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Comparison of methods used within Member States for estimating CO_2 emissions and sinks according to UNFCCC and EU Monitoring Mechanism: forest and other wooded land

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The national reporting for the EU Monitoring Mechanism on greenhouse gas emissions and for the United Nations Framework Convention on Climate Change includes data for greenhouse gas emissions/removals from land-use change and forestry. By comparing the reports of EU15 Member States, we identified a lack of transparency, consistency and completeness concerning chapter 5 on land-use change and forestry. For chapter 5A (Changes in forest and other woody biomass stocks) we discuss the differing ways of estimation in detail. In addition to an improved transparency we consider a key requirement, to come to more harmonised approaches and definitions, e.g., with regard to land areas and the factors used to expand from stemwood to total tree biomass. COST E21 may become the forum for supporting the scientific/technical discussion on the issue, provided all Member States of EU15 are participating in the action.
Keywords. Biospheric CO_2 sinks, greenhouse gas emission, land-use change and forestry, forest inventory, EU Monitoring Mechanism, UNFCCC, comparison of methods.

1. INTRODUCTION

The European Union (EU) established a Monitoring Mechanism for anthropogenic CO_2 and other greenhouse gas (GHG) emissions in the Community with Council Decision 93/389/EEC (EC, 1993, latest amendment 1999/296/EC (EC, 1999). Member States (MS) have to report to the Commission each year until 31st December their relevant data on GHG emissions and removals for the previous calendar year. The data have to be determined in accordance with the methodologies published in the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines, further referred to in this paper as the “IPCC Guidelines” (IPCC, 1997). Despite the fact that most MS deliver their data to the Commission since some years to fulfil the commitments of the United Nations Framework Convention on Climate Change (UNFCCC), for the time being there exists no unique methodology within the EU15 to estimate CO_2 sinks and sources from LUCF.

The study includes chapter 5 (Land-use change and forestry, LUCF) of the National GHG Inventories in total; the present paper refers to subchapter 5A only (Changes in forest and other woody biomass stocks). It gives results on total C-uptake increment of forests and points out some main topics to be looked at in future.

2. OBJECTIVES

The study is designed to:
- show in detail how the relevant definitions and methods for the estimation of biospheric CO_2 sinks differ between MS inventories and if respectively to what extent they deviate from the Revised 1996 IPCC Guidelines;
- give support for recommendations to standardise the definitions and methods used in the national inventories concerning CO_2 sinks;
- help in the preparation of an update/revision of the current IPCC Guidelines considering also the information available in the IPCC Special Report on Land Use, Land-Use Change and Forestry, referred in this issue as the “LULUCF-SR” (IPCC, 2000a) and the decisions taken at the 6th Conference of the Parties to UNFCCC (COP6) with regard to LULUCF;
- assist the necessary additions of the IPCC report on “Good Practice Guidance and Uncertainty Management in National GHG Inventories” (IPCC, 2000b) related to chapter 5 of the inventories.

3. MATERIALS USED

We used documents and information available at UNFCCC Secretariat and European Environmental

Agency (EEA) for a first overview. This included national inventories of MS reported to EC and National Communications (NC) of Parties reported to UNFCCC. In a next step we contacted MS authorities to add missing data and explanations concerning the methodology. The task included participation at the relevant Working Group Meetings of the Monitoring Mechanism Committee. As the final step we elaborate suggestions for a standardisation of inventories to be discussed with MS. This activity aims at the agreement on a common background reporting format similar to the UNFCCC guidelines on reporting and review (UNFCCC, 1999), but adapted to the specific needs of EU15.

4. RESULTS

According to the IPCC Guidelines (Workbook pp.5.3ff) the CO_2 emissions/removals due to changes in forest and other woody biomass stocks (Inventory subchapter 5A) have to be calculated in the following way (simplified description):

1. Area of forest (ha) × annual growth rate (t $dm{\cdot}ha^{-1}{\cdot}y^{-1}$) × C-fraction of drymatter = Total Carbon uptake increment (t $C{\cdot}y^{-1}$).
2. Total harvest (m^3) × expansion factor x biomass conversion factor (t $dm{\cdot}m^{-3}$) × C-fraction of drymatter = Annual Carbon release (t $C{\cdot}y^{-1}$).
3. 1.–2. = Net annual Carbon uptake or release × 44/12 = Net annual CO_2 emission or removal.

The information compiled in **table 1** includes only the MS data of annual forest biomass increment; the analysis of wood harvest reporting will be presented elsewhere.

Only few MS originally calculate their reported GHG inventory values according to the IPCC-format. We identified two main reasons:

– Some MS had well established forest inventories already in place well before the IPCC Guidelines have been set up.
– Other MS are only in the initial phase of building up a functioning systematic approach to estimate the raw data needed for this part of the GHG inventory.

Although the IPCC Guidelines allow estimating the initial data in a differing way, they clearly state that also for more detailed national[1] forest inventories (NFIs) it is necessary "…to reconstruct the calculations in a comparable form…" "…to present the results on a comparable basis." (Reference Manual p.5.16). According to the information we got from the national experts this seems not to be possible for all MS with established NFIs (**Table 1**). GB is calculating the emissions/removals for chapter 5 of the GHG inventory in a totally differing approach, using a dynamic model of the flow of carbon from tree through litter to soil (e.g. Cannell, Dewar 1995; Milne *et al.*, 1998); nevertheless, they kindly have delivered the reconstruction according to the IPCC guidelines (Milne, personal communication). The compilation in **table 1** is only for EU13, because GR is not reporting on chapter 5 of the GHG Inventory, despite the fact that the area of forest available for wood supply is about 3 Mha according to TBFRA 2000 (UN-ECE/FAO, 2000). From LU we received no answer on our questions how the reported value for subchapter 5A is calculated.

4.1. Forest area

Already the definition of a forest is highly variable between the MS. The differences may not be tremendous compared to other uncertainties involved in the sink calculations. Applying a given national forest area definition for the other MS over- or underestimates the area up to 10% but the mean value being much lower, about 1%. (TBFRA, 2000, p. 35 table R.3 and text). Nevertheless the differences may be relevant in special cases, e.g., plantations of Christmas trees in Denmark, which are explicitly included in the national forest area definition, whereas in Germany they are excluded. Available but not used for the reporting to UNFCCC are the data on forest area for differing tree species (groups) for ES, FI and FR (**Table 1**). For methodological reasons, these countries start their calculations directly with the annual roundwood increment ($m^3{\cdot}y^{-1}$). All other MS gave more or less detailed information on their calculations, starting with the forest areas for different tree species (groups). Obviously there is a wide variety of data quality with regard to the actuality of the forest data and the underlying uncertainty levels.

There are also remarkable differences in what is included into subchapter 5A of the GHG inventories (**Table 1**). While most countries report only data on managed forest and plantations, others like FR include also single trees, hedges, and wine-/ fruit- trees. IT and PT include coppice. Both are not contrary to the IPCC guidelines, which allow that "…other types of biomass such as non-forest trees… and woody shrubs in grasslands should be included when they are a significant component of total changes in biomass stocks" (Ref. Manual p.5.13).

[1] Following country codes are used according ISO 3161-1 Alpha-2 code elements in alphabetic order: AT = Austria, BE = Belgium, CH= Switzerland, DE= Germany, DK = Denmark, ES = Spain, FI = Finland, FR = France, GB= United Kingdom, GR = Greece, IR = Ireland, IS= Iceland, LU = Luxembourg, NL = The Netherlands, PT = Portugal, SE= Sweden.

Table 1. Calculation of total carbon uptake increment in EU13 (EU15 excepted Greece and Luxembourg).

Country	Tree Species	Forest area (1,000 ha)	Growth rate Stemwood o.b. (m^3 ha^{-1} y^{-1})	Increment (1,000 m^3 y^{-1})	Expan. Factor Stem Vol. to total Biomass	Increment (1,000 m^3 y^{-1})	Conv. Factor Biomass Vol. to Drymatter	Increment (1,000 t [dm] y^{-1})	Conv. Factor Drymatter to C	Increment (1,000 t [C] y^{-1})
Austria	Coniferous	2 534	8.7	22 047	1.45	31 968	0.39	12 467	0.49	6 109
	Broadleaf	818	6.6	5 398	1.46	7 881	0.53	4 177	0.48	2 005
	total	**3 352**		**27 445**		**39 849**		**16 644**		**8 114**
Belgium	Beech	44	5.2	231	1.70	392	0.58	225	0.50	
	Oak	100	6.0	599	1.70	1 018	0.60	611	0.50	
	Poplar/Fland.	26	13.0	341	1.70	580	0.35	203	0.50	
	Poplar/Wall.	70	6.5	454	1.70	771	0.54	418	0.50	
	other broadleaf / Fland.	42	5.9	245	1.80	441	0.51	225	0.50	
	other broadleaf / Wall.	45	6.0	269	1.80	484	0.52	249	0.50	
	total broadleaf	**327**		**2 138**		**3 686**		**1 931**	**0.50**	**966**
	Larch	13	8.5	110	1.50	165	0.45	74	0.50	
	Pine	75	7.0	524	1.50	787	0.42	330	0.50	
	Spruce	201	10.5	2 112	1.56	3 295	0.46	1 518	0.50	
	Douglas fir	11	16.0	184	1.65	303	0.46	139	0.50	
	other conifers	13	10.0	126	1.50	189	0.40	76	0.50	
	total conifers	**313**		**3 056**		**4 739**		**1 538**	**0.50**	**969**
	Brussels + Reforest		8.1 / 5.1		1.62				0.50	9
	total	**640**		**5 194**		**8 425**		**3 469**		**1 943**
Denmark	Broadleaf	145	6.29	899	2.00	1 799	0.58	1 043	0.50	522
	Coniferous	268	8.21	2 200	2.00	4 401	0.38	1 672	0.50	836
	total	**413**		**3 100**		**6 200**		**2 716**		**1 358**
Finland	Pine			33 950	1.527	51 842	0.39	20 218	0.519	10 493
	Spruce			26 160	1.859	48 631	0.39	18 723	0.519	9 717
	Non-coniferous			17 090	1.678	28 677	0.49	14 052	0.505	7 096
	total			**77 200**		**129 150**		**52 992**		**27 307**
France	Broadleaf			50 095	1.60	80 152	0.54	43 282	0.50	21 641
	Coniferous			43 366	1.60	69 386	0.43	29 836	0.50	14 918
	total forest			**93 461**		**149 538**		**73 118**		**36 559**
	Poplar plantations			1 313	1.60	2 101	0.35	735	0.50	368
	sing. trees hedges			3 384	1.60	5 414	0.49	2 653	0.50	1 327
	wine/fruit-trees			7 234	1.00	7 234	0.49	3 545	0.50	1 772
	total			**105 392**		**164 287**		**80 051**		**40 025**
Germany	Oaks	876	6.1	5 347	1.24	6 630	0.56	3 713	0.50	1 856
	Beech	1 424	8.9	12 673	1.24	21 681	0.55	11 925	0.50	5 962
	broadleaf long rotation	398	4.6	1 850	1.24		0.55		0.50	
	broadleaf short rotation	745	4.0	2 979	1.24		0.55		0.50	
	Spruce	3 299	11.4	37 612	1.14	43 750	0.37	16 928	0.50	8 464
	Silver Fir	160	8.5	1 350	1.14		0.37		0.50	
	Douglas Fir	134	8.9	1 190	1.14		0.37		0.50	
	Pine	2 807	6.9	19 370	1.14	24 955	0.43	10 731	0.50	5 365
	Larch	300	8.4	2 521	1.14		0.45		0.50	
	total	**10 144**		**84 854**		**99 016**		**43 296**		**21 648**
Ireland	Coniferous	527	16.0	8 426	1.30	10 953	0.37	4 053	0.43	1 743
	Deciduous	102	4.0	408	1.30	531	0.55	292	0.45	131
	total	**629**		**8 834**		**11 484**		**4 345**		**1 874**
Italy	High-forest	2 961	7.8			23 095	0.55	12 714	0.50	6 357
	Coppice	3 623	3.0			10 869	0.64	6 989	0.50	3 494
	total	**6 584**				**33 964**		**19 702**		**9 851**
Netherlands	Forest trees	341	7.88	2 687	1.20	3 224	0.50	1 612	0.50	806
	Non-forest trees	98	7.88	772	1.20	927	0.50	463	0.50	232
	total	**439**		**3 459**		**4 151**		**2 076**		**1 038**
Portugal	Pinus pinaster	958	5.6	5 365	1.247	6 690	0.38	2 542	0.45	1 144
	Pinus pinea	79	5.6	442	1.247	552	0.38	210	0.45	94
	other softwood	45	5.6	252	1.247	314	0.38	119	0.45	54
	Eucalyptus	677	9.5	6 432	1.257	7 956	0.70	5 569	0.45	2 506
	Quercus suber	719	0.5	360	1.257	445	0.70	311	0.45	140
	Quercus ilex	464	0.5	232	1.257	287	0.70	201	0.45	90
	other Quercus	134	0.5	67	1.257	83	0.70	58	0.45	26
	Castanea sativa	40	5.0	200	1.257	247	0.70	173	0.45	78
	other hardwood	121	0.5	61	1.257	75	0.70	52	0.45	24
	total forest	**3 237**		**13 410**		**16 648**		**9 236**		**4 156**
	oth. wooded land	**224**		**991**		**991**		**270**		**121**
	total	**3 461**		**1 005**		**17 640**		**9 506**		**4 278**
Spain	Adult trees			30 089	1.60	48 142	0.50	24 071	0.45	10 832
	Young trees			483	1.40	676	0.50	338	0.45	152
	total			**30 571**		**48 817**		**24 409**		**10 984**
Sweden	Temperate (deciduous)	380	8.3	664	1.50	996	0.58	578	0.45	260
	Boreal (coniferous)	22 540	4.2	94 668	1.30	123 068	0.42	51 689	0.45	23 260
	total	**22 920**		**95 332**		**124 064**		**52 266**		**23 520**
United Kingdom	Coniferous	1 655	7.0	11 518	1.39	16 034	0.35	5 612	0.50	2 806
	Broadleaf	722	4.7	3 413	1.52	5 188	0.55	2 853	0.50	1 427
	total	**2 377**		**14 931**		**21 221**		**8 465**		**4 233**

4.2. Growth rates

All MS used national values for the differing tree species or groups when reporting growth rates (**Table 1**). This is well in-line with the IPCC Guidelines, which recommend the use of default values only in those cases where no (better) national values are available. Due to the original ground survey data from the forest inventory nearly all MS values are based on m^3 roundwood overbark$\cdot ha^{-1}\cdot y^{-1}$. This requires the subsequent multiplication with an expansion factor to account for the whole tree volume increment and a biomass density factor. The annual volume increment of marketable stemwood reported by MS for the different trees and tree-groups was between 0.5 and 16 $m^3\cdot ha^{-1}\cdot y^{-1}$, averaging at 6.9 $m^3\cdot ha^{-1}\cdot y^{-1}$. There appeared some inconsistencies like the different poplar growth rates of Flanders and Wallonia reported by BE, the very high growth rates of conifers in IR compared to GB (16 *vs.* 7 $m^3\cdot ha^{-1}\cdot y^{-1}$), or the very low values for Portuguese oaks and other hardwoods.

4.3. Expansion factor stemwood to total tree wood volume

As seen in **table 1** there is a high variation of expansion factors used to extrapolate the growth of stemwood to total tree biomass increase. The range for forest trees is from 1.14 taken in DE for coniferous trees to 2.0 used in DK, the reason being the different parts of the trees, which are included in the total biomass increase. The IPCC Guidelines recommend only aboveground wood but mention that the belowground tree biomass "…is an area for further development by the relevant expert groups…" (Reference Manual p.5.53). Hence, DE, NL and SE expand to above ground bio-mass only, while AT, BE, DK, ES, FI, FR, GB, IR, and PT include roots as well. IT gives growth-rates for the total tree directly but it remains unclear whether roots are comprised. Apart from the mentioned differences some MS embrace further biomass in their expansion. DK is additionally including "some carbon in the undergrowth and soil" (Fenhann, 1999), ES includes "part of the surrounding shrub vegetation" (Ferrero, personal communication) and FI states that "the used factor contains also foliage" (Tomppo, personal communication).

4.4. Biomass density and Carbon fraction

In their calculations ES and NL use the IPCC default value of 0.5 for the biomass density (conversion factor biomass volume to drymatter). All other MS use national values for the different tree species (groups), varying between 0.35 and 0.70, in accordance with the IPCC Guidelines. The IPCC default value for the carbon fraction of drymatter (Conversion factor drymatter to carbon in **table 1**) is 0.5. It is used by BE, DE, DK, FR, GB, IT and NL. The other MS are using slightly different national values, ES, PT and SE 0.45, FI up to 0.519, IR 0.43 and 0.45, AT 0.48 and 0.49.

5. CONCLUSIONS AND PERSPECTIVES

Our analysis identified a lack of transparency, consistency and completeness for the reporting on chapter 5 of the National GHG Inventories for UNFCCC and the EU Monitoring Mechanism. According to our preliminary comparison of latest forest inventories provided by MS (paper in preparation), the state of the art of forest inventorying and C-sinks/emission reporting is highly variable in different European countries. Some countries have a long-term forestry tradition and assess sampling errors for the total timber volume as low as 0.6%. Others never performed a forest inventory but sent questionnaires to forest owners; others made once an inventory some decades ago or lasting for some decades. Even within a country highly different procedures may have been applied in different regions.

Independent of the quality of the underlying NFIs, there remains the key problem that forest inventories are performed for assessing marketable stemwood and not for C-sinks/emission reporting. Therefore, harmonisation is needed with regard to the different expansion and conversion factors applied for transforming timber volume into overall CO_2-emissions and sinks. For subchapter 5A it may not be necessary to change the basic procedures in MS with a highly detailed forest inventory. On the other hand, there is the chance for those MS preparing structures for regular forest inventories, to take into account the mentioned issues when designing their national reporting policy. In case of ratification of the Kyoto Protocol to UNFCCC by EU15 there will be growing pressure to all MS to build up improved reporting structures on LULUCF; they must be based on recommendations of the LULUCF-SR (IPCC, 2000a) and on decisions taken at COP6.

On the short-term we propose to discuss and agree on a common background-reporting format for chapter 5 in the Monitoring Mechanism Committee. This could be related to the "Common reporting format sectoral background datasheets" which are given in the UNFCCC guidelines on reporting and review (UNFCCC, 1999) and which have to be filled by those Parties using strictly the IPCC default methodology. The sectoral background datasheet for LUCF adapted to the needs of EU15 would immediately increase transparency.

In parallel, a discussion on common methods should be initiated among national experts. The questions to be discussed should cover the types of woody biomass increase to be included in subchapter 5A, and how to agree on a uniform way for expanding from stemwood to total tree biomass (e.g., if and how to include roots and foliage ?). It may also include more general issues, e.g., if a model approach should be used instead or in addition, similar to the one applied by GB, including the carbon stocks in soils. In general, a forum is needed to integrate classical forest inventorying with novel indicators based on process understanding of the carbon and nutrient cycle of forests, and to translate the outcome of such integration into policy relevant monitoring concepts. A solution could be the combination of a subgroup on sinks within the Monitoring Mechanism Committee addressing the policy / technical level, with COSTE21 addressing the technical / scientific level.

Considering that previous reporting of carbon sinks and sources from LUCF is not sufficient to fulfil future requirements with regard to the Kyoto Protocol, two more activities were initiated in collaboration of JRC's Environment Institute and Space Applications Institute, to come to independent estimates for EU15 and to compare them with the reported 'traditional' inventory values for total carbon uptake increment:

– approach based on up-scaling of independent EU15 uniform data-sets;
– approach based on BIOME-BGC process modelling of annual NEE and NPP.

The following data sets are compiled for both activities: ICP–Forest data of DG AGRI; CORINE landcover map of EEA and satellite based land cover data available at SAI; data-sets of the European Soils Bureau at JRC; National Forest Inventories on NUTS 2/individual tree species level; data-sets from previous and ongoing research projects within the European Network CarboEurope of DG RES. A poster and paper giving first EU15 sink estimates based on the different approaches was presented at COP6.

The data-sets and modelling tools prepared during this project are intended to support - in due time - the definition of an EU-position with regard to "Updated Revised Guidelines" and "Good Practice Guidance" on LULUCF, in case COP6 will give such mandate to IPCC. More general, the information system created within the project is envisaged to provide scientific input to an integrated monitoring system for biospheric exchanges of GHG, and to contribute to setting up reliable but affordable protocols for monitoring, verification, validation, in case the decisions at COP6 are asking for such monitoring system at European and global level.

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