain relief an slope, exposure, herbs and shrubs), Soil characteristics (humus layer, kind of soil, proportion of skeleton, moisture conditions, soil rooting, soil type, depth of soil and geological parent rock, soil chemistry), Ecological characteristics (degree of natural character of stand, degree of loading of forest by anthropogenic activity (degree of stand stability, dying standing timber, lying died trees dbh > 7 cm, dbh < 7 cm, stumps, forest border)

The current Slovak UNFCCC LULUCF and Kyoto reporting systems are not based on NFI information. One inventory cycle it is not readily usable for estimating of carbon stock change in forest. However, in spite of mentioned fact, the Slovak NFI´s system was designed for providing information needs for this purpose. Information required for estimating and reporting stock change in the five carbon pools under UNFCCC can be supplied by or derived from the data of the NFI. The Slovak NFI would provide usable information on aboveground biomass, dead wood and litter. Additionally, NFI supplies information on soils and soil's carbon too. NFI can be also a vital resource for information on land areas. The NFI data would mostly be used when estimating land use transfers.

10.9.3. BEFs and allometric equations

The emissions and removals of GHG resulting from carbon stock change in forest living biomass belong to the key components of GHG emission inventory of the LULUCF sector. The carbon stock change in living biomass can be estimated by either the default or stock change method (GPG IPCC for LULUCF, IPCC 2003). For the case countries of the MASAREF project, namely Greece, Italy, Lithuania, Romania and Slovakia, the default method has been applied so far. This method is based on a separate estimation of increments and removals and estimating difference.

Various data sources have been used for the required parameters used in the calculation of carbon stock change in biomass. The required parameters and default parameters applicable for Tier 1 method according to GPG for LULUCF are as follows:

- basic wood density (**D**) **-** Default values in Table 3A.1.9 of IPCC GPG 2003;
- biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment (**BEF1**) – Default values in Table 3A.1.10 of IPCC GPG 2003;
- biomass expansion factor for conversion volumes of extracted roundwood to total aboveground biomass (including bark) (**BEF2**) – Default values in Table 3A.1.10 of IPCC GPG 2003;
- root-to-shoot ratio (**R**) – Default values in Table 3A.1.8 of IPCC GPG 2003

The MASCAREF case countries use either the IPCC default or various national or regional-specific biomass and conversion factors. This report presents the five selected countries in terms of i) tree species composition ii) forest type categorization iii) BEF (biomass expansion factors) and BF (biomass functions) used so far for the calculation of biomass carbon stock for and/or available in the latest NIR submissions and iv) the other sources of information on locally applicable biomass functions and factors. A report on procedures applied for expanding from timber volume to carbon stocks of forests in MASCAREF test countries is given in Chapter 8 of this volume.

10.10. *Thematic focus within MASCAREF*

10.10.1. Greece

Concluding from the previous chapters, for Greece the thematic focus lies on the basic lack of an NFI and a detailed soil map. Related to the requirements of the Kyoto Protocol reporting, and related to the current data situation, some special frame conditions results with regard to the assessment of trend for each of the C storage pools:

1) forest definition, and more specifically how shrublands relate to the generally accepted forest definition
2) estimating the effect of disturbance by fires, especially on litter, requires a clear definition of pools linked to methods how these can be estimated, as well as a good baseline for carbon storage. For the litter pools, this requires the development of methodology (considering that forest as reporting category will be a key source in Greece, and that GPG 2003, Tier 2 reporting is sufficient because advance methods and detailed data are not available).
3) difficulty to determine the sink behaviour of soils as SOC change detection is hindered by the biophysical properties of the soils and the limited data availability (high stone content increases the uncertainty of the stock assessments; limited density of the inventories, changes of the inventory between Level I and BioSoil)

The focus therefore lies on how to improve the UNFCCC reporting if the simple use of IPCC default is not preferred; i.e. how to go from Tier 1 to Tier 2. In Greece this implies the optimal combined use of European wide monitoring systems (like ICP, Forest Focus, European soil C map, BEF's from other countries) with ad hoc Greek research results, or partial national monitoring coverage.

10.10.2. Italy

In Italy, many data are available from a variety of studies (ICP, flux sites) with different goals. In view of this, a major step in the reporting for Italy will be to integrate the existing information with the new National Forest Inventory covering the whole country in a systematic way. This National Forest Inventory has recently started and data for the full country will not be available within the timeframe of this project. However, for some regions, good data are available from this new National Forest Inventory. Data from Veneto, Emilia Romagna, Umbria, Marche and Tuscany are currently available. In Italy, particularly in the Center and the South part, spatial heterogeneity, forest patchiness and diversity, different management practices (e.g. coppices vs. high stands) are important issues when considering aggregating plot level data for coarse scale estimates.

According to data quality and quantity and representativity, Umbria has been selected as test area within MASCAREF. Within the region, for most 10 x 10 km reference grid cells, fair to high numbers of sample plots are present within each grid cell, allowing a detailed estimation of spatial heterogeneity. Therefore the main focus for Umbria within the MASCAREF project will be to test approaches to aggregate data and calculate uncertainties. Umbria complements Lithuania in this respect, with a finer scale grid, no plot clustering and expected higher spatial heterogeneity.

10.10.3. Lithuania

Lithuania has an NFI system which has already completed one full cycle and combines many features that are found also in other countries with recent NFI design. Both permanent and temporary tracts of different size and level of detail are combined. Plot variables cover increments, dead wood and harvest data, allowing a very complete assessment of carbon balance of the live and dead tree component of the ecosystem. Even soil information is available to some extent for NFI plots, and from other sources. The country has a limited number of tree species, with three species covering more than 70% of the total area. For these species country specific biomass functions are available.

Despite these data, Lithuania reports mainly on Tier 1 level. Therefore the main focus for Lithuania will be on methods to make optimal use of the existing data. It will be one of the test regions for the approach to be developed in MASCAREF project to aggregate NFI plot level data, combine it with other data if needed and estimate uncertainties associated with spatial aggregation and error propagation.

10.10.4. Romania

With regard to the reporting requirements under the UNFCC and the KP, Romania is confronted with specific challenges, due to the land use situation: land use change, and the restoration of properties, lack of land/forest cadastral survey and still locally unclear ownership. In additional, for private lands, the forest management inventory is incomplete. The national NFI is just starting. and it includes private forests (cca. 39% of the forested area). Romania already reported at Tier 2 with national specific data, but based on the management planning inventories and non-nationally specific BEF's. Regarding the GHG inventory for LULUCF, the following aspects in MASCAREF should be pursued:

Local BEF tables based on height and diameter are available; thus, site index is indirectly considered. These resources will be provided/uploaded to JRC database. Additionally, BEF for younger age classes are available and applicable to AR lands, which also will be uploaded to JRC database.

The major test-region effort for Romania will be a construction of age-related BEFs. The approach will use the preliminary/pilot NFI 16 x16 km (to become 4x4 in mountains and hilly areas, 2 x 2 in lowlands, starting 2008) tree level data to construct age-related BEFs for two species – spruce and beech. The volume equations are available locally, while biomass functions will be taken from published literature.

10.10.5. Slovakia

Slovakia is a country with two major information resources on forests: a stand-wise inventory of management plans and a newly implemented statistical forests inventory with one cycle finalized in 2007. Hence, for Slovakia, the thematic focus lies on optimal use of the NFI and stand-wise data and improvement of the whole tree biomass estimates (i.e. national specific BEF's). Slovakia already reported at Tier 2 with national data, but a more optimal use of the available data (more spatial information), in combination with national BEF's, and national soil information is the focus here.

One of the key achievements of the current NFI in SK is the detailed description of volume of dead wood, dying standing trees, stumps, lying dead trees, and especially: small lying wood (<7cm). We will also assess the potential use of that information for the reporting of changes of the litter pool.

For Slovakia, it is proposed that tree-level data of NFI will be used to demonstrate the approach of constructing age-related BEFs. Such relations would then be applicable on the commonly available aggregated data from forest management plants. The BEF construction will use locally derived volume equations together with the representative biomass functions applicable for temperate region. The approach will be demonstrated on plots with dominant (over 50%) representation of the major tree species (spruce, pine, oak, beech). Additionally, uncertainty estimates will be assessed similarly as described in Lehtonen *et al*. (2007).

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11. Approaches to fulfil the GHG reporting requirements for soil carbon and litter in Greece

Kalliopi Radoglou, Argyro Zerva, Panagiotis Mixopoulos and **Dietmar Zirlewagen**
Forest Research Institute, National Agricultural Research Foundation and
Ministry of Rural Development and Food, Greece
Email: radoglou@fri.gr, zerva_ar@yahoo.gr

Rainer Baritz
Federal Institute for Geosciences and Natural Resources (BGR), Germany
Email: Rbaritz@pop3.bgr.de

11.1. *Introduction*

In order to provide figures to the national GHG inventory regarding changes of carbon in the soil and litter pools, Greece could utilize data from existing soil monitoring schemes. The discussion about the Greece greenhouse gas inventory has highlighted some important frame conditions which are necessary to further elaborate:

1. forest definition (see also D6.2, Ch. 3.2)
2. effect of disturbance (fire)
3. soil and litter carbon/change

An additional aspect was found by Blujdea (2008)[29] after evaluating the preliminary national contributions for the reporting under 5A1 (forest remaining forest). There, Greece has reported a very clear source for carbon in dead wood and litter, which appears to be opposite the trends in other Mediterranean countries like Italy and Portugal.

With regard to the availability of data for these aspects, some important restrictions need to be considered:

- no systematic monitoring of disturbance effects (fire, extensive grazing) has been established in Greece, so that data are lacking
- Greece participates in the BioSoil inventory (thus re-sampling of ICP Forests soil monitoring plots), but only with its four Level II plots.
- The following questions result:
- Can the litter layer be neglected using the regular Tier 1 approach? Is that accepted under KP 3.4?
- What data is at least needed to report soil C change under Tier 2? Can the reliability of national evaluations be improved by looking at larger trends, e.g. evaluated with larger data sets for larger areas (such as all Level I plots on the eastern Mediterranean)?

A large part of what is considered forest land under the national definition consists of a shrub-like, grazed vegetation. According to the 1st National Forest Inventory (1992), from a total of more than 6 million ha forest, some 3 million ha are seen as forest available for wood supply (2.034 M ha, referred to as high forest), with the rest being managed as coppice. With regard to the task to

[29] Blujdea, V. (2008). European Dimension to the COST 639 WG IV workshop on 19-20 July, Copenhagen

monitor changes of carbon pool it is important to consider that the reporting under KP3.4 will focus on the more or less intensively managed high forest. GHG reporting under the Kyoto Protocol will thus refer to that part of the forest which is for wood supply and not under coppice management.

Due to the hot and fairly dry summers, water supply of the vegetation in Greece is very limited. The forests are thus highly susceptible for fires. Roughly 49,000 ha of forest and other wooded land had been burnt annually between 1989 and 1998. It is expected that the fire regime affects the dynamics of the soil carbon storage compartments. The carbon content thus changes quite fast, and it does not necessarily correlate with natural site and growth properties. Consequently, indirect estimations based on correlations to forest type, stand age, ground vegetation type (parameters available in the EU/ICP Forests Level I crown condition survey) cannot be done. For that reason, the sampling design for the Greek soil inventory had to be revised before any re-sampling activities.

The reporting for Dead Wood contains effects of forests fires. Tier 1 is used for forests not affected by wildfires, Tier 2 if they are affected.

The detection of soil C change can be based on different approaches, such as on process-based or inventory-based systems. Both systems estimate net changes in C stocks over time, which is used for the reporting of most terrestrial CO_2 emissions and removals. For wet (organic) soils, but also non-CO_2 emissions, the gas flux rates to the atmosphere are directly reported using emission factors.

The inventory-based approach (default method) compares two (or more) consecutive (repeated) inventories, while the process-based (stock change method) applies change rates of the size of pools (e.g. by applying a loss or gain rate). The process-based approach has advantages if the inventory years do not correspond with the reporting years. If a repeated inventory is available, change rates can be calculated, and applied in order to extrapolate carbon stock changes to the reporting year. In that way inventory-based data are used for the so-called process-based reporting approach. However, the representativity of the available plots with measurements is crucial to determine the reliability of the carbon change estimates.

In Greece, such a coupled approach is needed. The change rate will be derived from a very restricted set of plots.

Given these frame conditions, the following specific tasks were selected for this case study:

- Representativity of the existing Level I sites with soil samples available
- Improving and testing the sampling design so that C changes in the litter compartment can be assessed
- In combination with national activities: implementation of the full repetition of the Level I soil inventory (concentrating on those aspects of the BioSoil project which specifically relates to soil C; storage of sample material for later analysis to complete the BioSoil requirements)

11.2. *Soil C change at ICP Forests Level II plots*

Repeated soil carbon values are available for N=4 Level II plots (Figure 11-1). This was possible through participation of Greece in the BioSoil project of Forest Focus (Reg. (EC) No 0703101/2006/440138/FF/B1). Unfortunately, the Level I plots were excluded in the case of Greece.

11.2.1. Methodical issues

After the plots were first sampled and analyzed in 1995, the plots were re-sampled in the summer and autumn of 2007 (Figure 11-1). In order to clearly apply the agreed nomenclature for Europe (WRB; World Reference Base for Soil Resources), a full soil profile pit had to be dug. Samples were collected for the L horizon (not sampled during the initial inventory 1995), the F+H horizon, and the following depth classes: 0-10 cm, 10-20 cm, 20-40 cm and 40-80 cm. The local sampling design follows two transects, along which a total of 24 subsamples were taken for each of the mentioned horizons/depth classes. Eight subsamples were combined to one composite sample, which then yields a total of three samples for analysis for each layer. The samples were analyzed by the INRA laboratory of France for C using the CN analyzer.

The fine earth bulk density of the 0-10 cm layer was calculated by collecting samples of constant volume. The bulk density of the rest of the layers was calculated using the pedotransfer function derived by Adams (1973). The % coarse material (gravel and stones) was measured for the 0-10 cm layer, and estimated by visual observation for the rest of the layers.

1. Maquis
2. Quercus conferta
3. Fagus sylvatica
4. Abies borisii regis

Figure 11-1 Location of the Level II plots in Greece

11.2.2. Soil carbon changes

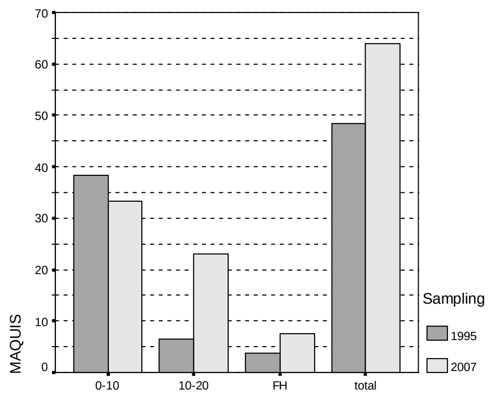
Figure 11-2 presents the SOC changes as simple charts. No statistical ranges/uncertainties can be quantified unless the subplots would be analysed/presented. The sites were selected for typical forest and site types in Greece. The sites 2-4 are considered under high forest, thus directly relate to the definition of forest management for the reporting under KP 3.4.

The results seem to very clearly indicate a strong trend for Greek forest soils (productive high forest) to act as a net sink for carbon at a rate of 1-2 tons C/ha per year for F/H +0-20 cm (during the last 12 years). These numbers are enormous when comparing the data to (cropland) afforestation rates (0.45 ± 0.25 t C/ha/yr, Arrouays et al. 2002[30]).

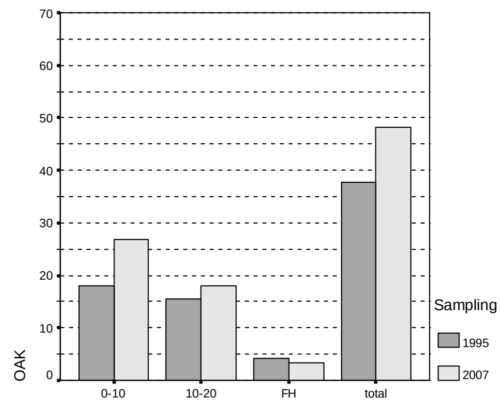
Vesterdal and Raulund-Rasmussen (1998)[1] have evaluated chronosequences for different tree species, for example the sequestration rate for Norway spruce amounts to 0.15-0.30 t C/ha/yr in the O layer. However, with regard to the results presented earlier, the values are in the range of other observations.

[30] References see Task 2

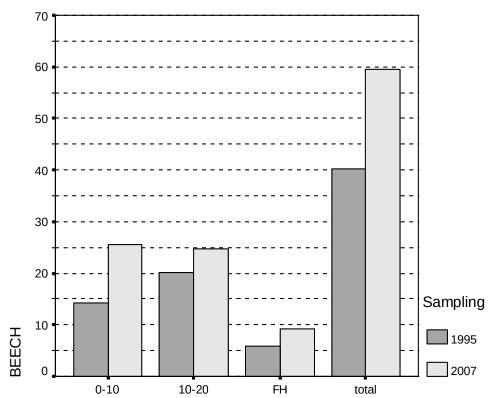
plot1: Maquis



plot 2: Oak



plot3: Beech



plot4: Fir

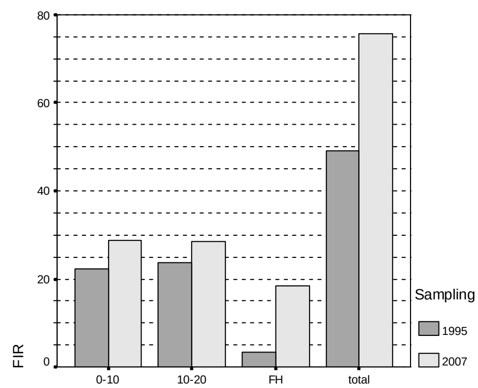


Figure 11-2 Changes of soil organic changes at the Greek Level II sites (C t/ha for 0-10 cm, 10-20 cm, O-layer, total)

However, before the results can be further interpreted, some drawbacks from the analytical setup have to be considered, namely the difference in the analytical method, and the processing of separate (1995) and mixed (2007) samples. The later questions still has to be discussed.

With regard to the analytical methods, wet oxidation was used for the 1995 Level II samples, while dry combustion was used in 2007. Even though many studies have indicated that comparability between wet oxidation and dry combustion would exist, the recovery rate for organic carbon of the wet oxidation method is still a significant uncertainty factor, especially when comparing the cold variant with dry combustion at high temperatures. It can be assumed that analytical results as presented here may not be directly comparable.

In order to test for differences induced by the different analytical method, archived (mixed) samples (gathered in 1995) were delivered to BGR for re-analysis (dry combustion CNS analyzer). The results are not yet available. However, since only mixed samples were sent to BGR the issue of mixed and separate samples still needs clarification.

11.3. *ICP Forests Level I representativity*

11.3.1. Data sources

Soil data

A. Soil plot data

The Greek Level I (Reg. (EEC) 926/93) network consists of 84 plots in the high forest (16x16 km), and 16 plots in maquis (total 487,000 ha). Only 15 of the plots in the “high forest grid” were sampled for soil during the summers 1993 and 1994 (Figure 11-3). The main criteria for selecting plots for soil sampling were to monitor forest health on more or less acidic soils, which are mostly under high forest.

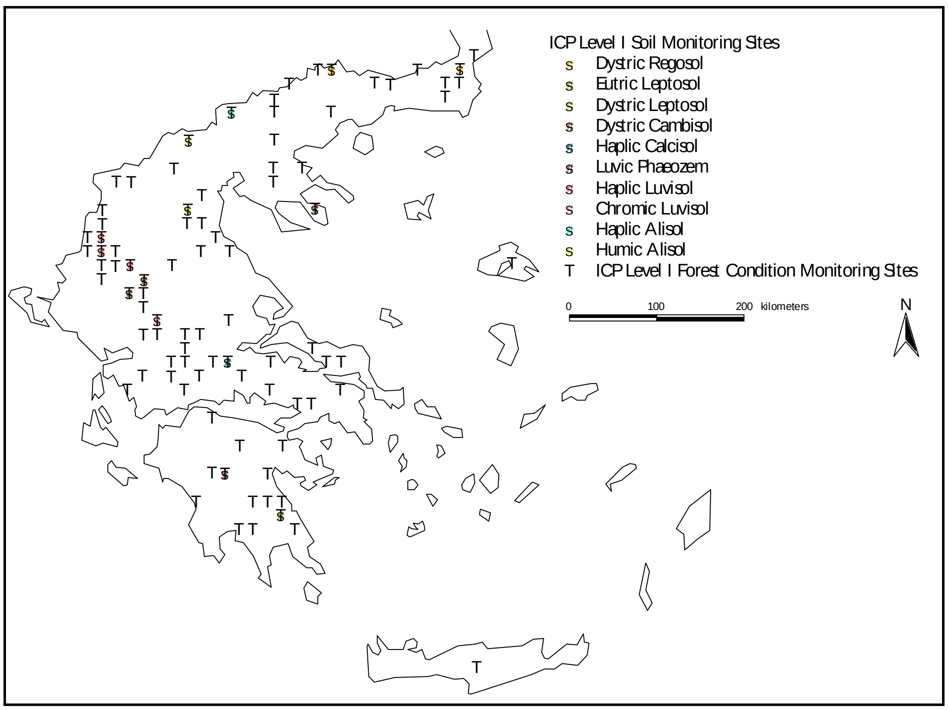


Figure 11-3 Distribution if Level I plots in Greece

Sampling of the litter layer/O layer

The differentiation between the litter layer, fine woody debris, fresh residues, humus horizons, O layer and soil carbon were discussed above. Before the humus horizons were sampled, the material L was removed. Then, the F+H horizons were sampled together after fresh plant material and any coarse organic matter (such as fine woody debris) were removed. The F/H horizon was separated to the A horizon by hand. Cylinders were used to sample the humus horizons.

Sampling of the mineral soil

Only small soil pits were dug with a shovel which had prevented to estimate the stone content, and to sample for bulk density. Only the mandatory depth classes under the ICP Forests Level I inventory were sampled: 0-10 cm and 10-20 cm. If the stone content appeared to be too high, sampling took place in an adjacent area. At each subplot, there was no particular place for sampling. Roots were removed by hand or by knife.

Laboratory analysis

The concentration of soil organic carbon was analysed using wet digestion (cold oxidation) by means of a dichromate-sulfuric acid mixture ($K_2Cr_2O_7$). With this method, carbon is oxidized only by the dichromate, heated at 120°C (internal heat). Without external heating, the oxidation of carbon is incomplete, and a so-called **oxidation (recovery) factor** needs to be applied (76% are usually assumed to be oxidized). These frame conditions have to be maintained if a second sample is analysed for changes in organic C.

B. Soil map data

a. Soil Geographical Database of Europe

The mapping data of the Soil Geographical Database of Europe SGDBE, scale 1:1,000,000 (version 3.2.8; European Soil Data Base 1.0) were used (Figure 11-4).

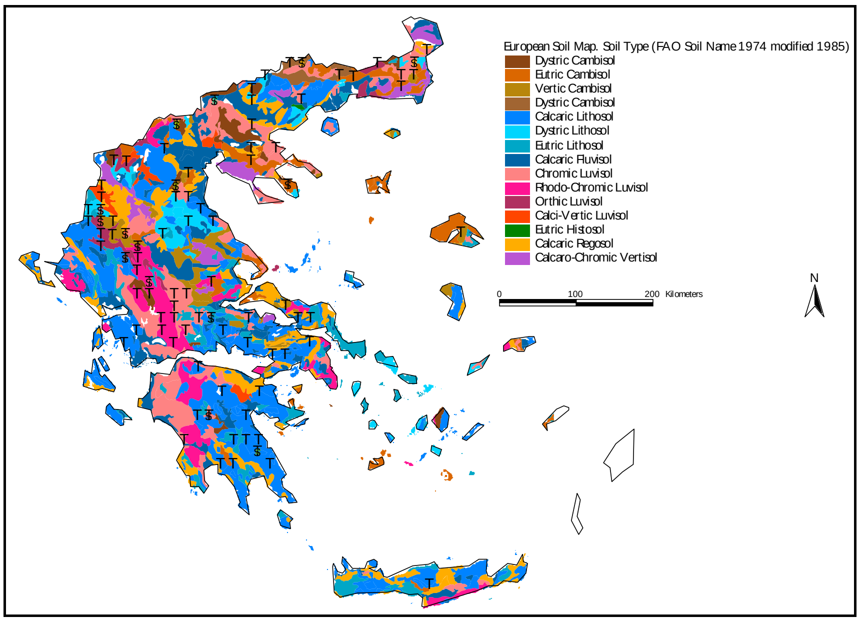


Figure 11-4 Soil map data for Greece

b. Land Resource Survey of Greece

In a later stage of the GHG reporting systems, the Land Resource Survey of Greece (Nakos et al. 2009) might be utilized as higher resolution for the regional distribution of soils. The data base has been developed from roughly 2,260 plots sampled 1979-1998 (the forest floor was included in the sampling). The data were used to draw soil maps at the scale 1:50,000. The forest soils are fairly well represented there.

It has to be note that even though the maps are not digital, some important results are relevant for evaluating the ICP Forests monitoring plots, e.g. to study the representativity of the existing soil plots:

– list of main parent materials under forest:	Flysch, Hard Limestone, Tertiary deposits, Peridotite, Schist, Gneiss and Granite
– list of main elevation classes (also used to indicate vegetation zones)	– the Mediterranean zone (0-500 m) – Sub-Mediterranean (500-1000 m) – Mountainous (1000-1700 m) – pseudoalpine (1700-2500 m).

The vegetation zones are further described with the representative plant species in Greece. The evaluations of the plot data were able to provide some average soil carbon stocks (and uncertainty estimates) for each of the above-mentioned strata.

It is currently under debate whether these values could help developing a representative soil carbon baseline (thus Tier 2 defaults values) for all of Greece, combined with the Level I soil data. Change rates received by the repeated Level I/II measurements could be applied to those strata, for which the plots are assumed to be typical. In that case, Greece would adopt the process-based approach to determine the sink/source behaviour of the soil carbon pool.

Climate

Climate and land use are the most dynamic external site factors in the soil process chain. In managed environments, most of the temporal variability originates there. Climate data thus are fundamental in explaining the distribution of soil carbon. The available observation plots under Level I should represent the most important climate types in Greece.

For that purpose, the meta data about most suitable (and available) climate data sets were evaluated (table 11-1). The objective in using this continental-wide data is to develop a soil carbon predictive model which helps to validate regional SOC data (based on insufficient plot densities). In this first descriptive approach to representativity, the distribution of Level I soil plots in different climatic areas is interpreted by the locations of plots and the expression of the climate at the same location in the climatic grids.

Table 11-1 List of Europe-wide (and beyond) climate data sets suitable for spatial modelling

Data set	Web-link	layers of interest for SOC modelling
POSTEL	http://postel.mediasfrance.org/en/DOWNLOAD/Biogeophysical-Products/ Niederschlag über http://www.gmes-geoland.info/CS/CSP/download.php downloadbar resolution: 0.04° = 0.4 x ~ 111 km = 4.4 km	– **precipitation** 1995-2004, 0.04°, 10 days (source: METEOSAT) – **surface temperatures** 1999-2005, 0.05°, 0.5h / 10 days / month (METEOSAT) (see also Annex I)
CRU TS 2.1 Climate Database	http://cru.csi.cgiar.org/ **CRU** = Climatic Research Unit **TYN** = Tyndall Centre for Climate Change Research CRU TS 1.2 10' Europe 1901-2000 time-series t resolution: 10' = 10 x ~1.86 km = 18.6 km	– **frost day frequency days** (frs) – **precipitation millimetres** (pre) – **daily mean temperature** degrees Celsius (tmp) (see also Annex I)
PRUDENCE project	PRUDENCE climate data sets: the PRUDENCE data server is a collection of climate model output from the PRUDENCE project. http://prudence.dmi.dk/ resolution: unclear	monthly means generated on a daily data set 30 or 31 years of coverage interpolated to a common grid (the CRU grid) (see also Annex I)
WORLDCLIM	http://www.worldclim.org/current.htm) Climate database 1960 – 1990 (Historical Climatology Network GHCN/ FAO); 30 s spatial resolution - interpolated at 1 km grid	– monthly mean, min., max. temperature, monthly precipitation – 20 additional bioclimatic variables derived from temp. and precip. Data – scenarios

Because of the favourable spatial resolution of ca. 300 m, and a sufficient agreement to topographic data (visually compared), the WOLRDCLIM data sets seems superior to the other data sets (Figure 11-5).

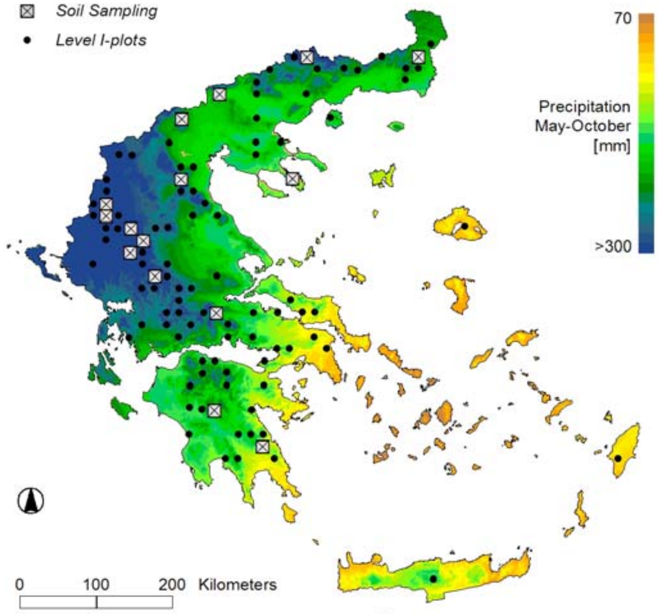


Figure 11-5 WOPRLDCLIM data for Greece [precipitation May-October]

Bio-geographic regions

Site factors vary at different scales throughout the landscape. In previous soil C studies it was found that different parameters help to split large data sets into ecologically meaningful strata. One very important data source is the border of bio-geographic regions, which separate landscapes based on the dominant physio-geographic features, which affect the potential national vegetation. Bio-geographic regions thus represent the dominant macro-scale site factors acting on the living environment.

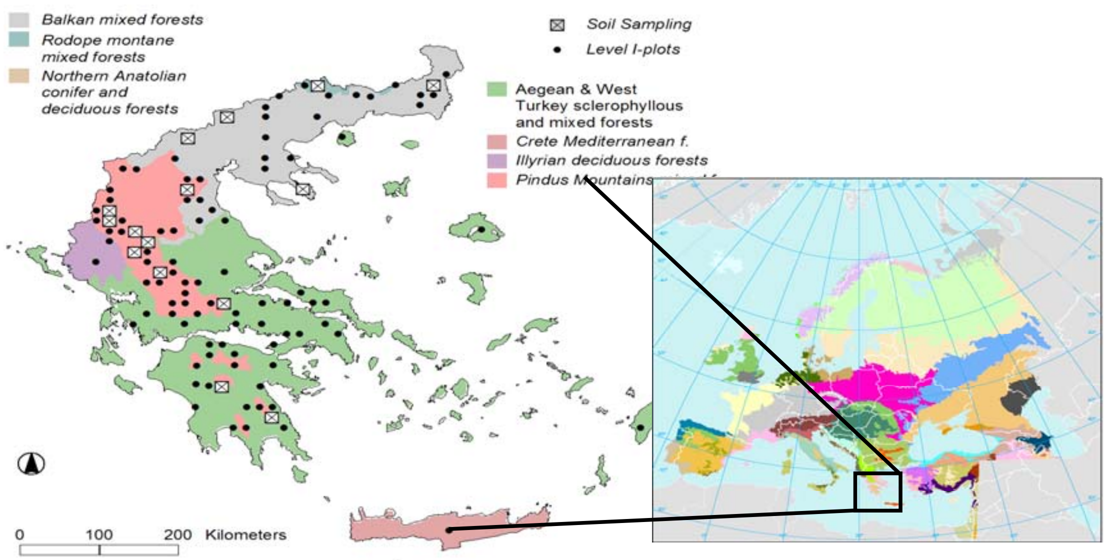


Figure 11-6 Bio-geographic regions of Europe (clipped for Greece)

The general idea of bio-geographic classifications is to identify "homogenous" areas within the complex landscape pattern in Europe for ecological landscape stratification.

For MASCAREF, the *Map of European Ecological Regions* [DMEER] (EEA/ETC BD 2000) was used [N = 68 classes; 1:2,500,000] (Figure 11-6). The main data basis is the Map of the Natural Vegetation of Europe, Scale 1:2,500,000 (Bohn et al. 2003). Thus, the eco-regional map provides a rough overview of the natural site conditions in Europe including climate.

Relief

Relief parameters such as elevation and slope aspect play an important role to predict soil C in the landscape. This is especially true for mineral soil carbon. Relief affects vegetation growth, the disturbance pattern, the distribution of soil water. It represents meso-scale effects on the soil climate, and vegetation growth. Figure 11-7 presents elevation for Greece.

The data base used for MASCAREF is the Shuttle Radar Topography Mission (SRTM), an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). Unedited SRTM data is released to the public. For areas outside the United States 3 arc-sec (~90 m) resolution data is available (via ftp at: ftp://edcsgs9.cr.usgs.gov/pub/data/srtm/).

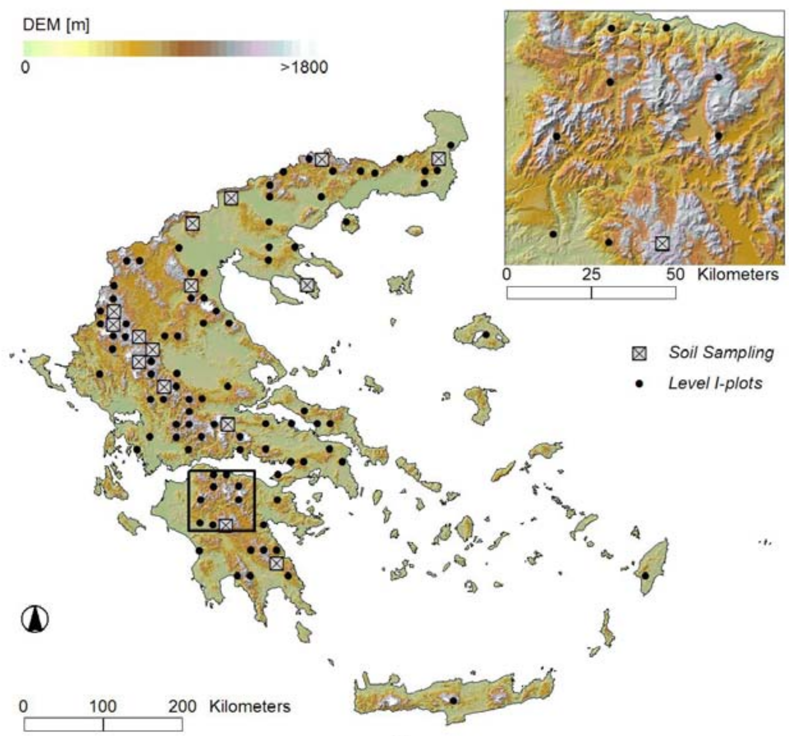


Figure 11-7 Elevation for Greece from the SRTM digital elevation model

Land cover

CORINE 100 m resolution data were downloaded from EIONET (Figure 11-8). The layers for mixed, broad-leaved and coniferous forests were used. The definitions of these land cover categories are expected to match the national definition of high forest.

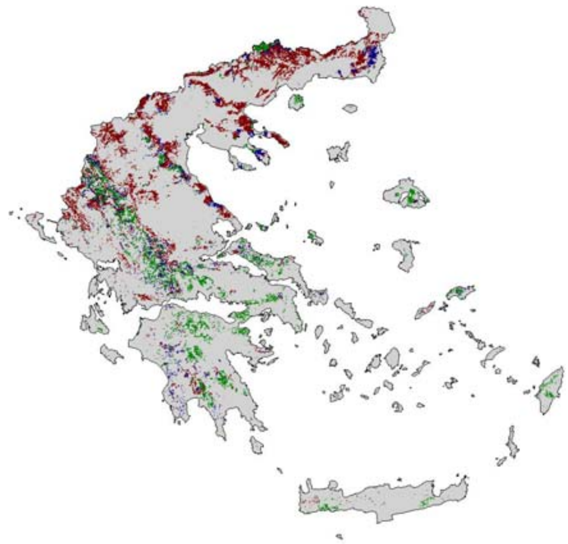


Figure 11-8 CORINE land cover for Greece (mixed, coniferous and broad-leaved forest categories)

11.3.2. Representativity

The representativity of the inventory sites is crucial as to assess the validity of estimated soil properties. Especially if the number of sites, for which measured data are available, is low, the locations for sampling have to be carefully selected. An inventory where the locations of the inventory plots[31] are coming from an expert-based selection process (could also be statistical if adequate representativity criteria and sufficient data were available) would be called a stratified sampling design. Given a proper local sampling design and given that the local variability is captured (by having sufficient subsamples), few plots at the landscape level may be sufficient to detect SOC changes (with high accuracy at the plot level).

However, the Level I inventory is systematic, thus the locations are selected randomly. In addition, the number of subsamples is fairly low. In order to statistically verify SOC changes from repeated measurements for such an inventory, the validity of site/forest stand conditions for which the results are valid, is restricted.

At each plot, one sample was taken from each of the four subplots. From the reconstruction of the sample processing, it is assumed that all four subsamples were analysed separately, and a mean of the four values was reported. It is further assumed that the mean value contains all four subsamples, meaning none of the subsamples was excluded because of local site conditions which might have differed from those dominating at the plot. For the check for systematic errors it is important to know that only one lab was involved in the analysis (Forest Research Institute of Athens), and that two researchers and two technicians were conducting the sampling of all N=15 plots.

[31] A **plot** here refers to the Level I location which represents a forest stand as one point in the 16 x 16 km grid. At each site, four **subplots** are sampled, at which one **sample** or several **subsamples** could be taken. Any location at which samples are taken, could be a sampling site. Statements involving plots usually refer to the (macro-/meso-) landscape scale, while the local sampling design (samples/subplots/subsamples) refers to the local (micro-)scale (e.g. effects of forest stand structure, micro-topographic pattern).

11.3.3. Method

Considering the available data, basically two approaches to investigate the representativity of a network of sampling or observation plots are feasible:

1. descriptive approach
2. semi-quantitative approach

The **semi-quantitative approach** has been applied in the CarboInvent project. A model of predictors for soil C was developed, and the distribution of the available sampling plots to represent the expressions of the predictors could be tested (quantitative part). At the end, simple descriptive comparisons based on area proportions determine the number of needed samples per predictor or inventory stratum. Because such a model is not yet finalized for soil carbon in the Mediterranean (though under construction), the descriptive approach has to be excluded for now.

The **descriptive approach** is based on comparisons (area proportion/number of plots) of important Section 3.1. In order to receive an approximation to the distribution of important site factors for the high forest (see selected CORINE categories), a random set of 1,000 plots was established for the forested part of Greece. The frequency of the investigated site factors in the random plots could then be compared with the actual frequency in the Level I crown condition survey and the Level I soil subsample.

11.3.4. Results from the descriptive approach

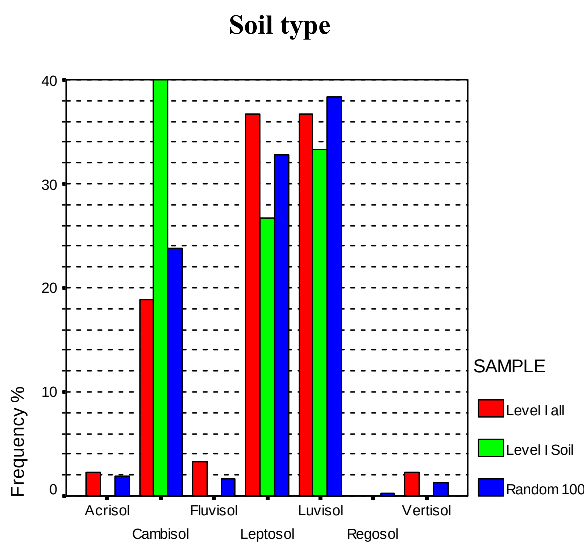


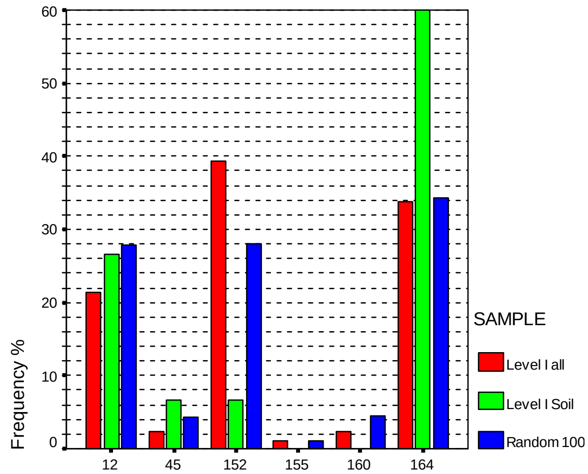
Figure 11-9 Representativity of soil types

Figure 11-9 presents the comparison between the soil types found at the plot locations of the three inventory systems:

- Level I all: the full Level I crown condition plots
- Level I soil: a subset of the previous network where soil was sampled
- Random 100: a randomly selected network of sites N=1,000

It becomes clearly visible that the Cambisols are by far over-represented. However, this was to be expected due to the selection criteria for the Level I subset for soil sampling.

Ecoregion



12 = Balkan mixed forests

45 = Rodope montane mixed forests

152 = Aegean & West Turkey sclerophyllous and mixed forest

155 = Crete Mediterranean forests

160 = Illyrian deciduous forests

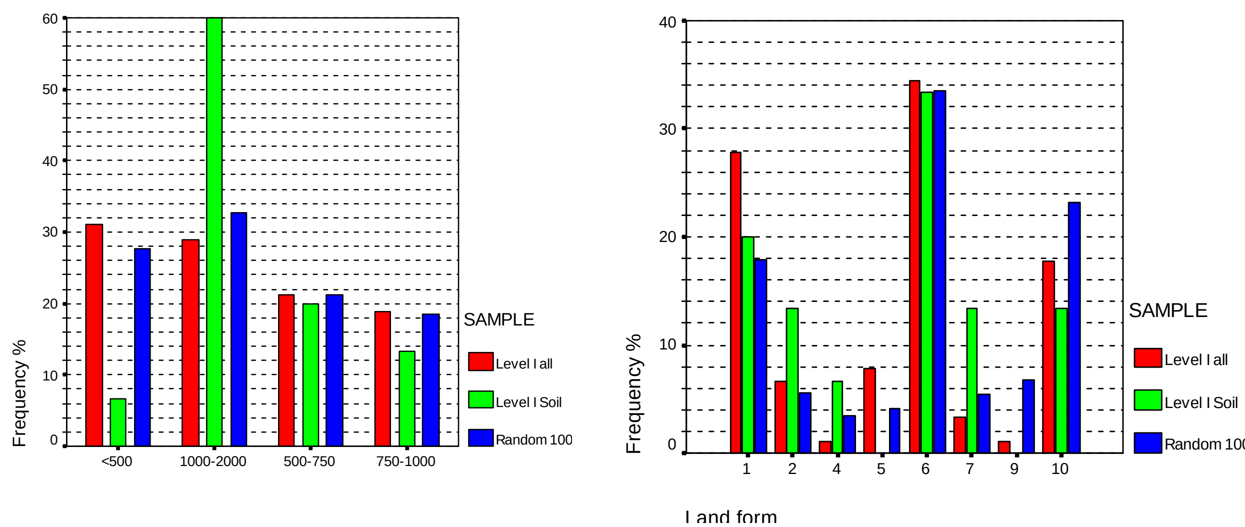
164 = Pindus Mountains mixed forests

Figure 11-10 Representativity of Ecoregion

It can be seen in Figure 11-10 that the Level I soil subset is clearly under-represented in the Aegean & West Turkey sclerophyllous and mixed forest (code 152). Again, this is the result of the selection criteria for the soil network.

Relief

a: Land form units **b: elevation**



1 = Canyons, deeply incised streams

2 = Midslope drainages, shallow valleys

4 = U-shaped valleys

5 = Plains

6 = Open slopes

7 = Upper slopes, mesas

9 = Midslope ridges, small hills in plains

10 = Mountain tops, high ridges

Figure 11-11 Representativity of geomorphographic units (land form units, elevation classes)

The evaluations with the digital elevation model show that the lowland forest sites are clearly under-represented – as expected. Because various relief-derived site factors affect the distribution of soil carbon (especially mineral soil C), average regional baseline values for soil C which are based on 15 soil plots only will be strongly biased when compared to the total area of high forest.

Temperature

[Mean of the monthly maxima, May to October]

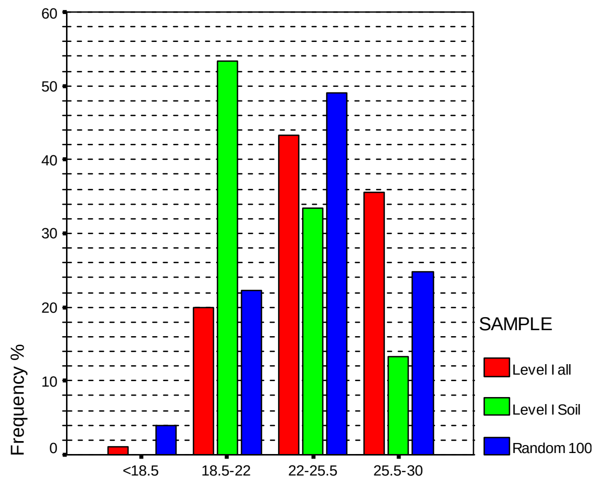


Figure 11-12 Representativity of temperature

The approach taken for temperature shows that the soil inventory clearly dominates in lower temperature regimes, which relates to high elevation sites. The same evaluations were also conducted for precipitation (results not shown here).

11.3.5. Conclusions

Strong deviations from the site conditions are to be expected because of the selection criteria for the soil inventory plots. It must be investigated whether the selection criteria (acidic forest soils with high forest) correspond to those defining the "Kyoto forest" for Greece. From the statements received about the forest definition, and what will be reported under the Kyoto Protocol, it seems that the full Level I inventory reflects the typical site conditions rather nicely.

Given that there is currently no capacity to extend the inventory , and give that repeated measurements will only be available for the Level I soil plots, this representativity analysis will provide auxiliary information as to judge the reliability of the sink/source estimate for the "Kyoto forests".

11.4. *Improved sampling for GHG reporting*

11.4.1. Sampling design

Consistency with the initial sampling design

In order to minimize systematic errors, any deviations from the sampling design of the first inventory in 1993/1994 must be prevented. In order to be as consistent as possible, a member of the former sampling team must accompany the second assessment.

The re-sampling visits each of the four subplots, which are located 25 m in distance to the plot centre. While the plot centre is not necessarily clearly marked or visible (the adjacent dominant tree was marked with a spray; sometimes the tree is felled, or thrown, etc.), the subplots can be easily found because they are marked with a wooden pole (that sticks out ca. 50 cm above-ground, its tip is painted). The location for sample is determined to be directly adjacent to the pole.

While a shallow soil pit was dug for the sampling mineral soil, a 20x20 cm metal frame was used to sample the F and H horizon. In order to facilitate further re-sampling, notes are to be taken for the aspect and distance of the sampling site from the pole

Soil pits to estimate the stone content and bulk density

The stone content has to be visually assessed in the field. Also the gravel content in the material sampled with the cylinders has to be taken into account. With the data for stones and bulk density, also the carbon concentrations from the first inventory (sampling 1993/1994) can be re-calculated to soil carbon stocks (mineral soil 0-20 cm, humus layer: F and H horizons). Thus, the carbon stocks between the two inventories become comparable. In addition, the pits must be large enough so that the cylinder to measure the bulk density can be pushed into the soil. It was experienced during the testing (see below), that enough space must be available to avoid losing sample material while pulling the cylinder out of the soil. In addition, the pit must have a minimum with (ca. 2 or 3 x shovel) so that a measure stick can be kept in the profile the same time the samples are taken (Figure 11-13).

At least one of the four shallow pits has to be large enough so that the soil can be classified, the stone content be reliably estimated, and the cylinders can be correctly inserted into and pulled back out of the profile wall (Figure 11-13). Even though the soil pits are fairly shallow, the re-sampling will extend the initial sampling design to lower soil depths, including depths of 20-30 cm, and 30 to 40 cm. In the improved design, a total of 4 depth classes is sampled.

Figure 11-13 Soil pit for sampling 0-10, 10-20, 20-30, 30-40 cm

Litter layer

An additional major improvement to the sampling design is the sampling for litter. This was done even though the sampling would be conducted only for the first time. **If possible, a repeated assessment can be conducted at the end of the commitment period. This is currently being discussed.**

Usually, any coarse, fairly fresh and non-decomposed organic material is removed from the soil before sampling the O layer. Therefore, soil inventories systematically exclude litter from sampling. In rare cases the L horizon is sampled (see Chapter 3), but still the coarse organic material (fine woody debris) is excluded. With this sampling design we attempt to fill this gap in a limited amount of soil plots. This part of the re-sampling can therefore be considered a feasibility study.

Figure 11-14 Vegetation quadrat for sampling the litter pool

A $1m^2$ quadrat for vegetation sampling was built and used for sampling the litter layer (Figure 11-14). In order to be consistent with the ForestBiota pool definitions for dead wood (compare with definitions in Chapter 3; the smallest sub-pool is "lying downed pieces" with a diameter at the thick end ≥ 5 cm), all coarse organic material below a diameter of 5 cm (at the thick end) was sampled and brought to the lab to determine its dry weight. The litter layer was sampled at each of the four subplots. Figure 11-15 presents an image of the litter layer (L horizon and fine woody debris).

In order to determine the C stock in the litter layer, conversion factor to estimate the carbon content of the dry weight is needed, either as a default of 0.5, or determined analytically. The analysis, for example, could focus on some typical sites, or fractions of the litter sample (e.g. leaves, twigs, cones, for typical tree species).

Figure 11-15 Litter: Fine wood debris and L horizon in high-altitude Pine forest

Consistency with the sample processing, storage and laboratory analysis

During the initial soil inventory, the samples from the four subsamples were archived separately. It assumed the NAGREF laboratory has separately analyzed all four subsamples, and only a mean value was reported to the ICP Forests Soil Coordinating Centre. This is necessary, because the variability at the plot level is extremely high, considering the 25 m distance to the plot centre (thus the subsamples are located at 50 m distance).

Storage of the samples after 40°C drying, and sample analysis after 105°C will be maintained. Coarse organic material from the mineral soil sample will be removed prior to the analysis, by sieving the sample (2 mm ∅).

The original method to analyze soil carbon in the initial design is the wet oxidation wet oxidation with $K_2Cr_2O_7$. This method will be maintained for the analysis of the re-sampling.

11.4.2. Testing the design in the field

In soil monitoring, the repeated sampling of exactly the same site is impossible – partly because each sampling is disturbing the soil, partly because vegetation dynamics, mechanical disturbance from grazing, burning, management activities, natural die back, prevent it. Therefore the same frame conditions for the production, distribution and decomposition of litter can not be found again. These aspects add to the local variability, which can only be compensated by a large quantity of plots and/or sub-samples.

These limitations have to be especially taken into account, if the total number of samples is fairly low. As of today, we have little knowledge about identification and quantification of errors from sampling. This can be done for the Greece soil inventory when the sampling campaign will be completed. The initial testing of three of the 15 soil plots has refined the sampling design already, and has been incorporated into the design description under Section 4.1 (for example, the decision not to mix samples was taken after experiencing the variability of the local (and typical) site conditions during field visits).

11.4.3. Outlook

The objectives of this case study were to identify important frame conditions for soil carbon and litter carbon monitoring. The requirements to monitor these pools at a Tier 1/2 level are coming from the decision to elect forest management under Kyoto Protocol Art. 3.4 (KP 3.4). In the case of Greece, that part of forest included in KP 3.4 is restricted to high forest. This type of forest is also covered by the 16x16 km Level I forest crown condition survey. Unfortunately, personnel and laboratory capacities prevented a complete Level I baseline survey, so that only a subset of 15 plots is available. In addition, Greece did not participate in the BioSoil project (only with its N=4 Level II plots), so that major drawbacks are to be expected unless the experiences from the MASCAREF project are being used to re-sample the full soil subset. In addition, methodological ideas regarding the representativity of the plots can be used to estimate the quality of soil C stock change estimates.

11.5. *References*

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Annex I: European climate data sets - details

1. CRU/Tyndall: List of data offered for download

CRU CL 2.1 10' Europe 1961-1990 climatology cld, vap Mitchell et al, 2003 available on request

CRU TS 1.2 10' Europe 1901-2000 time-series pre, tmp, dtr, vap, cld Mitchell et al, 2003 available on request

TYN SC 1.0 10' Europe 2001-2100 scenarios pre, tmp, dtr, vap, cld Mitchell et al, 2003 available on request

TYN CY 1.1 country 1901-2000 countries pre, tmp, dtr, wet, vap, cld, frs, tmn, tmx Mitchell et al, 2003 available for download

TYN CY 2.0 country 2070-2099 countries pre, tmp Mitchell et al, 2002; extended available for download

TYN CY 3.0 country 1901-2100 countries pre, tmp, dtr, vap, cld Mitchell et al, 2003 available for download

Parameters offered:

a) ***cld*** cloud cover percentage

b) ***dtr*** diurnal temperature range degrees Celsius

c) ***frs*** frost day frequency days

d) ***pre*** precipitation millimetres

e) ***rhm*** relative humidity percentage

f) ***ssh*** sunshine duration hours

g) ***tmp*** daily mean temperature degrees Celsius

h) ***tmn*** monthly average daily minimum temperature degrees Celsius

i) ***tmx*** monthly average daily maximum temperature degrees Celsius

j) ***vap*** vapour pressure hecta-Pascals

k) ***wet*** wet day frequency days

l) ***wnd*** wind speed metres per second

2. Specifications of the parameters available for the PRUDENCE data set:

a) *t2m2*-**meter temperature (K)**

b) *precip* **Precipitation (mm/day)**

c) *clcov* **Total cloudiness (Fraction)**

d) *evap* **Evaporation (mm/day)**

e) *snow* **Snow water equivalent (mm)**

f) *runoff* **Total runoff (mm/d)**

g) *soilw* **Soil moisture (mm)**

h) *Psurf* **Surface pressure (hPa)**

i) *MSLP* **Mean sea level pressure (hPa)**

j) *t2max* **Daily maximum 2-meter temperature (K)**

k) *t2min* **Daily minimum 2-meter temperature (K)**

l) *w10m10*-**meter wind speed (average length of the wind vector) (m/s)**

m) *w10max10*-**meter daily maximum wind speed (m/s)**

n) *q2m2*-**meter specific humidity (kg/kg)**

o) *SWnet* **Net SW radiation (W/m^2)**

p) *positive SWdown* **Downward SW radiation (W/m^2)**

q) *positive LW***net Net LW radiation (W/m^2)**

r) positive LWdown Downward LW radiation (W/m^2) positive downward

12. Challenges and Possibilities in Implementing NFI-based LULUCF - sector Reporting in Romania

Olivier Bouriaud, Gheorghe Marin and **Viorel Blujdea**
Forest Research and Management Institute, Romania
Email: obouriaud@icassv.ro and ghmarin@icas.ro

Göran Ståhl and **Sven Hans-Olof Petersson**
Swedish University of Agricultural Sciences, Sweden
E-mail: Hans.Petersson@srh.slu.se and Goran.Stahl@srh.slu.se

12.1. *Introduction*

According to the IPCC good practice guidance 2003, inventories consistent with good practice are those which contain neither over- nor underestimates so far as can be judged, and in which uncertainties are reduced as far as is practicable given national circumstances.

According to the IPCC GPG 2003, there are some essential aspects that inventories should present, like transparency, the consistency in time, the assessment of uncertainties, a quality control and the reduction of uncertainties when information becomes available. These central characteristics of the inventories that are supported and encouraged by the IPCC GPG could not be achieved by a slight change of the existing inventory and reporting system in Romania because too radical. Instead of adapting the existing forest inventory, a new one was developed based first on the examination of the current demands.

Romania's GHG reporting and emission reduction commitments are related to forestland and forest management activities. Romania is an Annex I country with an emission reduction target listed in Annex B of the Kyoto Protocol. Consequently, it annually reports GHG removal and emission both associated with all land use categories under the Convention. Romania prepares as well mandatory reports on afforestation, reforestation and deforestation activities (ARD) under Art. 3.3, and forest management activities (FM) under art 3.4 of the Kyoto Protocol, for 2008-2012.

12.1.1. Description of current GHG reporting system in 5A Forestland ("old" system)

The current reporting adopted Approach 1 for land representation and Tier 2 for C stock change estimations, both for the activity data and the C stock change factors. It is based on available national data and information and it uses the gain loss method. Activity data is given by national statistics, which is a time and space aggregate of the forest area, as provided in forest management plans. The estimate of C stock change factors relies on the aggregation of forest management plans data (from 1985). The plans cover only annual wood increment, while other pools are not reported or are reported based on various other sources (IPCC, national literature). The current reporting under the Convention has numerous weaknesses. For example, forest growth is given according to old forest inventory performed in 1985; the age structure of forests is not taken into account; the current system has no ability to rigorously detect degradation and deforestation areas.

12.1.2. Description of new data sources for GHG reporting system in 5A Forestland (“new” system)

A National Forest Inventory (NFI) was started in 2006, designed to cover all Romania’s forest vegetation, inside or outside forest lands. The Romanian NFI is a continuous inventory on a five-year inventory cycle. It is based on a two-phase, systematic and stratified sampling that combines repeated measurements of permanent plots with measurements of temporary plots. The first phase consists in aerial photo interpretation over a 500x500 m grid. The ground plots (second phase) are located on a 4x4 km grid over foothill and mountain regions, and a 2x2 km grid on the plains because of a very low forest cover (sub-sample of the first phase grid). The estimation of the forest area is based on the total country land and inland water areas, and aerial photo-interpretation of a 500x500m grid.

With the new NFI, the future reporting would be based on Approach 2 or 3 for activity data (land area and changes) and on Tier 3 for C stock change estimation.

The current reporting capacity for supplementary reporting under Kyoto Protocol has numerous weaknesses, such as those related to the estimation of removals and emissions from the forest sector; these emissions/removals may be used for crediting and target compliance.

Luckily, the, reporting does not require many data from base year due to the accounting rules. This means that the decision to develop methodologies for the estimates of emissions and removals in the LULUCF sector is still in due time (with the exception of revegetation for which base year data from national statistics are available and reliable).

The present report serves to investigate the *challenges imposed by a transition* from reporting based on current system (based on National Statistics) to a new system (based on new National Forest Inventory), and to *early identify related research needs* and their timely settlement, as well as to identify *any necessary improvement* that National Forest Inventory (NFI) approach may need, in order to improve its appropriateness under GHG inventory and Kyoto Protocol reporting.

The following table presents the basic parameters used in GHG reporting under UNFCCC, the difference between the current and the potential reporting based on NFI and the methodological approach needed to improve the reporting based on NFI, endeavored in the near future.

In most situations, the new inventory either brings a higher resolution or provides data where defaults IPCC values have been used so far. In the situations where the two approaches can be implemented (the old one based on updating the 1985 forest inventory, the new one based on the systematic NFI) the estimations could be compared, but the interpretation of the differences would be tricky. The two estimations could be used to produce an uncertainty assessment.

With the new NFI, a change of GHG estimation method from current “Gain and loss” to “stock change” is expected. Lately it tends to be more reliable because of the decreasing reliability of national statistics (especially regarding loss by privatization of forests) in recent years.

12.2. *Estimation of land-use categories and land-use changes*

12.2.1. Land use consistency

While definitions of land categories did not change significantly since 1990, forestland definition changed twice, a first time in 1996 with the first forest code, and a second time in 2008 with the last forest code. There is no impact study on the quantitative effects of forest definition change, but in practice, it seems that there is no impact on the reporting of forestland area in National Statistics (it continued according the rules before).

It should be mentioned that the current system provides an “official land use” which may not match with the “actual land use”, because of lack of controls in the field.

One issue for the forestland is that under the “old” system, the total national area covered by forest vegetation was split into “national forest fund” and “forest vegetation outside forest fund”, from an administrative point of view. The “national forest fund” or “forest fund” includes all forest lands where forestry activities are realized according to an officially approved management plan, regardless of the land owner or the use (production, protection, reforestation, etc.). Since 2008, the definition of forestland changed to include all lands that are covered by forest vegetation with certain characteristics (Law 46/2008).

The national forest inventory uses IPCC categories. The definitions of forestland category are consistent with the IPCC GPG LULUCF (2003) therefore they directly meet reporting requirements. NFI will classify land use/cover at the country level, on a 500m x 500m grid and based on aerial photo-interpretation. Land use/cover classes are 7 classes and 67 categories, as in the FAO classification system (FAO 6th and 7th categories were merged at the 6th IPCC).

The fact that the land-use categories in IPCC GPG 2003 (Forest Land, Cropland, Grassland, Wetlands, Settlements, Other Land) match the Romanian statistic system of land use reporting enables the use of Approach 1 for land representation (data refer to net land use category at the end of year, rounded to thousands ha). The land classification is done according to land use and management data available since 1970.

12.2.2. Conventional definition of land use change

In the former system, conversions from forest were considered according to the legal definition, i.e. a permanent removal of forest trees and change of land use to non forest, without any area reference (it may be very small).

The new system uses the same definitions. It offers the support of the GIS to quantify and localize the area concerned.

12.3. *Forest area*

12.3.1. Definition

In the old system, the land that complied with the forest land definition was land with a minimum area of 0.25 ha and it had to be included in a management plan; no reference to height of trees or the consistency of the stand was made. A key advantage of the new NFI is that it will cover current "forestland" at national level by assessing the forestland according to the last definition of forest, which differs from 1990 one.

In contrast, the new system is defined by surface, crown cover and tree height: forest is defined as an area > 0.5 ha, with a crown cover >10% width > 20m and height > 5m. The area estimations are based on aerial orthophotographs (on a square grid of 500x500 m). The area will be re-estimated from aerial photographs every 5 years (at each NFI cycle). Other land uses inside forestland are included and described in the current inventory if they are bigger than 0.25 ha. Plots of the aerial 500x500 grid that belong to either the 4x4 or 2x2 km ground plots grids will be checked in the field.

Regardless of the definition, all forests are considered managed. Protected areas are included under managed forests, as well as understocked and degraded forests.

12.3.2. Estimation of forestland area

Currently, the forest area assessment is done each 10 years, when forest area is measured on basic forest maps (by planimetration), for the purpose of forestry planning. The initial forestland area is rolled over between two successive planning (each 10 years), by adding and subtracting annually deforested and afforested areas to the area in the previous year. Data are provided by the forest statistics and therefore they are available only for the "national forest fund". Records of the increase and decrease of the forest area is made at the smallest (most disaggregated) forest management unit level. The system does not provide uncertainty estimate for the area. Theoretically, the error associated with area measurement in forest management planning is less than 10 %. It includes the error associated with basic forest map (scale 1:5000) and planimetration operation, as well as errors associated with the measurement of added or subtracted areas from the forest fund. Additionally, rolling of forest area between 2 successive plans (10 years), is involving a high degree of autocorrelation for annual data that should be accounted for the estimation of uncertainty.

The current system is able to detect other land use inside forestland: roads (if above 4m width), nurseries, annual crops and short rotation woody crops (i.e. willow). The NFI would be able to detect other land uses inside the forestland if > 0,25 ha.

In the new system, the forest area assessment would be done once every 5 years only, based on aerial-photo interpretation on a 500x500 m grid, and it uncertainty estimates would be provided.

UNFCCC reporting: The forestland area dynamic since 1990 would have to be rechecked. If there is a good match between the available National Statistics and NFI results (i.e. small area differences on overlap years) it may not be necessary to re-estimate the annual national forest area according the new NFI data. But if there are significant differences according to the two approaches, it could be worthwhile estimating the area at least in the base year and other intermediate years (i.e. every 5 years, namely in 1995, 2000 and 2005), using a protocol that would allow comparability with NFI approach. Such approach could be based on satellite images, for example. This obviously implies backward extrapolation with costly procedures and limited outcomes in terms of precision and uncertainties.

KP reporting: It could be completely based on the first NFI cycle data. NFI shows a perfect match of timing with KP reporting commitments for forest management (FM): the 1st year of 1st NFI assessment in 2008 and the 1st year of 2nd cycle in 2012.

12.4. *Afforestation and reforestation*

The former system did not make any difference between afforestation and reforestation, as defined under UNFCCC. Conversions from non-forest land (CL, GL, SL, WL and OL) to FL are recorded as “afforestation of non-forest lands”, and the previous land use is not always mentioned or classified as “degraded”. Therefore, the original land use can not be accurately established. . Consequently, the current land use matrix is constructed using generic assumptions related to land conversions (i.e. increase of settlement area; the share of afforestation on cropland and grassland is deduced from afforestation documentation). The resolution -minimal area of land use change detection for “conversion from forest”- is indefinitely small because it is measured individually in order to achieve the deforestation documentation. On the other hand, the “conversion to forest” is detected if above 0.25 ha (area limit of forest definition). In the former system, all information on land use changes to/from forest is extracted from forestry statistics.

With the new system, data would become geographically explicit through a geographic information system implemented within the NFI, which would allow the adoption of Approach 1 for land representation and Tier 3 for activity data. Afforestation and deforestation area would become default NFI outputs. However, the data will not be available before the 2nd NFI cycle, i.e. after completing the first national-level cycle in 2011. The resolution for any conversion involving forest is set to 0.25 ha.

UNFCCC reporting: the afforestation statistics available are reliable and they will be used also from now on. When area data from NFI will be available, a cross check of the two sources should be performed in common years. Most likely, differences are to be expected between the two types of data, since NFI does not differentiate afforestation (a directly human-induced activity) from natural expansion of forest on other lands (succession) except if additional efforts are made. Therefore the area provided by NFI would probably be higher. A time combination between the old reporting (since 1990) and the new one (once the first NFI afforestation data will become available) may be used, because the total national forest area should match (i.e. sum of areas “under conversions” and “forest remaining forestland” in a year).

Kyoto reporting: GHG emissions/removals must be reported on afforestation area since 1990. Significant and unexpected efforts might be required to improve the NFI data to comply with reporting under Art 3.3. The solution is likely to be a combination between the old reporting (since 1990) and the new one (when the first NFI afforestation data will become available), as mentioned above.

12.5. *Deforestation*

Greenhouse gas emissions from deforestation must be reported, for the land areas where such activities occurred since 1990. Following the current system, conversions from FL to other lands (CL, GL, SL, WL and OL) are not transparently reported in forest statistics. Significant additional efforts to report for both areas converted to non forest and their future land use is will be needed. There are a legal definition and procedure to convert forest to other uses. The conversion from forest to non forest may occur only when permission is granted from the Ministry of Agriculture. The Ministry is supposed to produce a documentation containing the details on location, area and species involved in the land use change. The problem is that these data are not summarized anywhere, but only archived at the level of the forest districts and Territorial Forest Inspectorates.

The new system would enable the estimation of deforestation and deforestation rates through the interpretation of aerial photographs at high resolution, starting from 2008. All data are compiled in GIS, allowing the adoption of an Approach 1 for land representation and Tier 3 for activity data.

UNFCCC and Kyoto Protocol reporting: Data from the two sources may be easily combined. The old system will deliver deforestation area data for the period from 1990 to the point when the NFI data will be available (most likely during the next commitment period). Since archived data on the forest sector are not well structured, it is very likely that an improved or additional system will be needed to account emissions from deforestation area since 1990 (i.e. based on satellite imagery), and the area differences, when existing, should be transparently explained.

12.6. *Other land-use categories*

In the former system, the only other land-use category distinguished was “Woodlands”. Woodlands represent around 5 % of the national forest area according to the current definition and they are reported under National Statistics. Currently, woodlands are reported in GHG inventory as a sub-category of Forestland. The data (i.e. area) for woodlands are available in the old system under “forest vegetation outside forest fund”. The data are highly uncertain, because of a lack of clarity between “grassland with trees” and “forest grasslands in the classification at the municipality level.

The new NFI based system includes other land-use categories such as other wooded lands (area > 0.5 ha, crown cover>0.1, height <5m; or crown cover from 5 to 10% and height >5m) and trees outside forest.

UNFCCC reporting: other land-use can be reported with both systems.

KP reporting: Romania committed to report under KP only the forest management activities on “national forest fund, as of 1 January 1990” (Initial review report under KP), which means that woodlands, are not supposed to be taken into consideration neither for forest management nor for deforestation emissions/removal accounting. This issue could be indicated as a lack of completeness, and the review team may not accept it. In this case, firstly, “woodland” area may be reported under forest management, but a cross check of the area from National Statistics and from the first NFI will have to be compared (if necessary the cross check could be broke down at smaller geographical scale, i.e. county level where information on deforestation are reported). Secondly, forest removals on these lands should be accounted (deforestation) and a method based on satellite images or better/equivalent precision should be developed, thus involving a huge effort. NFI will contribute to this purpose only starting with the second cycle.

12.7. *Estimation of carbon pool change*

The former system entirely relies on inventories made for the forest management plans. These inventories, made every 10 years, were designed for the purpose of the management, not of the reporting, therefore having many gaps and limitations. Between two inventories, either models or add-and-subtract methods should be applied. NFI retains updated data on biomass, which will allow an accurate estimation of current stocks and annual sink. The advantages and disadvantages are shown in Table 12-1 and 12-2.

12.7.1. Aboveground biomass

Forest remaining forest

The forest area was classified by species but annual reports were based on add-and-subtract from previous year's areas, without any uncertainty assessment. The detection limit for the share of each species had a minimum threshold of 10% of either species area, volume or tree number. The stand age was classified in 20 year classes for high forest and 5-10 year classes for coppice and fast growing plantations. In addition to the data already reported in the management plans, the new system estimates tree age from tree cores.

There are some other noticeable improvements to the former system concerning the main biometric measurements. The first is a lower tree diameter, 5.6 against 8 cm. The NFI also provides by default diameter/height/volume distribution per region, species, etc. The average height per species can be derived from the NFI measurements while it used to be based on aggregated stand-level estimations, (again, without any uncertainty assessment) which were estimated with biometric tables.

In the former system, the volume was assessed by summing-up stand-level estimations from yield tables.

Leaves biomass is not assessed, neither by the new system.

The biomass increment is treated very differently in the new system when compared to the old one based on forest statistics. The latter based the growth estimations purely on forest growth models established in the 70's. The calculations were based on yield tables per species or species-share in the stand. They were done according to the age, the proportion and the crown cover class. The former method was assuming a modeled growth and productivity. No variations (breakdown, insect damages, climatic) could be taken into account. The predictions directly depended on the parameterization of the yield tables, which in turn depended on the updates on the situation observed in 1985. Tables are most likely outdated, since most of the biometric models were developed in Europe during the 60s/70s.

In contrast, during the first NFI cycle, the forest growth will be estimated on the basis of increment cores (tree-ring series), and all data will be available per species, region, land use categories etc. During the second NFI cycle, NFI will provide estimates based on re-measurements of the plots. The annual increment will be generated for the total above ground tree volume (not separately on stem and branches).

Afforestation and reforestation

The former system provides estimates of the C stock changes based on age and stand structure (i.e. species composition). Biomass equations (i.e. currently under development for main species used in afforestation over last 20 years) will be used to assess C stock changes in aboveground biomass at stand age level. This approach will allow both reporting under UNFCCC and KP.

Deforestation

Initially, the biomass removed by deforestation activities may be detected based on the documentation on the area converted from forest, when available (this documentation contains data on species, age of stand, total wood volume). The data on deforestation from NFI will be available only from the second inventory cycle.

Woodlands

For woodlands, data are only available from a survey realized in 1985, since there are no management plans for woodlands. The share of species estimated in 1985 is still being used nowadays within the former system to get the distribution of groups of species, while area changes are reported annually according to arbitrary inclusion or exclusion of wooded area in this category or another (usually grassland).

With NFI, the estimations of the volume or biomass per species would be realized using the same procedure as for any other forestland.

12.7.2. Belowground biomass

Belowground biomass is currently computed based on literature data and IPCC default shoot-to-root ratio that are applied at the species group level in the stand, regardless of the age.

New data on belowground biomass will not be directly available with the new NFI system until devoted equations will be developed. In the meantime, current IPCC or country specific factors may be used. Once the equations will be produced, the estimation will be systematic, dynamic and associated to an error estimate.

12.7.3. Litter

There are no fundamental differences between the former and the new system, except that the new one is not limited to the forestland but covers other land-use categories. In fact a decision has still to be taken, if the current ICP Forest data collection will be carried on or if the improved land coverage in the NFI could also cover these aspects.

The litter was assessed only in qualitative terms (thick, thin, missing) in management plans, so the annual carbon sink or source in the litter cannot be assessed.

Another chance to measure the carbon sink or source in the litter could be the ICP Forests database. In qualitative terms, the ICP Forest monitoring made two assessments of the litter C content in 2000 and 2005. However, despite the existence of the database, there is no interest in developing a GHG analysis for the litter layer to improve the GHG inventory.

Additional study should be implemented to comply with GHG reporting requirements. Existing ICP Forest measurement (2000, 2005) may be continued as such and the methodology to combine it with NFI measurements must be developed (as all these measurements to be continued by NFI). Definition of dead organic matter must be checked. Statistical coverage between ICP plots (level II) and NFI's various strata must be assessed and improved.

Additional research may be needed to include the root volume or annual growth as well as to quantify the effect of new threshold diameter used by NFI. Using wood density (WD) would induce a high uncertainty (as WD varies along the tree, is less in branches compared to hard wood). In order to develop biomass equations additional effort is needed, but in a project matched on NFI plots, as to maintain a lower uncertainty.

12.7.4. Forest understory

Understory is visually estimated, so additional research is needed to quantitatively estimate the carbon pool size and its change over time. Most likely, the annual sink is negligible in this pool and therefore it is fair to assume that it can be neglected in the estimations of removals. For a conservative approach, the emissions from this pool should be counted in case of forest fires. Currently, there are no data on understory in burnt areas. With NFI, the data on understory will be available for burned areas, while advantages compared to current approach still need to be understood (Table 12-3). In order to accurately account for the emissions from this pool, additional research is needed.

Table 12-1 Comparison of former system and NFI on carbon pool estimations

Parameters	Current approach (based on old forest inventory and national statistics)	Future approach (based on statistical National Forest Inventory)	NFI advantages (Av) / disadvantages (Dv) compared to national statistics as used in GHG inventory
Standing volume (on area, on composition)	Detailed (on area, on species within the parcel to national level)	Detailed (per region, ecoregion, land use, property etc.) but enlarged to all forest vegetation plus associated to an uncertainty estimate	Av: updated distribution of forest on wood volume Dv: upscaling
Stand composition on area	Detailed on species. Former annual area on species was generated by adding/ subtracting to previous year area	Detailed (per region, ecoregion, land use, property etc.) but enlarged to all forest vegetation plus associated to an uncertainty estimate.	Av: updated distribution on species, autocorrelation amongst years is removed which generate reduction of uncertainty. They would benefit from the estimation of errors, which the former method did not permit Dv: a reliable method to fill the annual in-between inventory years
Detection limit of the share of species (% of area, volume or number of trees)	> 10 % (according every 10 years field inventories and management plans data)	>0% (in NFI plots)	Av: better stratification of national forest land according distribution of minor species Dv: No apparent advantage
Stand volume	Computed based on above parameters and yield tables	Direct output from the NFI measurements, detailed (per region, ecoregion, land use, property etc.)	Av: Estimated with a higher precision, broken down in more categories for detailed reporting, and uncertainties estimated Dv: root is not included in either method so far
Annual increment of wood volume on stand (and on species share in total composition) (m^3/ha/yr)	Growth increment on species and groups of species is given in NFI (1985).	First NFI cycle: based on increment cores analysis. Second NFI cycle: re-measurements of plots.	Av: updated increment, available on simple or combined strata. With radial increment estimation on cores the precision is not nominal Dv: Dv: No apparent advantage
Biomass increment	Not delivered by NFI 1985.	Not delivered by current NFI	Av: Biomass increment provided in more categories. Biomass increment can be compared to changes in area or land use. Geographic interpolations can be made. Biomass increment realized both by tree-ring proxy and plot re-measurements (starting from the second cycle). Uncertainty assessment possible. Dv: More labor-intensive
Branch share (in tree aboveground volume or/and biomass).	Included in broadleaved trees volume. Not included in resinous trees volume. Volume share is available in the Forest Yield table	Same as in the older system.	Av: Uncertainty assessment possible
Leaves biomass	Not assessed	Same as in the older system (not directly available)	Av: The systematic tree-level data basis constituted through the NFI would enable regional to national estimations

Wood density on species	Available form national literature	Same as in the older system (not directly available)	No change
Wood C content on species	IPCC default	Same as in the older system (not directly available). Can be obtained based on an allometric model application or additional research.	No change
Stand age (yr)	Class of 20 years for high forest system for old forests, (1)5 -10 years for coppice and fast growing plantations system	Default NFI output	Av: Continuous. Classes can be adapted to specific demands

Table 12-2 Comparison of Forest increment, wood volume and biomass estimations for the NFI versus former system

Parameters	Current approach (based on old forest inventory and national statistics)	Future approach (based on statistical National Forest Inventory)	NFI advantages (Av) / disadvantages (Dv) compared to national statistics as used in GHG inventory
Minimum tree diameter counted (threshold)	8.0 cm	5.6 cm	Av: - NFI provides more details and increased precision Dv: limited comparability with former data, except under additional effort
Diameter distribution (on stand, stand shares, on species)	For non exploitable stands the average stand diameter is used, while for exploitable stands there is used actual measured volume.	Default NFI output.	Av: unified standard for different ages and management types stands. Majority of Romanian forests are even aged.
Average stand height (per species, stand shares)	Average tree height is computed for each species or stand	Default NFI output.	Av: high stratification possibility of stands, according various criteria

Table 12-3 Comparison of understory and belowground biomass estimations following the former system or the NFI

Parameters	Current approach (based on old forest inventory and national statistics)	Future approach (based on statistical National Forest Inventory)	NFI advantages (Av) / disadvantages (Dv) compared to national statistics as used in GHG inventory
Area covered by shrubs and its structure (i.e. species)	Assessed every 10 years and recorded in description of the forest fund. Not reliable as procedure is qualitative.	Included. Bush species (60 species) are recorded. If DBH ≥5,6 cm the tree is recorded as a tree. If diameter is smaller, the number of species, average height, coverage and distribution type are recorder (rare, dense)	Av: NFI provides both qualitative and quantitative data on understory, a better representation at the level of existing forests (i.e. on types) allowing better association with forest type and other categories (i.e. forest). Data is provided for shorter periods (every 5 years), better fitted on understory biological cycles. Dv: Difficult check of provided area. Check with former forest management planning may be done, but it is difficult as there is no global assessment at national level
Biomass (t DM/ha)	Not assessed	Not directly available (as in the older system), additional research is needed	Biomass estimations should be completed with additional information on understorey biomass, which demands additional research. For reporting, this forest pool may conservatively be neglected (the annual area where understorey is completely removed is much less than area where it strives)

12.7.5. Dead wood

Dead wood is currently not reported. Only the deadwood C stock at the level of species groups is estimated, based on ICP data. In the estimation of the C stock in dead organic matter, there is no differentiation between litter and dead wood.

The new inventory brings many substantial improvements concerning the dead wood which was not assessed by the former system. NFI covers both standing and lying dead wood. Standing dead wood is described by species, whenever the identification is possible or the species can be deduced with reasonable confidence from the stand composition. The stratification by stand type, management, land use categories is a default output, while advantages compared to current approach still need to be understood (Table 12-4).

Once the second inventory cycle started, it would be possible to include the dead wood in the report using the stock change method. However, this would require the use of specific conversion factors for each decay class distinguished in the field measurements.

Table 12-4 Comparison of dead wood estimations

Parameters	Current approach (based on old forest inventory and national statistics)	Future approach (based on statistical National Forest Inventory)	NFI advantages (Av) / disadvantages (Dv) compared to national statistics as used in GHG inventory
Standing dead wood	Not assessed	Included. Dead standing trees are accounted: species, DBH, height, decomposition class.	Av: national systematic data regarding dead wood and lying wood
Lying dead wood	Not assessed	Included: laying wood, stumps and branch stacks	
Minimum diameter considered	Not assessed	5.6 cm for standing dead trees, 10 cm for lying wood, 5,6 cm for stumps, and > 1m width/diameter of the branch stack	
Minimum height considered	Not assessed	> 1.3 m for standing dead tree 0,1-1,2 m for stumps > 0,5 m for branch stack	

12.7.6. Soil organic carbon

Soil organic carbon stock or change is not currently estimated, despite ICP data on soil exist for two different years (median 2000 and 2005), as well as numerous research studies. Reliable data on soil C stock in different type of forests are not available (this kind of data would allow using Tier 2 to estimate removals/emissions from deforestation or afforestation). For other land uses (i.e. cropland) there is no available data on C stock that would allow the estimate of GHG emissions/removals from afforestation and deforestation, while advantages compared to current approach still need to be understood (Table 12-5).

Table 12-5 Comparison of soil estimations and data availability

Parameters	Current approach (based on old forest inventory and national statistics)	Future approach (based on statistical National Forest Inventory)	NFI advantages (Av) / disadvantages (Dv) compared to national statistics as used in GHG inventory
Soil type/subtype distribution on area	Available for the forest fund (area, ha). Based on soil sampling and data processing for management plans. Soil classification is achieved at parcel level (max 30 ha) based on ecological features (sites and forest)	Included (available on type/subtype on area). Soil classification is made according SRTS (Sistemul Roman de Clasificare a Solurilor) 2003 (similar to the European one). One soil sampling is considered relevant for 1600 ha of forest. Soil type is established on vertical profile down to 120 cm	Av: Slight difference between soils classification systems (regarding subtypes). Better correlation between stands/management approaches with soils may be achieved. Dv: Higher errors in soil classification with NFI compared to classic approach. Likely low soil type/subtype sensitivity. Versatility from genetic to geometric layers is limited. Reporting: there is no current reporting on soils.
Organic C content in soils (tC/ha)	Humus content in the soil is computed for a depth of 100 cm	Included. Organic C is determined in each soil sample in NFI sampling plots Soil sampling is made in each NFI sampling plot. 500g of soil sampled are collected per horizon/layers down to 120 cm. The pooled samples are used to assess the total C by dry combustion method (ISO 10694).	Av: Continuity of soil characterization on genetic horizons to 120 cm depth. Dry combustion method used, replacing old method (Black Walkely). DV: versatility from genetic to geometric layers is limited. Soil bulk density is not measured

12.8. *Estimation of non-CO2 gases*

The current approach relays on numerous sources. It is not expected that NFI would bring additional inputs on the quality of estimation of non CO_2 gases. It is expected that emission factors to assess GHG emissions in forest fires, for different biomass pools will be improved.

12.9. *Reporting*

12.9.1. Reporting under UNFCCC

With the NFI based reporting, "stock change" method may be safely and conservatively used: with 2008 and 2012 data collecting years, in-between there is practically a continuous measurement of forest (of different trees). In order to allow 1990 backward estimation of removal/emissions, the effect of the change threshold diameter must be estimated in quantitative and qualitative terms (i.e. on species distribution, on increment and wood volume), in an additional research work. These data can be compared to the one used in the former approach. The former approach that is purely based on models can be applied to the NFI data.

Some pools must be extrapolation back to 1990 (i.e. dead wood) based on relevant characteristics (stand type, management type), as derived from NFI, while for the period 2008 to 2012, data from NFI 1st cycle may be used. The new NFI uses a lower tree diameter threshold. The effect of the adoption of a lower diameter should be tested by applying a diameter threshold to the tree data-base to filter trees and hence reproduce (simulate) the former inventories. This exercise will probably be necessary to compare the former to the new system, and to develop an interpolation procedure.

For reporting under UNFCCC there is the need to combine with ICP data, and estimate emission/removal backward to 1990, with an expected uncertainty growing backward to base year. Methodologically, there is need to digitize forest soils maps (1/5000), then to associate each soil type/subtype with emission/removal over the ICP monitoring period.

12.9.2. Reporting under the Kyoto Protocol

A change toward the "stock change" method would be required for the Kyoto Protocol reporting as NFI data become available: over 2008 - 2012 there is practically a continuous measurement of forest and data would be stratified (stand type, management type, etc).

For a conservative approach, the emission from understorey pool should be counted in case of forest fires. Currently, there is no data on understory in burnt areas. With NFI, the data on understory will be available for burned areas.

For KP reporting purpose there is need for second NFI cycle, in order to be able to produce estimates of the C stock changes in dead wood pool. Under the KP reporting, dead wood pool may be included as there is available data in 2008 and 2012, based on relevant stratification (stand type, management type, etc). Most feasible option may be to develop allometric equations or model based on stand structure (and other parameters, species, management type) as to built time series since 1990 for UNFCCC reporting (possibly starting from 1985 inventory, last forest inventory).

For Kyoto Protocol reporting the second cycle of NFI would generate necessary data for reporting of soil pools. For art 3.4 Forest Management an annual extrapolation between the two moments in time of available data would be sufficient to prove at least that "soil pool is not a source". For art 3.3 afforestation/reforestation and deforestation NFI would provide basic data to build carbon reference soils (under desirable scale: site specific or aggregated at regions/national level). Modeling approach may be an additional option for reporting under plenty available data, but also under the constraint of available capacity.

12.10. *Crosscutting issues*

Quality assurance and control approved in the NFI inventory is transferred to the GHG inventory.

Uncertainty will likely decrease under NFI, especially because of unique methodology used across the country, and it will involve same data type for all land subcategories and activities. The calculation of uncertainties is a default output for the NFI-based reporting which would be based on error propagation and would account for model errors.

Recalculations are now performed every year, caused by minor inputs. ERT identified major issues and urged for improvement.

12.11. *Discussion*

12.11.1. Filled gaps

Essentially, the new NFI system offers updated data, a continuous survey according the same measurement and data processing protocols and which implements a self improvable quality assurance and quality management system. As well NFI gives an increased accuracy and precision, removing the bias introduced in the old system by the use of 1985 annual increment data.

Crucial in GHG reporting is to capture the actual emissions (i.e. in the moment they occur), an issue that will be solved by NFI based reporting as updated data and repeated measurements and cycles.

NFI allows estimations of uncertainties based on unitary procedures for field measurement and processing of data. This is not the case of current system which relay on multi-source data, each with own quantifiable and hidden errors.

Romanian NFI is methodologically harmonized with other NFIs in other EU countries, which allows, thus converging toward higher tiers for emission factors and explicit approaches for activities data.

NFI would be able to be used for KP mostly, as it mainly overlaps on first commitment period (2008-2012).

NFI would allow increased regionalization of GHG removal, as to further support regional or local environmental and climatic initiatives.

NFI is recognized as an independent tool to assess changes related to the forestland, and it may parallely continue to collect data with statistical system, what will allow for cross checks of relevant data.

12.11.2. Remaining gaps

There are two categories of gaps. Some are temporary, some are permanent.

Temporary gaps are those that cannot be assessed yet through the current (new) NFI but will be in the future. Typically, these are gaps related to the estimate of the changes in the GHG balance. They can also be gaps that will be filled once the first cycle will be done, such as the assessment of the areas.

The monitoring of wood removals with the NFI-based reporting is a good example of the temporary gaps that will be filled when the permanent plots will be re-measured in the future. During the second cycle, the stock change approach will indeed become available and will allow a statistical assessment of the harvests. Until then, the estimations will have to be based on management- and industry-based statistics. Other approaches such as coupling a carbon bookkeeping model to satellite imagery could be tested.

Permanent gaps are those that cannot be filled with the new NFI without setting assumptions or using default parameters. These gaps typically concern the interpolation and the representation of what was in the reference year.

Those gaps concern some models or parameters needed for the estimation of some of the carbon pools such litter, leaves, belowground biomass, wood density and wood C content. Additional researches are needed to establish the models or to estimate the parameter sets required to fill the gaps. Some are under investigation but it would take time until results would be applicable at national level.

As an example, a program to develop new biomass equations will start soon to provide devoted and detailed equations to the NFI system to assess the tree biomass for the main species, including the belowground pool. The program will promote more accurate estimations of the root biomass, but not before the end of the first NFI cycle.

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13. Different approaches to carbon stock assessment in Slovakia

Tibor Priwitzer and **Vladimir Šebeň**
National Forest Centre, Slovakia
Email: priwitzer@nlcsk.org

Emil Cienciala and **Zuzana Exnerova**
IFER - Institute of Forest Ecosystem Research, Ltd., Czech Republic
Email: emil.cienciala@ifer.cz and zuzana.exnerova@ifer.cz

Aleksi Lehtonen
The Finnish Forest Research Institute, Finland
Email: aleksi.lehtonen@metla.fi

Abstract

The first aim of this study was to describe the construction of the new BCEFs for Slovakia based on new NFI data. Biomass conversion and expansion factors (BCEFs) based on new Slovakian NFI data were developed for Norway spruce (*Picea abies*), Pine (*Pinus sylvestris*), Oak (*Quercus robur*) and Beech (*Fagus sylvatica*). The methodology to construct the factors follows a common procedure that is described in this study and elsewhere, e.g., in Lehtonen *et al*. (2004). Since age-dependent BCEF were needed, the estimated BCEF values for aboveground biomass were also approximated using the relation based on Lehtonen (2004). The second task was to compare the estimation of aboveground biomass using the newly derived BCEFs and other available approaches. These are i) methods so far adopted in Slovakian NIR, ii) default factors of GPG for LULUCF (IPCC 2003) and iii) default factors from the AFOLU guidance (IPCC 2006). The effect of adopting different approaches to estimate aboveground biomass was evaluated for total biomass and carbon stock change for the major tree species. The major outcome of this work is a demonstration of the use of NFI data to create age-dependent BCEFs as recommended by AFOLU (IPCC 2006). Using national available data and higher-tier methods would avoid using the default Tier 1 factors of GPG for LULUCF (IPCC 2003) and/or of AFOLU (IPCC 2006), which apparently do not provide consistent results.

13.1. *Introduction*

Slovakia is a country with two major information sources on its forest[32] resources: a stand-wise inventory of management plans and a newly implemented statistical forests inventory with the first cycle finalized in 2007. An optimal use of the NFI and stand-wise data and an improvement of the whole tree biomass estimates to assess carbon stock change in living biomass would improve the GHG inventory of Slovakia. So far, Slovakia used wood density and expansion factors for major tree species to calculate total tree biomass and the corresponding carbon stock. These factors are based on national-specific data (Tier 2 method), but the available data on forests have not been fully used.

[32] Slovakian forest, forestry and geographical information have been already presented in Chapter 10 of current report, describing the state of current emission reporting practices, including forest definition, pools and Tiers and key decisions under the Kyoto Protocol.

In this contribution, we describe a process to create country-specific biomass conversion and expansion factors (BCEFs) using the latest tree-level data from the NFI. The new factors are also age-dependent and they can be applied on the commonly available aggregated data from forest management plans. The estimation of age-dependent BCEFs as explored in this work is considered as a demonstration of the use of available data for representative and therefore also more accurate above-ground biomass estimation. The age-related BCEFs are suited for the application on stand-wise data of merchantable volume (growing stock) from forest management plans, which are aggregated by age classes at different scale and may be used for reporting at regional or national level.

The construction of age-related BECFs was based on the measured tree-level data from the first statistical NFI cycle in Slovakia and on tree-level volume and above-ground biomass functions. In this compilation, not all of the functions utilized were derived in Slovakia, but some of them were taken from the relevant literature and suitable allometric studies from the neighboring countries in Central Europe (see description of methods). This has no implication for the demonstrated approach. However, the BCEF estimates may be improved whenever better, country-specific biometric studies will be available in Slovakia.

The first task of the study was to describe the construction of the new BCEFs estimated for Slovakia based on new NFI data. The second objective was to compare the estimation of aboveground biomass using the newly derived BCEFs and the other possible approaches. These are i) those so far adopted in Slovakian NIR, ii) default factors of GPG for LULUCF (IPCC 2003) and iii) default factors from the AFOLU guidance (IPCC 2006).

13.2. *Material and Methods*

The new age-dependent biomass conversion and expansion factors (BCEFs) were prepared for the four major tree species in Slovakia (beech, oak, pine, spruce) based on the major data sources on forests available in the country. These are the National Forest Inventory (NFI) and the taxation data of forest management plans. The estimation of BCEFs is based on the tree level data of the statistical forests inventory (the first and so far only cycle finalized in 2007) and the already available volume and biomass functions, while the data of growing stock by age classes were used for the test application of BCEFs to estimate above-ground biomass.

13.2.1. National Forest Inventory data

The first cycle of Slovak NFI was performed during 2005 and 2006. The NFI is based on combined ground-photo method with systematic allocation of sampling units on the whole national territory on a 4x4 km grid. In total the ground inventory comprises about 1 422 permanent sample plots. This network density (one inventory plot with the area of 500 m^2 represents about 1,600 ha of the territory).

In the field, four kinds of experimental plots represent the sampling units (Figure 13-1):

1. A – constant circle with diameter r = 12.62 m for the detection of site, stand and ecological characteristics, and for the inventory of dead lying wood and stumps
2. B – two concentric circles (r = 3 m and 12.62 m) for measuring trees with a diameter $d_{1,3}$ = 7-12 cm (in small circle) and $d_{1,3} \geq 12$ cm (in large circle) ,
3. C – variable circle for small trees with d1,3 <7 cm (its diameter r = 1.0, resp. 1.41, resp. 2,0 m) is chosen according to the concrete density of individuals,
4. D – extended constant circle with r = 25 m for the inventory of forest borders, roads and water resources.

The tree level data were collected from inventory plots of type B. All trees with diameter over bark $d_{1,3} \geq 7$ cm in the circle were located into polar coordinates (azimuth was measured – horizontal angle from the north and distance from the centre of inventory plot (IP) up to the tree axis at its foot). The following qualitative and quantitative characteristics were determined:

A) Qualitative characteristics

Tree species

- Bio sociological status of the tree in the stand
    - According to Kraft (dominant, co-dominant, intermediate, subdominant, fully shaded/under shelter wood)
    - According to IUFRO classification (height status – in upper, middle or lower third of maximal height of stand, vitality – very high, normal or weak, growth tendency – growing, normal or declining)
- Stand layer (storey) and age or growth degree/class of the tree
- State of the crown (shape, density, damage)
- Bifurcation of stem axis (height below and above 1.3 m from the ground)
- Quality of stem (quality class A – excellent, B – standard, C – low; the evaluation of the lower 1/3 of the stem is used as a basis for monitoring the development of stands quality and for sorting the supply of potential logging volume)
- Stem damage (kind, extent, fresh damage, old damage, repeated damage)
    - Mechanical (during logging and skidding)
    - Game (bark scaling, browsing)
    - Insects
    - Rot
    - Breakage
    - Other damage
- Significance of the tree for nature protection (with nest, with cavity, so-called large trees" and others).

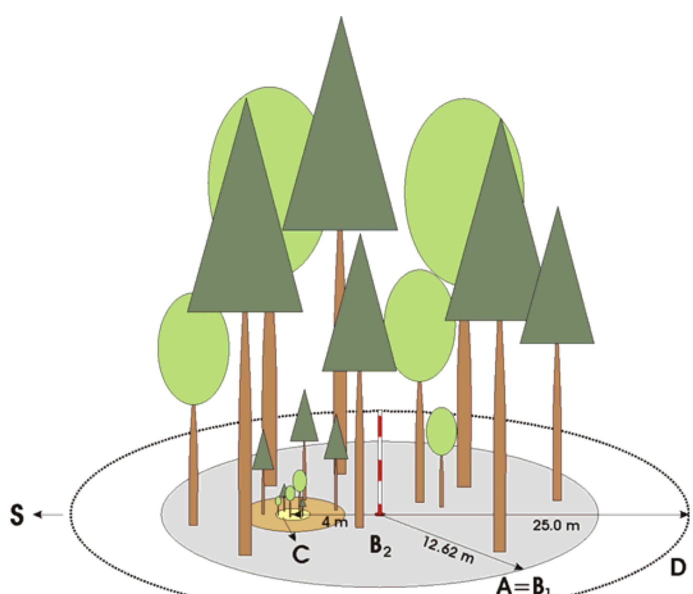

Figure 13-1 Scheme of the inventory plot

B) Quantitative characteristics

– they were measured or found out by combining the estimate and measurement (E/M)

- Tree diameter $d_{1,3}$ (calliper to 0.1 cm, one measurement perpendicularly to the IP centre, measurement at 1.3 m height from tree foot were fixed on the tree)
- Tree height and live crown height; on trees with $d_{1,3}$ > 30 cm also the height of the stem part meeting the criteria of quality class A (E/M, M – height meter to 0.1 m)
- Crown width (E/M, M – horizontal projection perpendicularly to IP centre, or in two directions, on slope at right angles to the contour to 0.1 m)
- Stem diameter $d_{0,3}$ at 30% of the height of tree and stem diameter d_0 at the level of the tree foot or also at the level of the potential height of the stump = 0.5.$d_{1,3}$ (only on trees M and for main tree species – Field Map technology and calliper) – as a variant for more objective monitoring of individual shape of the stem of trees and specifying the state of growing stock and timber assortments (Šmelko et al. 2005).

To construct age-related BCEFs, only the plots where the tree growth area of concrete tree species was over 50 % of the entire plot area were included. If the "real" crown projection is measured, the total crown area is shown, larger than inventory plot area. The crown projection is necessary to reduce to inventory plot area. For this purpose was calculated the tree growth area - parameter, which reduces the actual measured crown projection of individual tree by the function published in the report. The sum of growth areas must be equal to real inventory plot area. The input data sets were subsequently divided according to the four main tree species, including the information on tree species composition (%), age, tree diameter and height and altitude above sea level of the plot (this is an altitude above sea level for a concrete plot not for a tree).

The main criterion to select the plots to be used for the calculation was the tree growth area. The assignment of tree growth area to the trees belonging to different tree species and layers was solved as a separate and rather difficult problem, because in the NFIR SR inventory plots were divided into subplots situated next to each other or one above the other, if they consisted of different age classes, growth stages of forest categories.

The tree growth area was determined from the regression models derived from the whole NFIM data set separately for the individuals with height below 1,3 m (in this case the tree growth area is a function of the height), and for the trees with the height above 1,3 m (in this case tree growth area is a function of diameter- $d_{1,3}$). This model was applied separately for the coniferous and broadleaves tree species. The function used in the model is a power regression model $Y = a * X^b$ (Šmelko et.al., 2008).

13.2.2. Forest Management Plans

The input data from 2007 (growing stocks and areas of age classes) were classified in 15 age classes, each age class representing a 10 year age interval (e.g. age class one covers the years from 1 to 10). Then, the growing stock per hectare for each tree species and age class was calculated.

The data on growing stock (merchantable volume, defined as tree stem and branch volume under bark with a minimum diameter threshold of 7 cm) and on the area of the age classes for the main tree species (spruce, pine, beech and oak) were selected from the Compendium of Slovak Forestry Statistics (CSFS). The CSFS is issued annually by the National Forest Centre – Institute for Forest Resources and Information (NFC-IFRI), Zvolen. The estimation of growing stock in Slovak forests is established by the Regulation of Ministry of Agriculture SR no. 5/1995.

The figures in the CSFS are based on aggregated data from Forest Management Plans (further denoted as FMP). The data for FMP are gathered separately for different forest division units (compartment, crop group, storey, standards left after regeneration cut) and they are used to review the future management measures. The data are usually updated every 10 years and. one tenth of the territory (180 000 - 200 000 ha) is reviewed each year. Growth tables and ocular estimation methods are used for this purpose. Gathered data are stored in databases and further processed into aggregated files used for reporting and the compilation of various documents including the

Compendium of Slovak Forestry Statistics (CSFS), the Aggregated Forest Management Plan (AFMP), and the Permanent Forest Inventory (PFI).

13.2.3. National Emission Inventory Report

The National Emission Inventory Report (NIR 2007) of Slovakia describes the conversion/expansion factors to convert annual wood volume increment data to annual tree biomass increment. The basic inventory component in Slovak forestry is merchantable volume (tree stem and branch volume under bark with a minimum diameter of 7 cm). The conversion/expansion factors were estimated for the main forest tree species (Table 13-1), according to data published by Požgaj et al. (1993), Šebík and Polák (1990) and from the database of Permanent Forest Inventory.

The biomass *conversion and expansion factors* for individual tree species are derived from the wood density coefficients and from the expansion factors, namely as a sum of these two values.

The current Slovak UNFCCC LULUCF and Kyoto reporting system is not based on NFI information. With only one inventory cycle conducted so far, the NFI it is not readily usable to estimate carbon stock change in forests. However, the Slovak NFI system is designed to provide comprehensive information, including the one needed for the LULUCF GHG inventory.

Table 13-1 Major tree species and biomass expansion/conversion factors used to calculate the carbon stock in the Slovakian NIR (taken from the 2008 NIR submission of Slovakia)

Tree species	Coefficients of wood density	Expansion factors	Biomass Con./Exp. factors
Spruce, fir	0.4	0.2	0.6
Pine	0.5	0.3	0.8
Larch	0.6	0.2	0.8
Other coniferous	0.4	0.2	0.6
Beech	0.7	0.5	1.2
Oak	0.7	0.6	1.3
Poplars	0.4	0.2	0.6
Other broadleaves	0.6	0.5	1.1

13.2.4. Growing stock

The total growing stock of the four main tree species in Slovakia in the period 2006-2007 is presented in Table 13-2. The information on the growing stock and the forest area by age-classes and tree species are presented in Table 13-3. The distribution of the growing stock in 2007 is also shown graphically in Figure 13-1.

Table 13-2 Total growing stock in Slovakia by individual tree species in the period 2005-2007

	Growing stock (under bark, in million m^3)				
	Beech	Oak	Pine	Spruce	All
2007	143.520	40.648	28.642	148.283	361.092

Table 13-3 Growing stock by age-classes for individual tree species in Slovakia for 2007

Age class	Growing stock (under bark, m^3)			
	Pine	Beech	Oak	Spruce
5	453	222	280	3 580
15	145 418	306 925	66 688	825 993
25	1 106 928	2 993 288	480 728	4 595 486
35	2 089 150	5 553 157	758 945	6 968 273
45	2 430 153	7 448 225	1 307 340	8 382 572
55	2 800 252	12 631 774	4 102 061	14 251 926
65	3 154 511	15 282 903	6 015 942	19 994 515
75	3 861 750	16 732 318	6 471 904	21 055 045
85	4 176404	20 182 422	6 362 744	22 504 206
95	4 022 966	20 420 490	5 748 488	20 502 082
105	2 645 584	15 868 386	4 559 234	11 754 473
115	1 071 646	9 394 125	2 599 564	5 840 723
125	465 567	5 910 012	937 372	3 485 916
135	287 239	3 840 168	479 887	2 340 905
145	383 859	6 955 287	756 486	5 777 545

Table 13-4 Forest area by age-classes for individual tree species in Slovakia for 2007

Age class	Forest area (in ha)			
	Pine	Beech	Oak	Spruce
5	8 321.4	41 807.1	8 631.3	34 523.9
15	10 586.4	47 186.8	9 102.3	42 253.6
25	12 827.9	41 661.9	8 335.2	42 843.8
35	14 249.9	39 174.2	7 182.8	37 393.4
45	12 439.5	37 979.2	8 614.4	32 393.9
55	11 799.6	53 094.1	23 471.8	42 945.4
65	11 687.0	56 564.7	30 508.2	51 790.1
75	13 168.1	55 224.4	28 884.3	49 750.8
85	13 605.1	60 404.8	26 843.9	49 313.6
95	12 608.4	56 013.0	22 660.3	42 903.2
105	8 099.7	40 533.4	16 383.4	24 629.7
115	3 447.0	24 165.9	9 196.5	13 350.6
125	1 607.4	15 880.5	3 507.3	8 901.7
135	1 000.6	10 840.4	1 825.1	6 472.8
145	1 514.8	19 705.9	3 274.3	17 517.2

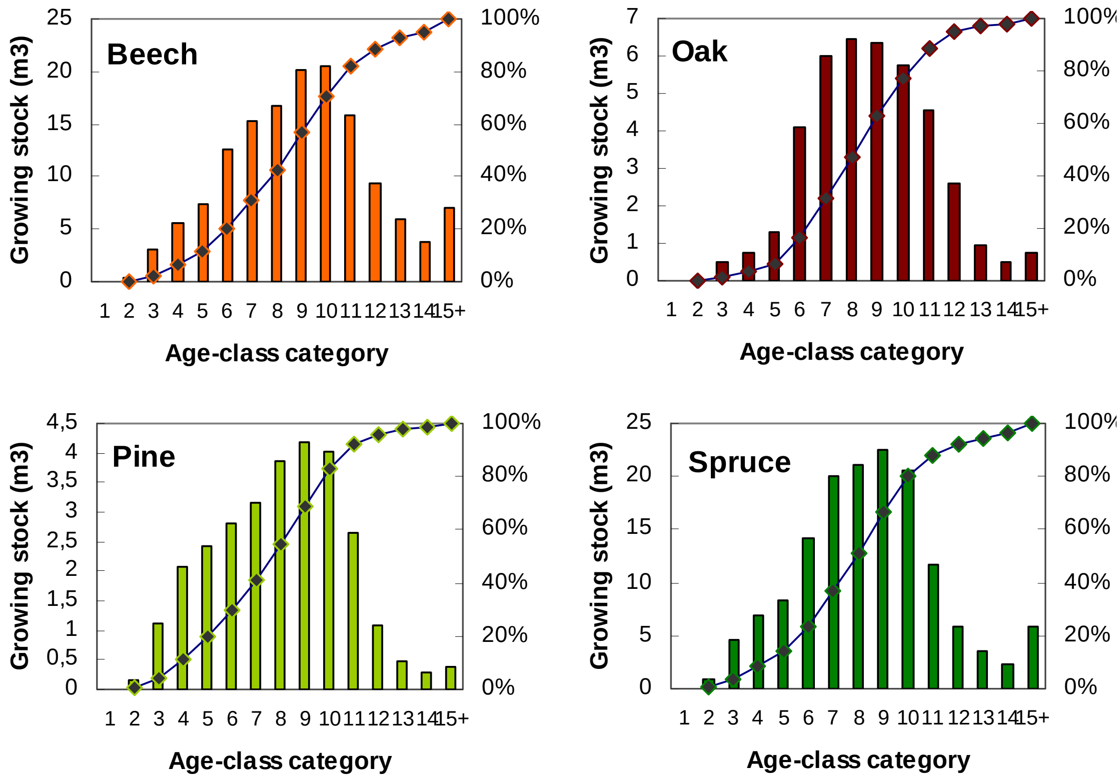

Figure 13-2 Forest growing stock distribution by age-class and individual tree species in Slovakia in 2007. The second Y-axis represents the cumulative growing stock on relative scale

13.2.5. Constructing Biomass Conversion and Expansion Factors

Biomass conversion and expansion factors (BCEFs) were developed based on new Slovakian NFI data. BCEFs were constructed for Norway spruce (*Picea abies*), Pine (*Pinus sylvestris*), Oak (*Quercus robur*) and Beech (*Fagus sylvatica*). The methodology follows a common procedure described in Lehtonen *et al*. (2004) and cited in IPCC (2006).

The expansion and conversion factor (BCEF) is generally defined as

$$BCEF_i = \frac{W_i}{V} \quad (1)$$

where i indicates a tree biomass component, W_i (Mg) is the dry biomass of component i and V (m^3) is the tree merchantable volume.

Tree-level data of the new NFI in Slovakia were used to construct age-related BCEFs. Only inventory plots that contained a dominant share (at least 50 % of the basal area) of any of the four key tree species (beech, oak, pine and spruce) were used for the analysis. This selected database contained over 22 thousand trees and tree volume and tree aboveground biomass was calculated. The national volume equations of Petras and Pajtik (1991) were used:

$$V_{spruce} = a*(DBH+1)^b * H^c - e*(DBH+1)^f * H^g \quad (2)$$

where a ($3.199*10^{-5}$), b (1.847), c (1.147), e ($8.291*10^{-3}$), f (-1.020) and g (0.896) are the parameters.

$$V_{oak} = (a + b/H + c/H^2 + e/DBH + f*H/DBH + g*H^2/DBH + k/DBH^2 + \\ +l*H/DBH^2 + m*H^2/DBH^2 + n/DBH^3 + p*H/DBH^3 + \\ +r*H^2/DBH^3)/\pi*DBH^2*H/40000 \quad (3)$$

where a (0.453), b (2.155), c (9.105), e (-12.05), f (0.181), g ($-4.011*10^{-3}$), k (-6.825), l (9.438), m ($-2.445*10^{-2}$), n (33.69), p (-9.100) and r (-2.158) are the parameters.

$$V_{beech} = (a + b/DBH + c/DBH^2 + e/DBH^3 + f*H + g*DBH*H + k*DBH^2*H \\ +l*DBH^3*H)/\pi*DBH^2*H/40000 \quad (4)$$

where a (0.542), b (-3.118), c ($4.434*10^1$), e ($-2.360*10^2$), f ($-1.072*10^3$), g ($-1.860*10^{-5}$), k ($8.806*10^{-7}$), l ($-5.996*10^{-9}$)

$$V_{pine} = a*(DBH+1)^{(b+c*\log(DBH+1))}*H^e - f*(DBH+1)^g*H^i \quad \textbf{(5)}$$

Where a ($2.258*10^{-5}$), b (2.115), c ($-1.272*10^{-2}$), e (0.980), f ($6.426*10^{-2}$), g (-2.124) and I (1.373) are the parameters.

The aboveground biomass functions from the following studies were used: Wutzler et al. (2008) for beech trees, Cienciala et al. (2008) for oak trees, and Cienciala et al. (2006) for pine trees, Wirth et al. (2004) for spruce. In the case of spruce, the aboveground biomass was estimated as a sum of the biomass of the tree stem, the living and dead branches and foliage.

$$AB_{beech} = a*DBH^b*H^c \quad (6)$$

Where a ($5.23*10^{-2}$), b (2.124) and c (0.655) are parameters

$$AB_{oak} = a*EXP(b + c*\log(DBH) + e*\log(H)) \quad (7)$$

Where a (0.999), b (-3.069), c (2.137), e (0.661) are parameters

$$AB_{pine} = a*DBH^b*H^c \quad (8)$$

Where a ($3.191*10^{-2}$), b (1.898) and c (0.899) are parameters

$$AB_{spruce} = ST + FL + BR_{live} + BR_{dry} \quad (9)$$

$$ST = EXP(a + b*\log(DBH) + c*\log(DBH)^2 \\ +e*\log(H) + f*\log(Age))*1.0052*1.0045 \quad (10)$$

Where a (–2.840), b (2.552), c (–0.150), e (–0.192), f (0.257) and g ($-8.278*10^{-2}$) are parameters.

$$BR_{live} = EXP(a + b*\log(DBH) + c*\log(H) + e*\log(H)^2)*1.0831*1.0138 \quad (11)$$

Where a (–0.646), b (2.854), c (–2.985) and e (0.418) are parameters

$$BR_{dry} = EXP(a + b*\log(DBH) + c*\log(H) + e*\log(Age))*1.1037*1.1135 \quad (12)$$

Where a (–3.091), b (2.048), c (–1.287), e (0.628) are parameters

$$FL = EXP(a + b*\log(DBH) + c*\log(DBH)^2 + e*\log(H) \\ +f*\log(H)^2 + g*\log(Age))*1.0533*1.0183 \quad (13)$$

where a (–0.581), b (3.638), c (–0.213), e (–2.778), f (0.465) and g (–0.429) are parameters.

The tree level volume and biomass was summed to calculate the volume and biomass at the plot level and the stand BCEF was estimated using Eq. 1. An average tree age was also calculated at the plot level on the basis of the basal area of individual trees.

Since age-dependent BCEF were needed, the estimated BCEF values for aboveground biomass were approximated using the method in Lehtonen (2004). A non-linear form was used to relate *BEF* to stand age (*Age*). Biomass conversion and expansion factor (BCEF) was defined as

$$BCEF = a + b \cdot e^{-Age/c} \quad (14)$$

where *a, b, c* are parameters and *Age* is the mean age of the forest class.

Default values for wood density recommended by IPCC (2003) were applied to calculate biomass stocks, namely 0.40, 0.42 and 0.58 t/m^3, respectively for spruce, pine, beech and oak, respectively. These values represent a conventional density, which is defined as oven-dry mass divided by fresh volume. It is important to note that the BCEFs described here include all aboveground biomass components, i.e., stem, branches and stump volume aboveground.

13.2.6. Approaches to estimate total biomass

In this study, we compare four approaches to estimate total biomass for the purpose of the GHG inventory. These are: 1) applying the BCEFs as estimated here based on the NFI data (Section 2.4), 2) using BCEF calculated from BEF and conversion factors in the Slovakian NIR, 3) Tier 1 default factors of IPCC (2003) and 4) Tier 1 default factors of IPCC (2006). These approaches are summarized in Table 13-5.

Table 13-5 Total biomass estimation by using four different BEF or BCEF and other parameters

Sources	Description	Total biomass estimation (eq.)
NFI	newly developed based on NFI data	TB=GS* BCEF*BB
NIR	used in Slovakian emission inventory of LULUCF sector, BCEF incl. BB and bark components	TB=GS* BCEF
2003 GPG IPCC	default values by recommend IPCC materials	TB=GS* BEF_2*BB*D*bark
2006 AFOLU	default values related to individual growing stock by recommend IPCC materials	TB=GS* $BCEF_{STOCK}$*BB*bark

Notes: GS is growing stock, *BB* is the root:shoot ratio (i.e. ratio between belowground and aboveground biomass), *D* is wood density (conversion to mass), *bark* is an expansion factor to include bark biomass.

In Table 13-5, the coefficient of 1.23 was used to expand aboveground biomass to total biomass (i.e., including belowground biomass) and 1.1 to expand growing stock under bark to growing stock over bark.

The effect of adopting different approaches to estimate aboveground biomass was evaluated for total biomass and carbon stock change for the major tree species. The total biomass was used as it was the only common variable needed for reporting under the Convention.

13.3. *Results*

13.3.1. Growing stock change

Figure 13-2 shows that most of the growing stock volume (about 90 %) is located in the age classes 4 to 12 for each of the major tree species, i.e., beech, oak, pine and spruce. This implies that biomass expansion and conversion factors in Slovakia are particularly important in that range of age classes, while it is less relevant for the youngest stands. The change of growing stock volumes by tree species between 2006 and 2007 are shown in Table 13-6. It can be observed that the volume has been increasing for all tree species except for spruce.

Table 13-6 Growing stock changes in Slovakian forests during the period 2006-2007

Period	Annual growing stock changes (in Mm^3)				
	Beech	Oak	Pine	Spruce	All
2007	1.22 (0.2 %)	0.53 (0.9 %)	0.06 (1.3 %)	-0.81 (-0.5 %)	0.99 (0.3 %)

13.4. *Estimation of BCEF on the basis of NFI data*

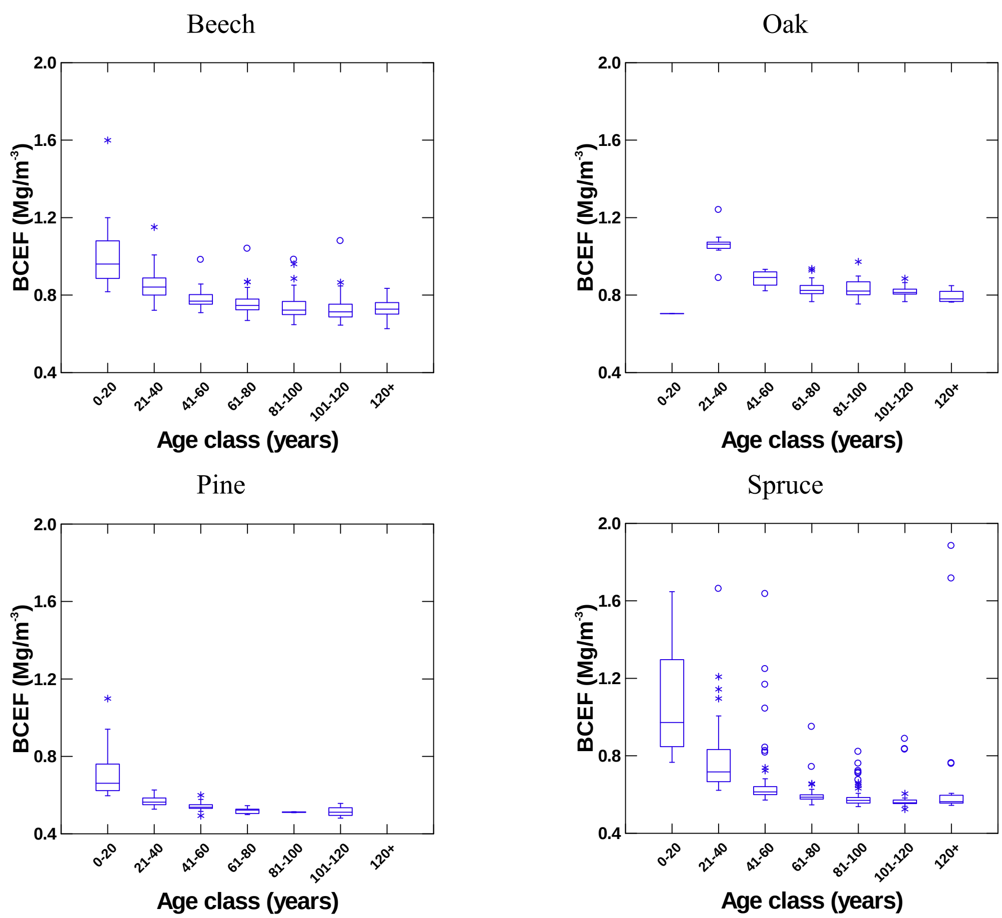

Figure 13-2 BCEFs values (y axis) based on the NFI data for the major tree species and age classes (x axis) in Slovakia.

The BCEFs estimated for each age class and major tree species are shown in Table 13-7. Graphically, BCEFs are shown in the form of box plots for major trees species and age classes in Figure 13-2.

Table 13-7 The values of BCEFs by age classes (Age), major tree species (Species) – mean, median, variance (var) and standard deviation (std) are shown

Age	Species	BCEF			
		Mean	median	var	std
0-20	Beech	1.015	0.960	0.197	0.200
21-40	Beech	0.852	0.841	0.093	0.079
41-60	Beech	0.779	0.769	0.056	0.043
61-80	Beech	0.755	0.746	0.069	0.052
81-100	Beech	0.739	0.722	0.082	0.061
101-120	Beech	0.729	0.713	0.097	0.070
-121	Beech	0.729	0.727	0.068	0.050
0-20	Pine				
21-40	Pine	1.061	1.063	0.080	0.085
41-60	Pine	0.885	0.891	0.051	0.045
61-80	Pine	0.830	0.824	0.053	0.044
81-100	Pine	0.833	0.821	0.062	0.052
101-120	Pine	0.819	0.813	0.036	0.029
-121	Pine	0.793	0.780	0.049	0.039
0-20	Oak	0.727	0.661	0.226	0.165
21-40	Oak	0.569	0.564	0.048	0.027
41-60	Oak	0.543	0.537	0.048	0.026
61-80	Oak	0.519	0.522	0.030	0.016
81-100	Oak	0.512	0.512	0.005	0.003
101-120	Oak	0.515	0.511	0.061	0.031
-121	Oak				
0-20	Spruce	1.166	0.987	0.396	0.462
21-40	Spruce	0.780	0.717	0.245	0.191
41-60	Spruce	0.670	0.614	0.264	0.177
61-80	Spruce	0.599	0.586	0.090	0.054
81-100	Spruce	0.589	0.570	0.101	0.059
101-120	Spruce	0.604	0.557	0.185	0.112
-121	Spruce	0.701	0.563	0.530	0.371

The relation *BEF* to stand age (*Age*) was expressed as a non-linear fitting equation (eq. 12); the three constant parameters (*a*, *b*, *c*) in the equation are presented in Table 13-8. That table also shows the fitting results in terms of coefficient of determinacy (R^2), which ranged from 0.48 for the spruce plots to 0.67 for the oak plots. The curves of these equations are plotted in Figure 13-3, together with the underlying BCEF values at the plot level.

Table 13-8 Equation parameters (*a, b, c*) to estimate *BCEFs* for four main species including asymptotic standard error (ASE), coefficient of determination (R^2) and number of qualified sample NFI plots (n)

Species	Parameters			Statistics	
	a (ASE)	b (ASE)	c (ASE)	R^2	n
Beech	0.737 (0.005)	0.856 (0.104)	16.169 (1.502)	0.513	388
Oak	0.814 (0.010)	1.306 (0.422)	18.177 (3.631)	0.670	86
Pine	0.524 (0.015)	1.266 (0.713)	10.032 (3.237)	0.552	54
Spruce	0.598 (0.011)	1.653 (0.218)	13.98 (1.382)	0.488	275

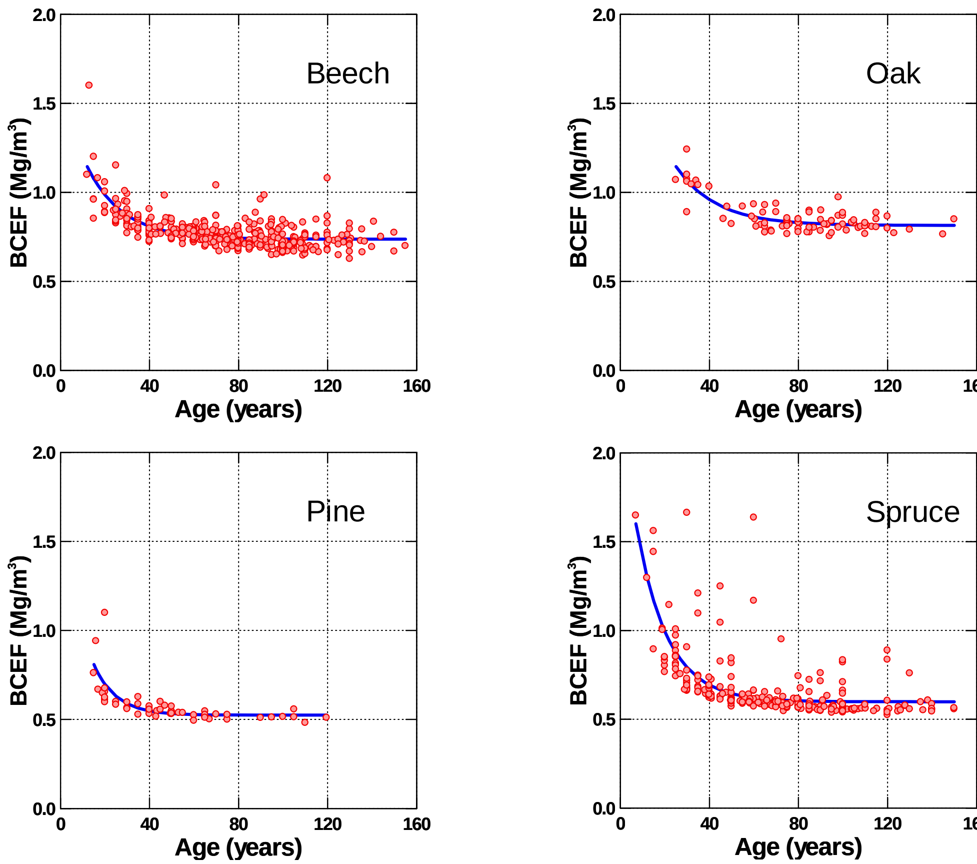

Figure 13-3 The BCEF curves by age classes and individual species. The blue lines represent *BCEFs* as the outputs of Eq.1

13.4.1. Analysis of BCEF and total biomass

This section describes the effect of adopting four different approaches to assess total biomass. The estimated total biomass for 2007 for the four major tree species is shown in Figure 13-4.

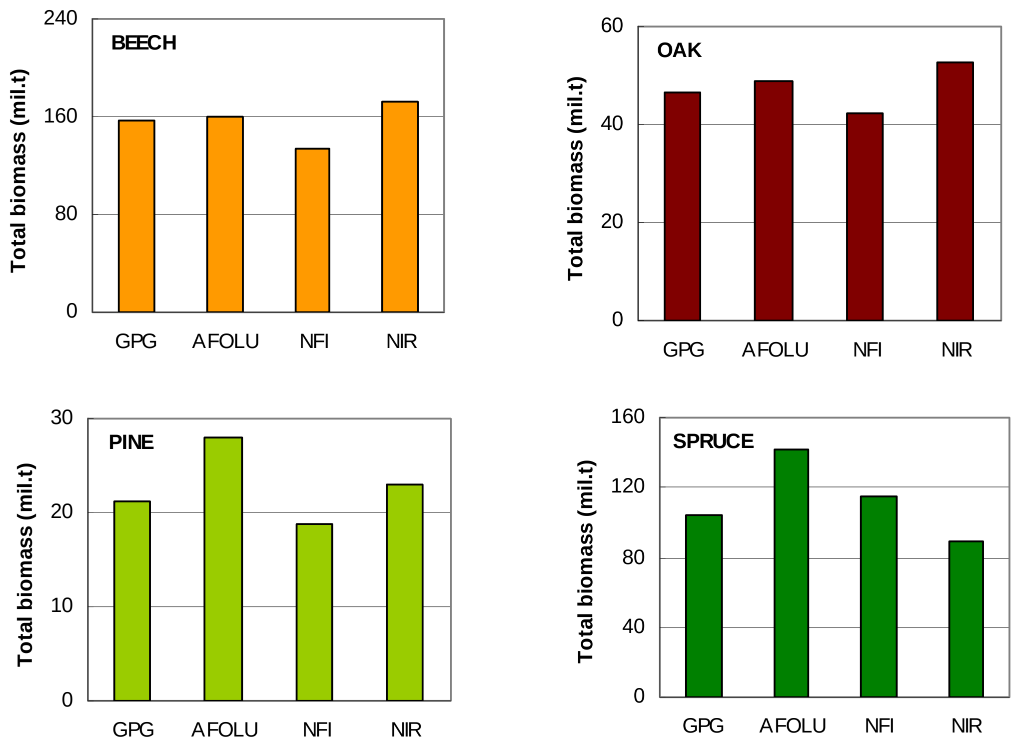

Figure 13-4 The total biomass stock for individual tree species in Slovakian forests in 2007. The four approaches of biomass calculation are 1) IPCC (2003) Tier 1 values (GPG), 2) IPCC(2006) Tier 1 values (AFOLU), 3) BCEFs as derived in this study (NFI) and 4) approach as used in the current NIR of Slovakia (NIR)

It is evident from Figure 13-4 that the assessed biomass differs largely for all species, depending on the adopted approach. In general, the largest values of total biomass for broadleaved species are those utilizing the approach of the Slovakian NIR, while the largest biomass estimates for conifers are those based on the AFOLU approach. This latter result confirms the observation made previously in our analysis of GPG for LULUCF and AFOLU Tier 1 default factors in Chapter 6. The BCEFs as estimated here were the most conservative for broadleaved species and pine, while they provide intermediate results for spruce, higher than both the GPG and the NIR approaches. Interestingly, the approach in the Slovakian NIR gives the largest and smallest estimates for the two most important tree species, namely beech and spruce. This approach gives also the largest estimate for oak.

In comparison to the GPG for LULUCF:

- The total biomass assessed by AFOLU approach was 1.8, 4.5, 32.0 and 35.7 % higher, respectively for beech, oak, pine and spruce
- The total biomass assessed by the newly derived BCEF (NFI) was -15.5, -9.6, -11.2 and 9.6 % higher, respectively for beech, oak, pine and spruce
- The total biomass assessed by coefficients currently adopted in the Slovakian NIR was 9.2, 13.2., 8.3 and -14.7 % higher, respectively for beech, oak, pine and spruce stands.

A more detailed insight into the differences among approaches to estimate total biomass is presented in Figure 13-5, by showing the biomass estimation per age class and major species.

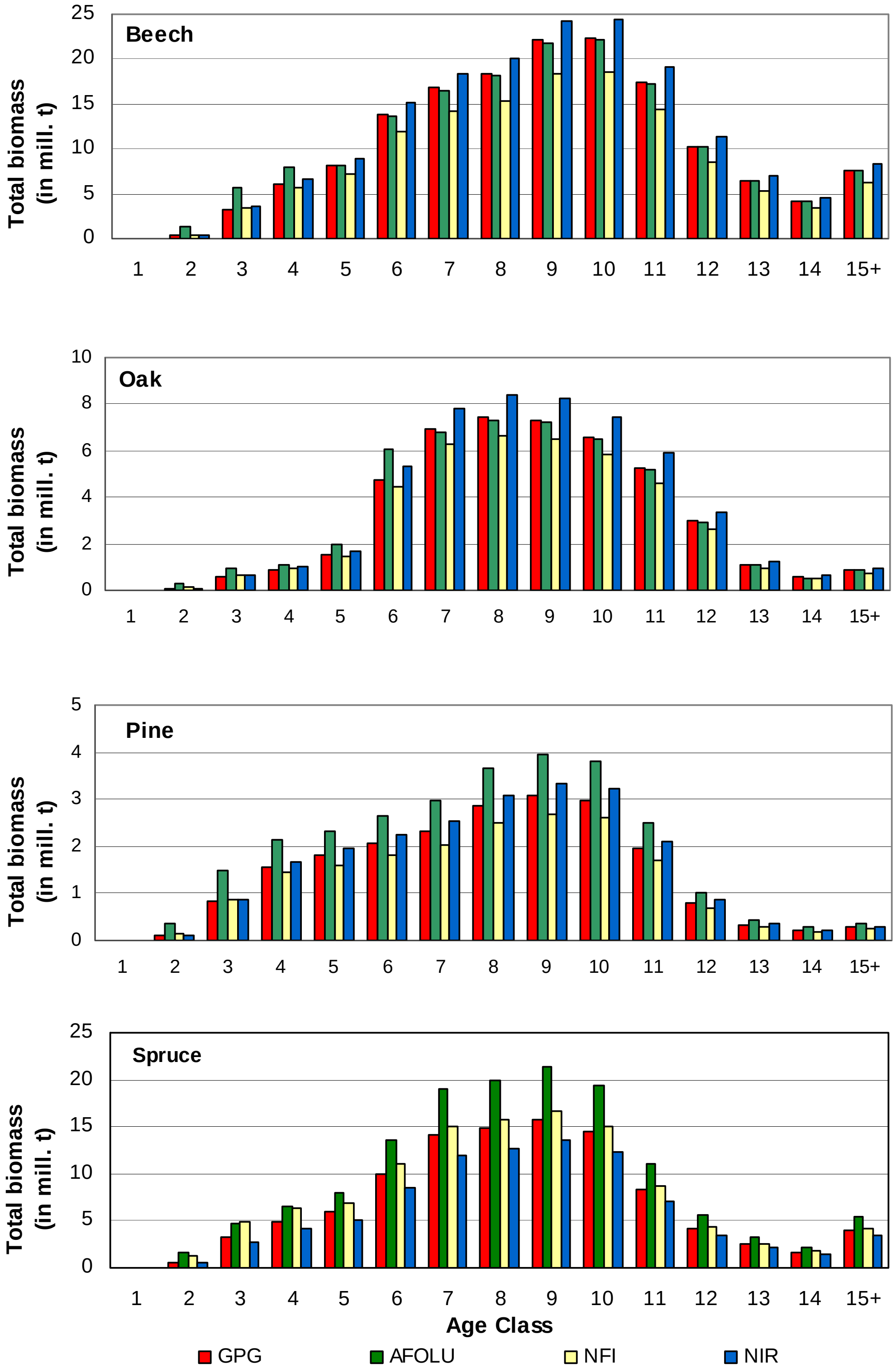

Figure 13-5 The distribution of age-class biomass stocks in beech and spruce forests in Slovakia in 2007 calculated with 4 different sources of *BEF or BCEFs* (*red – 2003 GPG IPCC, green – 2006 AFOLU, yellow – NFI, blue – NIR*).

13.5. *Discussion*

Although biomass factors and equations are widely applied in reporting carbon stocks and stock changes, little is known about the uncertainty involved. However, the published studies indicate that the uncertainty can be substantial (Lehtonen *et al*. 2007).

This report highlights the likely sources of uncertainty when adopting biomass expansion and conversion factors. The four approaches explored here show large differences in the total carbon stock change estimates.

The major outcome of this Slovak study is a demonstration of the use of NFI data to create age-dependent BCEFs as recommended by AFOLU (IPCC 2006). Using the nationally available data and higher-tier estimation methods would avoid using of the default factors of GPG for LULUCF (IPCC 2003) and/or AFOLU (IPCC 2006), which apparently do not provide consistent results.

The newly estimated BCEFs may be utilized for the data from forest management plans, aggregated by age classes and major tree species as traditionally reported from stand-wise forest inventories. The current BCEFs may further be improved by utilizing national biomass functions, which were not available for this study. The estimates may also be improved by adding the uncertainty analysis, when all underlying components would be known (Lehtonen *et al*. 2007).

Note that a detailed analysis of the effects of different approaches to estimate carbon stock change would require disaggregated data on forest volume and/or biomass. Therefore, the differences demonstrated in this study are only indicative.

13.6. *Conclusions*

Since higher-tier methods and approaches for estimating carbon stock change in biomass should be applied, the nationally available data and resources must be utilized whenever feasible. This study demonstrates a pragmatic approach of creating robust age-dependent biomass conversion and expansion factors for major tree species using the available tree volume and biomass functions and the NFI data. The next step could be an assessment of overall uncertainty associated with these factors.

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Abstract

The present study was developed in the context of Regulation (EC) 2152/2003 on the monitoring of forest and environmental interactions, the so-called "Forest Focus" Regulation. The specific objectives of this study on *"Climate change impact and carbon sequestration in European forests"* were:

- Strengthening and harmonizing the existing national systems in such a way that they meet the requirements of international monitoring and reporting of Green House Gas (GHG) emissions and sinks in the forestry sector.
- Improving the comparability, transparency and accuracy of the annual greenhouse gas inventory reports of the Land Use and Land Use Change in Forestry (LULUCF) sector of Member States, as implemented under the EU Monitoring Mechanism.

The results of this study set the basis for future reporting GHG and looked into the comparability of data in several European countries in which information was not readily available. It represents a step towards addressing the challenges of GHG inventories and the reporting under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto protocol related to forest land and forest activities

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