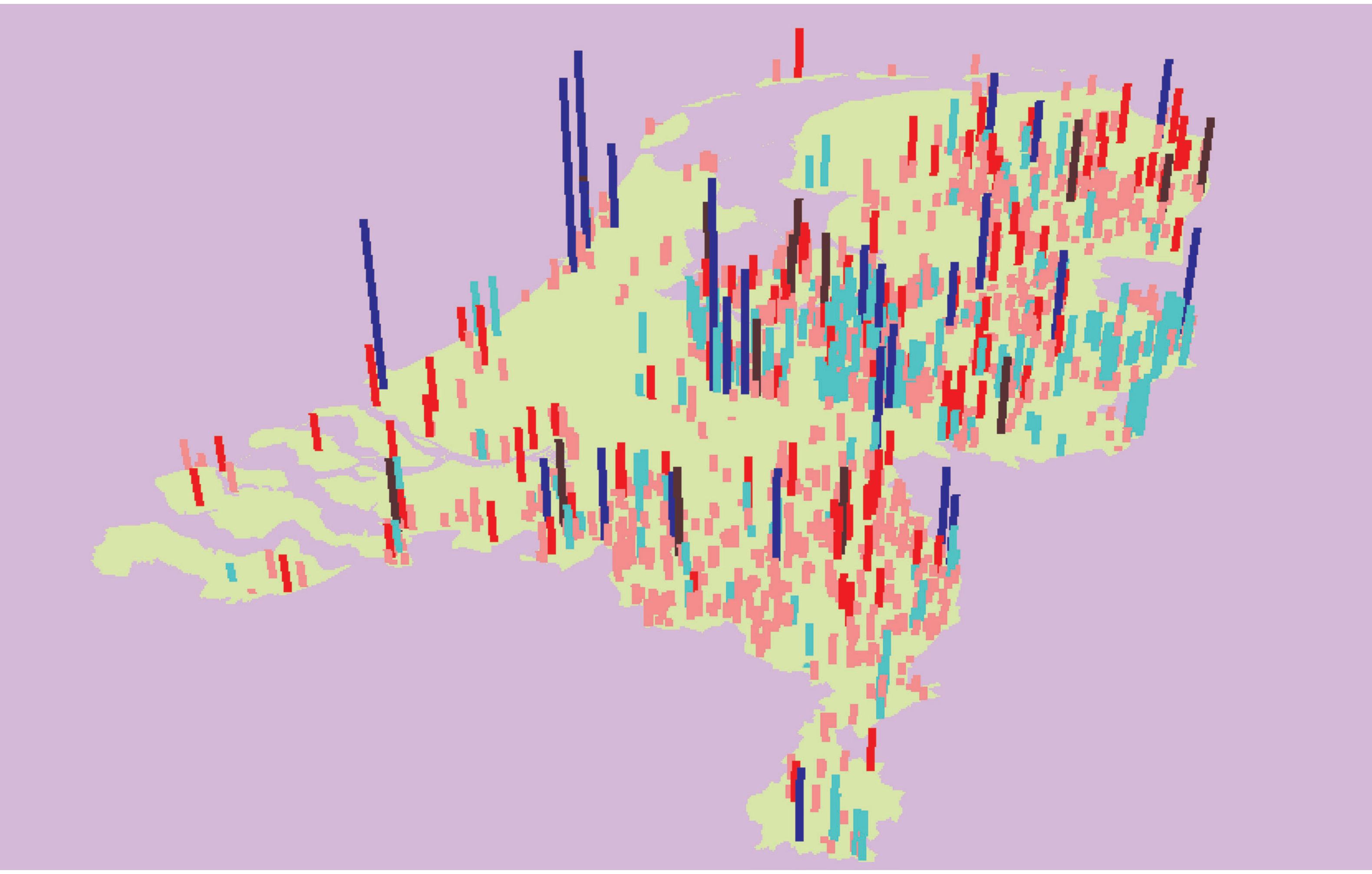

Greenhouse gas reporting of the LULUCF sector

Background to the Dutch NIR 2012

Alterra report 1035.9
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I.J.J. van den Wyngaert, E.J.M.M. Arets, H. Kramer, P.J. Kuikman and J.P. Lesschen

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Abstract

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Alterra report 1035.9
Wageningen, 2012

Contents

Preface

This report contains a complete description of the Dutch National System for Greenhouse gas Reporting of the LULUCF sector used for the 2012 submission.

The authors would like to thank Bas Clabbers, Gert-Jan van den Born, Klaas van der Hoek, Jenny van der Kolk and Harry Vreuls, who contributed to the quality of this report by reading and commenting on earlier versions.

Summary

This report contains a complete description of the Dutch Greenhouse gas calculations and reporting of the LULUCF sector used for the 2012 submission. Description of earlier versions can be found in Nabuurs et al. (2003, 2005), De Groot et al. (2005), Kuikman et al. (2003; 2005) and Van den Wyngaert et al. (2007, 2008, 2009, 2011). An overview of the history of this system since its development is given in Chapter 2.

In Chapter 3 a comprehensive overview is given of how land use information was classified into the six IPCC land use categories (Forest Land, Cropland, Grassland, Wetland, Settlements and Other land). This Chapter concludes with a table indicating all Dutch land use classes and how they relate to the IPCC categories.

For the 2012 submission a land-use map for 2009 is introduced enabling the development of a new land-use change matrix covering the years 2004-2009. The procedures to produce this land-use map and matrix were the same as fort the 2004 map and 1990-2004 land-use change matrix that was discussed in detail in Kramer et al. (2009). The new land-use map has not been published in a separate report but detailed information on the methodology followed is provided in Chapter 4, that also includes a summary of the development of the previous maps and land-use matrices. Additionally, the overlay of the land use maps and a soil carbon map, as well as a peat soil map, is also discussed in Chapter 4.

In Chapters 5 and 6 the calculations related to Forest Land as well as land conversion to and from Forest Land are described. In response to reviewer's demands for a more complete inventory from this 2012 submission onwards changes in biomass in land-use conversions to and from Croplands and Grasslands will be calculated based on default carbon stocks for total biomass (Chapter 5).

In Chapter 7 the motivation for the reporting of 0 as a conservative estimate for all carbon stock changes in mineral soils is given, as well as the basic calculation of the carbon emissions from organic soils.

In Chapter 8 the values submitted in the NIR 2012 are presented, and an extensive comparison is made between those and the values reported in the NIR 2011. The implementation of the new land-use map 2009 resulted in a change of all activity data since 2003. Other difference stem from the introduction of tier 1 biomass loss or biomass gain during land-use conversions to and from Croplands and Grasslands and an update of the 2010 emissions for liming.

In Chapter 9 and Annex F the formal QA/QC is presented. Finally, in Chapter 10 some outlook into the future is proposed.

1 Introduction

As a Party to the United Nations Framework Convention on Climate Change the Netherlands has the obligation to design and make operational a system for reporting of greenhouse gases (GHG) (Article 5 of the UNFCCC). For GHG reporting of the Land Use, Land Use Change and Forests (LULUCF) sector, the Netherlands has developed and improved an overall approach within the National System since 2003. This LULUCF part of the National System has been deployed for the National Inventory Reports (NIR's) since 2005, covering the period since 2003. It was also used for a full recalculation of the period 1990 - 2003. This LULUCF part of the Dutch National System has been documented in several publications. See e.g. Nabuurs et al. (2003, 2005), Van den Wyngaert et al. (2007, 2008, 2009, 2011), De Groot et al. (2005) and Kuikman et al. (2003, 2005).
The list of reports over the years reflects the continuous series of improvements and updates to the LULUCF sector within the Dutch National System. This report describes the current version, as used for the 2012 submission under the Convention. Reporting under the Kyoto protocol is described in Van den Wyngaert et al. (2012).

An overview of the current version of the LULUCF sector, with the current Tiers and methodologies is provided in Chapter 2. The current definitions of land use categories as was written in 2009 is retained (Chapter 3). The latest land use change matrix is incorporated and consequences of recalculation and extrapolation for the submitted values are discussed (Chapter 4). The calculation methods for living biomass in Forest Land are elaborated in Chapter 5, while Chapter 6 deals with the calculation of carbon storage (changes) in dead organic matter in Forest Land. Chapter 7 deals mainly with reporting of carbon emissions from mineral soils. Chapter 8 summarizes all values and compares the net effect of all improvements with earlier submissions. The QA/QC process that has been followed is given in Chapter 9. The report concludes with a plan of future improvements to the National System for LULUCF (Chapter 10).

2 National System for GHG reporting for the LULUCF sector - an overview

The current national system is based on the establishment of a land use and land use change matrix for the period 1990-2004 and 2004-2009 based on topographical maps (see also De Groot et al. (2005) for motivation of topographical maps as basis for land use calculations). The maps for 1990, 2004 and 2009 are gridded in a harmonised way and an overlay produced all land use transitions within this period (Kramer et al., 2009; Chapter 4). An overlay between the three land use maps with the organic soil map (Kuikman et al., 2005) allowed estimating the areas of organic soils for reporting categories Forest Land, Cropland and Grassland.

The carbon balance for live and dead biomass in Forest Land remaining Forest Land is based on National Forest Inventory (NFI) data using a simple bookkeeping model (Nabuurs et al., 2005; Annex A). NFI plot data are available from two inventories: the HOSP dataset (1988-1992; 3448 plots) (Daamen and Stolp, 1997) and the MFV dataset (2001-2005; 3622 plots) (Dirkse et al., 2007). The accumulation of carbon in dead wood is based on measured values in the two inventories, combined with some general parameters. Carbon stored in litter is estimated from a combination of national data sets (see Chapter 7). From 2012 on the changes from forests according to the definition to trees outside forests involve a loss of dead wood and litter (Chapter 7).

The carbon balance for areas changing away from Forest Land is based on the mean national stocks as calculated from the NFI data for biomass and the combined data sets for forest litter. The carbon balance for areas changing to Forest Land is based on national mean growth rates for young forests derived from the NFI data (see also Chapter 6). The carbon stock changes from changes in biomass from land changing to and from Croplands and Grasslands are based on Tier 1 methodology (see also Chapter 6).

Carbon in the soil is based on a recent National Soil Sampling Programme (NSSP) carried out between 1990 and 2000 (De Groot et al., 2005). A national soil C map was constructed based on these samples (including some gaps). The C stock for each land use (transition) category was derived from overlays between the soil C map and the land use maps for 1990 and 2000 (De Groot et al., 2005). The carbon emission from cultivation of organic soils was estimated for all organic soils based on ground surface lowering and the characteristics of the peat layers (Kuikman et al., 2005). Ground surface lowering was estimated from either ditch water level or mean lowest groundwater level (Kuikman et al., 2005).

In the 2012 submission, the following calculated emission values are reported (Table 2.1).

Table 2.1
Pools for which emissions are reported in the National System per land use (conversion) category in 2012. New variables are printed with grey background.

From→ To↓	FL-FAD	FL-TOF	CL	GL	WL	Sett	OL
FL –FAD	BG – BL + DW	BG	BG - BL	BG - BL	BG	BG	BG
FL-TOF	BG – DW - Litt	BG	BG - BL	BG - BL	BG	BG	BG
CL	BG – BL – DW - Litt	BG - BL	Lime appl.	BG - BL	BG	BG	BG
GL	BG – BL – DW - Litt	BG - BL	BG - BL	Cult. of org. soils	BG	BG	BG
WL	– BL – DW - Litt	- BL	- BL	- BL	-	-	-
Sett	– BL – DW - Litt	- BL	- BL	- BL	-	-	-
OL	– BL – DW - Litt	- BL	- BL	- BL	-	-	-

BG: Biomass Gain; BL: Bioma

3 Definition of land-use categories

The IPCC GPG distinguishes six main groups of land use categories: Forest Land, Cropland, Grassland, Wetland, Settlements and Other Land. Countries are encouraged to stratify these main groups further e.g. by climate or ecological zones, or special circumstances (e.g. separate forest types in Forest Land) that affect emissions. In the Netherlands, stratification has been used for Forest Land, Grassland and Wetlands.

The natural climax vegetation in the Netherlands is forest. Thus, except for natural water bodies and coastal sands, without human intervention all land would be covered by forests. Though different degrees of management may be applied in forests, all forests are relatively close to the natural climate vegetation. Extensive human intervention creates vegetation types that differ more from the natural climax vegetation like heathers and natural grasslands. More intensive human intervention results in agricultural grasslands. In general, an increasing degree of human intervention is needed for croplands and systems in the category Settlements are entirely created by humans. This logic is followed in the allocation of land to land use categories. In addition, lands are allocated to wetlands when they conform to neither of the former land use categories and do conform to the IPCC GPG definition of wetlands. This includes open water bodies, which are typically not defined as wetlands in the scientific literature. Until and including the 2008 submission, open water bodies were included in the Other Land category for that reason. However, from the 2009 submission on they form a separate subcategory of wetlands. The remaining lands in the Netherlands, belonging to neither of the former categories, are sandy areas with extremely little carbon in the soil. These were and are again included in Other Land.

3.1 Forest Land

The land use category '**Forest Land'** is defined as all land with woody vegetation consistent with thresholds used to defined forest land in the national GHG inventory, sub divided into managed and unmanaged units and also by ecosystem type as specified in IPCC Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed the threshold of the forest land category (IPCC, 2003, 2006).

The Netherlands has chosen to define the land use category 'Forest Land' as all land with woody vegetation, now or expected in the near future (e.g. clearcut areas to be replanted, young afforestations). This is further stratified in:

- 'Forest' or 'Forest according to the Kyoto definition' (FAD), i.e. all forest land which complies to the following (more strict than IPCC) definition chosen by the Netherlands for the Kyoto protocol: forests are patches of land exceeding 0.5 ha with a minimum width of 30 m, with tree crown cover at least 20% and tree height at least 5 meters, or, if this is not the case, these thresholds are likely to be achieved at the particular site. Roads in the forest less than 6 meters wide are also considered to be forest. This definition conforms to the FAO reporting and was chosen within the ranges set by the Kyoto protocol.
- 'Trees outside Forests' (TOF), i.e. wooded areas that comply with the previous forest definition except for their surface (=< 0.5 ha or less than 30 m width). These represent fragmented forest plots as well as groups of trees in parks and nature terrains and most woody vegetation lining roads, fields etc… These areas comply to the GPG-LULUCF definition of Forest Land (i.e. they have woody vegetation) but not to the strict forest definition that the Netherlands applies.

The TOP10Vector map classes that are reported under FAD and TOF are deciduous forest, coniferous forest, mixed forest, poplar plantations and willow coppice. A patch of a certain forest class is allocated to FAD if it exceeds the minimum requirements and to TOF otherwise. Groups of trees are mapped as forest only if they have a minimum surface of 50 m^2, or of 1000 m^2 in built-up areas or parks.

3.2 Cropland

The land use category '**Cropland**' is defined as 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 (IPCC, 2003).

The Netherlands has chosen to define croplands as arable lands and nurseries (including tree nurseries). Intensive grasslands are not included in this category and are reported under Grasslands. For part of the agricultural land, rotation between arable land and grassland is frequent, but data on where exactly this is occurring are as yet lacking. Currently, the situation on the topographical map is leading, with lands under agricultural crops and classified as arable lands at the time of recording reported under Cropland and lands with grass vegetation at the time of recording classified as Grassland.

The TOP10Vectore class arable land is reported under Cropland, as well as the class Tree nurseries. The latter does not conform to the forest definition, and the agricultural type of farming system justifies the inclusion in Cropland. Greenhouses are not included in Cropland, but instead they are considered as Settlement.

3.3 Grassland

The land use category '**Grassland**' is defined as rangeland and pasture land that is not considered as croplands. It also includes vegetation that falls below the threshold used in the forest land category and are not expected to exceed, without human intervention, the threshold used in the forest land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastoral systems, subdivided into managed and unmanaged consistent with national definitions (IPCC, 2003). It is stratified in:

- 'Grasslands', i.e. all areas predominantly covered by grass vegetation (whether natural, recreational or cultivated).
- 'Nature', i.e. all natural areas excluding grassland (natural grasslands and grasslands used for recreation purposes). It mainly consists of heathland, peat moors and other nature areas. Many have the occasional tree as part of the typical vegetation structure. This category was in the previous submissions a subcategory within Forest Land.

The Netherlands currently reports under grassland any type of terrain which is predominantly covered by grass vegetation (equivalent to one general class of grasslands on the TOP10Vector maps). No distinction is made between agricultural intensively and extensively managed grasslands and natural grasslands. However, the potential and the need for this is currently under discussion.

Apart from pure grasslands, all orchards (with standard fruit trees, dwarf varieties or shrubs) are included in the category grasslands. They do not conform to the forest definition, and while agro-forestry systems are mentioned in the definition of Croplands, this is motivated by the cultivation of soil under trees. However, in the Netherlands the main undergrowth of orchards is grass. We therefore chose to report them as grasslands. As for grasslands no change in above-ground biomass is reported, the carbon stored in these trees is not reported.

The TOP10Vector map class heathland and peat moors, reported as Nature, includes all land that is covered (mostly) with heather vegetation or rough grass species. Most of these were created in the Netherlands as a consequence of ancient grazing and sod cutting on sandy soils. As these practices are not part of the current agricultural system anymore, conservation management is applied to halt the succession to forest and conserve the high landscape and biodiversity values associated it.

3.4 Wetland

The land use category '**Wetland**' includes land that is covered or saturated with water for all or part of the year and does not fall into the forest land, cropland, grassland or settlements categories. It includes reservoirs as a managed sub-division and natural lakes and rivers as unmanaged sub-divisions (IPCC, 2003).

Though the Netherlands is a country with many wet areas by nature, many of these are covered by a grassy vegetation and those are included under grasslands. Some wetlands are covered by a more rough vegetation of wild grasses or shrubby vegetation, which is reported in the subcategory 'Nature' of Grassland. Forested wetlands like willow coppice are reported in the subcategories FAD or TOF of Forest Land, depending on their surface.

In the Netherlands, only reed marshes and open water bodies are included in the Wetland land use category. Reed marshes are areas where the presence of Common Reed *(Phragmites australis)* is indicated separately on the TOP10Vector maps. These may vary from wet areas in natural grasslands to extensive marshes. The presence of reed is marked with individual symbols which are translated to surfaces (Kramer et al., 2007) and conform to neither of the previous categories.

Open water bodies are all areas which are indicated as water on the TOP10Vector maps (water is only mapped if the surface exceeds 50 m^2). This includes natural or artificial large open waters (e.g. rivers, artificial lakes), but also small open water bodies like ditches and channels as long as they cover enough surface to be shown in the 25 m x 25 m grids. Additionally, it includes so called 'emerging surfaces', i.e. bare areas which are under water only part of the time as a result of tidal influences, and very wet areas without vegetation. It also includes 'wet' infrastructure for boats, i.e. waterways but also the water in harbours and docks.

3.5 Settlements

The land use category '**Settlements**' includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories (IPCC, 2003).

In the Netherlands, the main TOP10Vector classes included in Settlements are urban areas and transportation infrastructure, and built-up areas. Built-up areas include any constructed item, independent of the type of construction material, which is (expected to be) permanent, fixed to the soil surface (i.e. to distinguish from caravans,…) and serves as place for residence, trade, traffic and/or labour. Thus it includes houses, blocks of houses and apartments, office buildings, shops and warehouses but also fuel stations and greenhouses.

Urban areas and transportation infrastructure include all roads, whether paved or not, are included in the land use category Settlements with exception of forest roads less than 6 m wide, which are included in the official forest definition. It also includes train tracks, (paved) open spaces in urban areas, parking lots and graveyards. Though some of the last class are actually covered by grass, the distinction cannot be made based on maps. As even the grass graveyards are not managed as grasslands, inclusion in the land use category 'Settlements' conforms better to the rationale of the land use classification.

3.6 Other Land

The land use category '**Other Land**' was included to allow the total of identified land to match the national area where data are available. It includes bare soil, rock, ice and all unmanaged land area that do not fall in any of the other five categories (IPCC, 2003).

In general, Other Land does not have a substantial amount of carbon. The Netherlands uses this land use category to report the surfaces of bare soil which are not included in any other category. It does not include bare areas that emerge from shrinking and expanding water surfaces (these 'emerging surfaces' are included in wetlands).

The TOP10Vector classes dominated by sand are completely included in it. It includes all terrains which do not have vegetation on them by nature. The last part of the phrase 'by nature' is used to distinguish this class from settlements and fallow croplands. It includes coastal dunes and beaches with little to no vegetation. It also includes inland dunes and shifting sands, i.e. areas where the vegetation has been removed to create spaces for early succession species (and which are being kept open by wind). Inland bare sand dunes developed in the Netherlands as a result of heavy overgrazing and were combated by planting forests for a long time. These areas were, however, the habitat to some species which have become extremely rare nowadays. Inland sand dunes can be created as vegetation and top soil is again removed as a conservation measure in certain nature areas.

3.7 Overview of land use allocation

The basis of allocation for IPCC land use (sub)categories is the TOP10Vector land use/cover classification. For most of the TOP10Vector classes, there was one IPCC land use (sub)category where it could be unambiguously included. For other TOP10Vector classes, there were some reasons to include it in one, and other reasons to include it in another IPCC land use (sub)category. In these cases, we allocated it to the land use category where (in sequential order):

the majority of systems (based on surface) in the TOP10Vector class would fit best based on the degree of human impact on the system (see also Introduction),

or

if this did not give an unambiguous solution, we allocated it where the different types of carbon emission considered/reported represented the situation in the TOP10Vector class best.

The resulting classification is summarized in Table 3.1.

Table 3.1
Overview of allocation of TOP10Vector classes to IPCC land use (sub)categories (based on Kramer et al., 2007)

TOP10Vector	Dutch TOP10Vector name	GPG classes
Deciduous forest	Loofbos	Forest Land
Coniferous forest	Naaldbos	Forest Land
Mixed forest	Gemengd bos	Forest Land
Poplar plantation	Populierenopstand	Forest Land
Willow coppice	Griend	Forest Land
Arable land	Bouwland	Cropland
Tree nurseries	Boomkwekerij	Cropland
Grasslands	Weiland	Grassland
Orchard (high standards)	Boomgaard	Grassland
Orchard (low standards and shrubs)	Fruitkwekerij	Grassland
Heathland and peat moors	Heide en hoogveen	Grassland
Reed marsh	Rietmoeras	Wetland
Water (large open water bodies)	Water (grote oppervlakte)	Wetland
Water (small open water bodies)	Oeverlijn / Water (kleine oppervlakte)	Wetland
Ditch	Sloten	Wetland
Emerging surfaces	Laagwaterlijn / droogvallende gronden	Wetland
'Wet' infrastructure	Dok	Wetland
Urban areas and transportation infrastructure	Stedelijk gebied en infrastructuur	Settlement
Built-up areas	Bebouwd gebied	Settlement
Greenhouses	Kassen	Settlement
Coastal dunes and beaches	Strand en duinen	Other land
Inland dunes and shifting sands	Inlandse duinen	Other land

4 Land-use change matrix

4.1 Introduction

The Netherlands has developed an overall approach within the National System since 2003, which has been deployed for the National Inventory Reports since 2005. After an extensive inventory of available land use datasets in the Netherlands (Nabuurs et al., 2003), information on the surface of the different land use categories and conversions between categories was based on a wall-to-wall map overlay, resulting in a national scale land use and land use change matrix (Nabuurs et al., 2005). The current submission for the LULUCF sector is based on land use change matrices that are derived from three maps representing the land use in 1990, 2004 (Kramer et al., 2009) and 2009. In Kramer et al. (2009) all steps involved in the calculation of the land use and land use change matrix used from 2009 on are described in detail. In this Chapter only a short summary of the methodology is given with additions for the map for 2009 and land-use change matrix from 2004 to 2009 that will be used from the 2012 onwards.

4.2 Methodology

The land use maps are based on maps that are used for monitoring nature development in the Netherlands, 'Basiskaart Natuur' (BN). These maps were based on different topographic maps of the Dutch Kadaster (Land Registry Office). The source material for BN1990 consists of the topographic map 1:25,000 (Top25) and digital topographical map 1:10,000 (Top10Vector). Map sheets with exploration years in the period 1986-1994 were used. The paper TOP25 maps were converted to a digital high resolution raster map. The source material for BN2004 consists of the digital topographic map 1:10,000 (Top10Vector). All topographic maps have been explored in the period 1999-2003. Auxiliary information on areas managed for nature purposes was dated on 2004. The Top10Vector has an update frequency of four years, now decreasing to between two and four years. Higher update frequencies occur in urban areas, lower in rural areas.

The maps were initially created to monitor changes in nature areas, but because of its national coverage and inclusion of other land use types it is also very suitable as land use data set for the reporting of the LULUCF sector. The latest BN maps, therefore, paid attention to the requirements for UNFCCC reporting. In Table 4.1 the characteristics of the three maps are presented.

The Top10Vector file, digitised Top25 maps and TOP10NL maps were (re)classified to match the requirements set for both the monitoring changes in nature areas and UNFCCC reporting. In this process additional data sets were used. Simultaneously, harmonisation between the different source materials was applied to allow a sufficiently reliable overlay (see Kramer et al., 2009 for details). The final step in the creation of the land use maps was the aggregation to 25 m × 25 m raster maps. For the 1990 map, which had a large part of the information derived from paper maps, an additional validation step was applied to check on the digitising and classifying processes.

Table 4.1
Characteristics of the maps BN1990, BN2004 and BN2009.

Characteristics	BN1990	BN2004	BN2009
Name	Historical Land use Netherlands 1990	Base map Nature 2004	Base map Nature 2009
Aim	Historical land use map for 1990	Base map for monitoring nature development	Base map for monitoring nature development
Resolution	25 m	25 m	25 m
Coverage	Netherlands	Netherlands	Netherlands
Base year source data	1986-1994	1999-2003	2004-2008
Source data	Hard copy topographical maps at 1:25,000 scale and digital topographical maps at 1:10,000	Digital topographical maps at 1:10,000 and additional sources to distinguish specific nature types	Digital topographical maps at 1:10,000 and additional sources to distinguish specific nature types
Number of classes	10	10	10
Distinguished classes	Grassland, Arable land, Heath land/peat moor, Forest, Buildings, Water, Reed marsh, Sand, Built-up area, Greenhouses	Grassland, Nature grassland, Arable land, Heath land, Forest, Built-up area and infrastructure, Water, Reed marsh, Drifting sands, Dunes and beaches	Grassland, Nature grassland, Arable land, Heath land, Forest, Built-up area and infrastructure, Water, Reed marsh, Drifting sands, Dunes and beaches

4.2.1 Land use map and statistics for 2009

The methodology for the 1990 and 2004 land-use maps is explained in more detail in Kramer et al. (2009). For the submission in 2012 a new land-use map for 2009 has become available, which is not published in another report. Here we will provide more detailed information on the methodology followed for this map.

The procedure followed to create the 2009 land use map for the Netherlands is the same as the procedure for the 2004 land use map as described in Kramer et.al. (2009). The source remains the 'Basiskaart Natuur' that was updated to version 2009 (BN2009). The source material for BN2009 is based on the digital topographic map 1:10,000 (Top10NL). The aerial photographs for this topographic map were taken in the period 2004-2008 (Figure 4.1). The format of the source topographic map of BN2009, however, differs from the source of the BN2004. This Top10NL map is the successor of Top10Vector maps that were used for BN2004. Both types are created by the Dutch Kadaster, but there is a gap in time between the last version of Top10Vector, produced in 2006, and the first version of Top10NL, produced in 2009. This is caused by technical problems that deal with the implementation of the workflow for Top10NL. During this period, map sheets were updated but the exact update timestamp for the topographic elements was not stored in the Top10NL. To get an overview of the exploration year, a best possible guess was made based on the acquisition dates of the aerial photos that were used for updating the map sheets. This overview with exploration year by map sheet is presented in Figure 4.1.

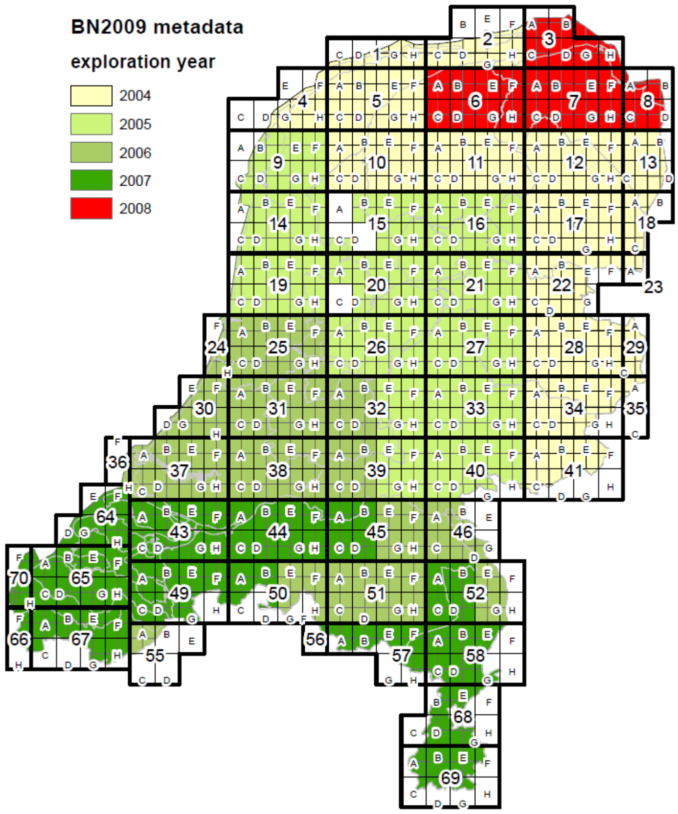

Figure 4.1
Exploration year by map sheet used for BN2009.

Table 4.2
Land-use statistics based on the 2004 and 2009 land-use maps.

Code	Land use	2004		2009	
		Area (ha)	% of total	Area (ha)	% of total
10	Other grassland	1 233 176	29.7	1 201 729	28.9
11	Nature grassland	126 973	3.1	140 632	3.4
14	Small forest	22 207	0.5	22 092	0.5
20	Arable land	939 617	22.6	924 863	22.3
30	Heath land	47 915	1.2	49 128	1.2
40	Forest	370 041	8.9	373 480	9.0
70	Water	780 139	18.8	785 994	18.9
80	Reed swamp	27 126	0.7	25 947	0.6
90	Drifting sands	2 971	0.1	3 766	0.1
91	Dunes, beaches and sand plates	35 002	0.8	34 747	0.8
101	Built-up area	326 353	7.9	349 284	8.4
102	Railroads	6 195	0.1	6 561	0.2
103	Roads	233 784	5.6	233 279	5.6
	Total	4 151 500		4 151 500	

The final land use map for 2009 is presented in Figure 4.2 and the land use statistics are shown in Table 4.2. Like the observation between 1990 and 2004 (Kramer, 2009), the overall land use pattern did not change very much between 2004 and 2009. Built-up and (rail)roads areas increased from 13.6% in 2004 to 14.2% in 2009, while also an increase of the nature areas from 15.2% to 15.7% of the total land area was observed (see Table 4.2). Again, this is mainly at the expense of agriculture, which decreased from 52.3% in 2004 to 51.2% in 2009.

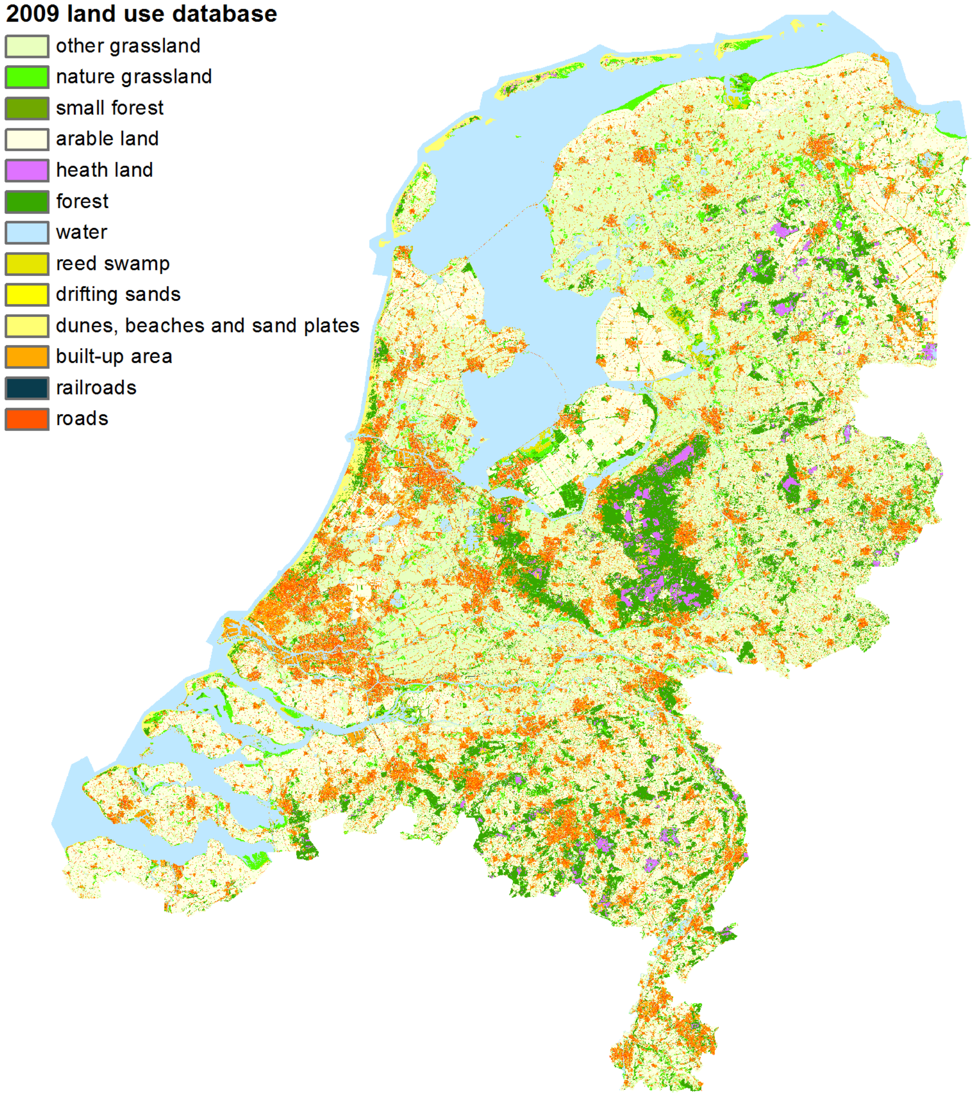

Figure 4.2
Land-use map of 2009.

While analysing the land use changes between 2004 and 2009, several counterintuitive land use changes were observed. A further exploration of the topographic maps from 2004 and 2009 in combination with the corresponding aerial photos showed that there is a difference in the way topographic elements are recorded for Top10Vector and Top10NL.

For instance roads on the 2009 map are represented in more detail and higher resolution, resulting in more narrow representations on the map. Other examples where this happens are airfields and industrial sites that on the 2004 topographic map were classified as other land-use, but now has the runways, buildings and roads and surrounding grasslands classified separately. Since these represent only a relatively small area there was no correction applied. The next land-use map for 2013 will again be based on TOP10NL source data and therefore it is expected that this problem will not occur in the next land-use change matrix 2009-2013.

4.3 Land use change matrix

The land use change matrices are the result of overlays between the 25 m × 25 m land use maps of 1990 and 2004 and of 2004 and 2009. The overlay of the land use maps of 1990 and 2004 resulted in a land use and land use change matrix over fourteen years (1 January 1990 - 1 January 2004) (Table 4.5). The overlay of the land-use maps of 2004 and 2009 results in a land-use change matrix over five years (1 January 2004 - 1 January 2009) (Table 4.6).

These matrices shows the changes for thirteen land use categories. For the purpose of the CRF and NIR, the thirteen land use categories are aggregated into the six land use classes that are defined in the LULUCF guidelines (Tables 4.3 and 4.4). The definition of the UNFCCC land use categories is given in Chapter 3.

Table 4.3

Land Use and Land Use Change Matrix for 1990-2004 aggregated to the six UNFCCC land use categories (in ha).

				BN 1990			
BN 2004	Forest land	Cropland	Grassland	Wetland	Settlement	Other land	*Total*
Forest land	350,751	14,560	22,540	1,217	2,530	651	*392,248*
Cropland	1,605	739,190	196,595	596	1,623	8	*939,617*
Grassland	17,902	176,797	1,190,740	9,092	10,987	2,547	*1,408,064*
Wetland	1,822	6,821	18,641	776,007	1,390	2,583	*807,265*
Settlement	10,019	81,783	78,259	2,836	392,805	630	*566,332*
Other land	809	201	907	2,791	122	33,144	*37,974*
Total	*382,907*	*1,019,353*	*1,507,682*	*792,539*	*409,457*	*39,563*	*4,151,500*

Table 4.4

Land Use and Land Use Change Matrix for 2004-2009 aggregated to the six UNFCCC land use categories (in ha).

				BN 2004			
BN 2009	Forest land	Cropland	Grassland	Wetland	Settlement	Other land	*Total*
Forest land	377,584	2,304	8,827	466	6,155	238	*395,573*
Cropland	487	813,282	106,547	177	4,367	2	*924,863*
Grassland	6,417	108,480	1,243,329	9,633	23,123	506	*1,391,488*
Wetland	829	1,794	10,610	794,785	3,033	890	*811,941*
Settlement	6,694	13,729	37,705	1,441	529,417	137	*589,123*
Other land	238	27	1,047	762	237	36,200	*38,512*
Total	*392,248*	*939,617*	*1,408,064*	*807,265*	*566,332*	*37,974*	*4,151,500*

The total area of land use change in the period 1990 to 2004 was about 6,700 km^2, which is around 16% of the total area and in the period 2004 to 2009 3,569 km^2 changed, which is about 8.6% of the total land area. The largest changes in land use are the conversion of cropland to grassland and vice versa. Other important land use changes are the conversions of cropland and grassland to settlement (urbanisation).

Table 4.5
Land Use and Land Use Change Matrix based on the classification in thirteen classes (in ha). Shaded cells indicate surfaces not changing land use between 1990 and 2004.

	BN1990													
BN2004	10	11	14	20	30	40	70	80	90	91	101	102	103	Grand Total
10 Grassland	1047,889		2,781	159,806	255	6,388	3,924	1,196	130	216	9,505	134	953	1,233,176
11 Nature grassland	58,206	40,878	380	16,350	759	4,918	1,679	1,958	74	1,438	275	8	51	126,973
14 Trees outside Forest	3,949	306	11,336	2,039	220	2,852	274	54	15	83	979	13	85	22,207
20 Arable land	195,545	1,002	386	739,190	48	1,218	523	73	4	5	1,456	9	158	939,617
30 Heather	332	338	155	641	42,083	3,280	291	44	437	252	52	5	5	47,915
40 Forest (Kyoto)	10,194	3,065	2,352	12,520	4,806	334,211	569	319	205	348	1,198	24	230	370,041
70 Open water	8,019	1,763	247	5,042	739	1,197	757,870	1,419	171	2,332	1,248	5	86	780,139
80 Reed marsh	3,813	4,274	71	1,780	33	306	1,141	15,577	1	78	44	3	3	27,126
90 Shifting sands	94	21	9	88	147	197	103	1	2,303		8		1	2,971
91 Coastal dunes	139	381	101	113	124	502	2,663	24	3	30,838	103	0	10	35,002
101 Built-up area	67,151	889	2,768	71,942	334	6,344	2,398	158	235	345	163,204		10,587	326,353
102 Railways	372	2	29	590	7	103	20	4	0	1		4,885	183	61,95
103 Roads	9,434	60	192	9,252	11	583	240	17	6	43	10,456	119	203,371	233,784
Grand Total	1,405,136	52,979	20,806	1,019,353	49,567	362,100	771,696	20,843	3,584	35,979	188,529	5,205	215,723	4151,500

Table 4.6
Land Use and Land Use Change Matrix based on the classification in thirteen classes (in ha). Shaded cells indicate surfaces not changing land use between 2004 and 2009.

	BN2004													
BN2009	10	11	14	20	30	40	70	80	90	91	101	102	103	Grand Total
10 Grassland	1,062,501	10,549	1,067	102,201	73	1,873	753	1,362	27	10	11,525	175	9,613	1,201,729
11 Nature grassland	20,644	102,625	89	6,177	315	1,772	527	6,888	33	248	753	8	552	140,632
14 Trees outside Forest	1,231	432	16,893	297	45	1,516	41	51	4	25	742	15	802	22,092
20 Arable land	105,509	1,027	137	813,282	11	350	138	39	2	0	2,309	20	2,038	924,863
30 Heather	88	1,024	43	102	45,512	1,574	96	6	126	62	360	8	128	49,128
40 Forest (Kyoto)	2,514	3,355	1,701	2,007	1,249	357,474	119	254	40	169	2,027	45	2,525	373,480
70 Open water	2,785	2,345	76	1,662	190	302	774,288	766	59	810	1,827	5	879	785,994
80 Reed marsh	1,484	3,560	50	132	247	401	2,115	17,616	1	21	267	1	54	25,947
90 Shifting sands	76	164	5	26	144	95	78	3	2,650	383	127	0	13	3,766
91 Coastal dunes	23	594	26	1	45	112	660	21	0	33,167	62	0	35	34,747
101 Built-up area	27,309	981	1,639	10,608	63	3,734	1,044	97	28	87	301,488	30	2,177	349,284
102 Railways	161	14	9	48	3	19	8	4	0	0	397	5,820	80	6,561
103 Roads	8,853	304	474	3,074	19	819	271	17	2	20	4,471	68	214,888	233,279
Grand Total	1,233,176	126,973	22,207	939,617	47,915	370,041	780,139	27,126	2,971	35,002	326,353	6,195	233,784	4,151,500

4.4 Peat soils

The areas of peat and mineral soils have to be reported separately under cropland, grassland and forest land. Therefore an overlay between the new land use maps and the Dutch soil map (De Vries et al., 2003) indicating the peat areas was made. The results are presented in Table 4.4. Regarding the six UNFCCC land use categories, 283 km^2 of peat soils was under cropland, 2050 km^2 under grassland and 131 km^2 under forest land in 2004. More information about the emission from organic soils can be found in Chapter 7.

Table 4.7
Peat areas under different land uses in 1990 and 2004

Land use	Peat area 1990 (ha)	Peat area 2004 (ha)	Total area 2004 (ha)	% total land 1990	% total land 2004
Other grassland	199,552	175,028	1,233,176	16.2	14.2
Nature grassland	10,330	24,963	126,973	8.1	19.7
Small forest	1,305	1,377	22,207	5.9	6.2
Arable land	31,265	28,336	93,9617	3.3	3.0
Heath land	5,260	4,999	47,915	11.0	10.4
Forest	10,341	11,724	370,041	2.8	3.2
Water	9,509	11,059	780,139	1.2	1.4
Reed swamp	7,625	8,909	27,126	28.1	32.8
Shifting sands	12	10	2,971	0.4	0.3
Dunes, beaches and sand plates	1	2	35,002	0.0	0.0
Built-up area	5,661	13,078	326,352	1.7	4.0
Railroads	268	325	6,195	4.3	5.2
Roads	7,741	9,060	233,784	3.3	3.9
Total	288,869	288,869	4,151,497		7.0

4.5 Conclusions

The 'Basiskaart Natuur' matches the requirements for a primary land use dataset for carbon reporting in a small, intensively managed country as the Netherlands. It is spatially explicit, covers the entire country and the spatial resolution allows sufficiently detailed representation of the fine-grained land use mosaic in the Netherlands. It is the basis for the monitoring of nature in the Netherlands, and as such it has a legal status and is updated regularly. It is based on the digital topographical maps (Top10Vector and Top10NL) which had an update frequency of four years, and which is expected increase in the future. The spatially explicit land use map allows overlays with other maps to fulfil additional needs like reporting the areas on peat soils.

Two land use change matrices was derived by overlaying the 1990 and 2004 and 2004 and 2009 land use maps. The results were compared with expectations from policies and other sources. Taking into account all uncertainties, the trends and results from the land use matrix matched other sources remarkably well and could be explained from the specific land use policies in the Netherlands. It is therefore concluded that the approach taken is in compliance with GPG-LULUCF and gives the best estimate currently possible for land use and land use change for the Netherlands.

5 Carbon emissions from living biomass

5.1 Forest land remaining Forest Land

The land use category 'Forest land' is defined as all land with woody vegetation consistent with thresholds used to defined forest land in the national GHG inventory. In the Netherlands, unmanaged forests are non-existent and the only subdivision is based on the extent of the forest occurring:

- 'Forest according to the Kyoto definition' (FAD) is all forest land which complies to the following definition: patches of land exceeding 0.5 ha with a minimum width of 30 m, with tree crown cover at least 20% and tree height at least five meters, or, if this is not the case, these thresholds are likely to be achieved at the particular site. Roads in the forest less than six meters wide are also considered to be forest. This definition is used for the Kyoto protocol article 3.3 and as requested by 16/CPM.1, Annex E, section 16, included in the Initial Report.
- 'Trees outside Forests' (TOF) are wooded areas on the map that comply with the forest definition except for their surface (=< 0.5 ha). These represent fragmented forest plots as well as groups of trees in parks and nature terrains and most woody vegetation lining roads, fields etc.

In the following paragraphs the methods are described to calculate the changes in carbon stock for Forest Land remaining Forest Land (both subdivisions), and changes to and from Forest Land, as used for the 2011 submission. Where any updates, changes or improvements relative to the 2010 submissions are implemented, this is noted but not elaborated. The reader is then referred to the respective annex where the full motivation and comparison with earlier submissions is given.

5.1.1 Forest according to the Definition

The basic approach follows the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry where a stock change approach is suggested. The net flux is calculated as the difference in carbon contained in the forest between two points in time. Carbon in the forest is derived from the growing stock volume, making use of other forest traits routinely determined in forest inventories. If no repeated measurements are available, the flux is derived from the volume increment in consecutive years. The last approach was used in the Netherlands until now.

For the period of interest, i.e. 1990 and on, two types of National Inventories were available for the Netherlands: the so called HOSP data (1988-1992) and the MFV data (2001-2005). The HOSP (Hout Oogst Statistiek en Prognose oogstbaar hout) inventory was designed to get insight in the amount of harvestable wood. In total 3448 plots were characterized by age, tree species, growing stock volume, increment, height, tree number and dead wood. Each plot represented a certain area of forest ('representative area') of between 0.4 ha and 728.3 ha. Together they represent an area of 310736.3 ha, the estimated surface of forest where harvesting was relevant in 1988 (The HOSP inventory was designed in 1988 and conducted between 1988 and 1992). The MFV (Meetnet Functie Vervulling Bos) inventory was designed as a randomized continuous forest inventory. In total 3622 plot recordings with forest cover were available for the years 2001, 2002, 2004 and 2005 (2003 was not inventoried because of a contagious cattle disease). Apart from the live and dead wood characteristics, in 2004 and 2005 litter layer thickness was measured in stands on poor sand and loss (Daamen and Dirkse, 2005).

Both forest inventories yielded the initial data for plot level calculation of the increase in volume of living and dead wood. The amount of wood harvested was available only at the national level and was downscaled to plot level according to the probability of harvesting as calculated from plot age and growing stock volume. The volumes harvested per year are taken from the FAO harvest statistics (www.fao.org) (see also Annex E). The wood production is given as production roundwood in m^3 underbark. The total annual volume removed from the forest includes bark as well as losses during harvesting and is calculated from roundwood underbark as follows:

$$H_{NL} = H_{NLub} \cdot f_{\frac{ob}{ub}} \cdot f_{\frac{tw}{rw}}$$

With:

H_{NL}	Annually extracted total volume overbark from forests in NL (m^3 $year^{-1}$)
H_{NLub}	Annually extracted volume roundwood underbark from forests in NL (m^3 $year^{-1}$)
$f_{\frac{ob}{ub}}$	Conversion from underbark to overbark (1.136 m^3 o.b. / m^3 u.b.)
$f_{\frac{tw}{rw}}$	Conversion from roundwood to total wood (1.06 m^3 wood / m^3 roundwood $year^{-1}$)

All harvests were calculated as thinnings.

The conversion from plot characteristics to whole tree carbon was based on allometric converting plot diameter and height to above and below ground biomass (Annex B). See Nabuurs et al. (2005) for the selection of the most suitable equations and a more detailed description of the database and a list of studies included. The use of allometric relations yielding biomass directly made any conversions including wood density obsolete. Carbon content of live biomass was calculated assuming a IPCC default carbon concentration of 0.5 g C g^{-1} DM (IPCC, 2003). The conversion of dead wood volume to carbon did not take into account anything but the volume of the logs. This was converted to mass using an average dead wood density half that of live trees. The full set of equations converting plot data into carbon fluxes for forests remaining forest is given in Annex A(I).

These calculations were performed for all plots with complete data coverage (missing data category (0)). Plots with missing data were separated into three categories:

(1) Plots with volume and increment data, but missing one or more of the following variables: height, diameter or recording year.
For these plots, volume increment was converted to a carbon flux based on a national mean BEF2 (= carbon flux due to biomass increase / increment). This was calculated from plots with full data coverage. Carbon flux from dead wood was scaled using growing stock volume.

(2) Plots with no volume and increment data but with the designation 'clear cut area'.
Plots with the designation 'clear cut area' were assumed to have no volume and no increment, and no carbon flux from live trees or dead wood.

(3) Plots with no volume or increment data.
Plots with no data at all were extrapolated using the area corrected average for the other three categories.

Thus the following calculation is used to correct for missing data for carbon stock change due to biomass increase:

$$\Delta C_{(1)} = I_{(1)} \frac{\Delta C_{(0)}}{I_{(0)}}$$

$$\Delta C_{(2)} = 0$$

$$\Delta C_{(3)} = \left(\Delta C_{(0)} + \Delta C_{(1)} + \Delta C_{(2)}\right) \cdot \frac{Area_{(3)}}{\sum_{x=0,1,2} Area_{(x)}}$$

$$\Delta C_{FF_G} = \Delta C_{(0)} + \Delta C_{(1)} + \Delta C_{(2)} + \Delta C_{(3)}$$

With

$\Delta C_{(x)}$	annual increase in carbon stocks (in Gg C) due to biomass increase in area represented by plots with missing data category x.
$Area_{(x)}$	total representative area for plots with missing data category x.
$I_{(x)}$	total increment in m^3 $year^{-1}$ for area represented by plots with missing data category x.
ΔC_{FF_G}	annual increase in carbon stocks in Gg C due to biomass increase in forests in the Netherlands.

The net carbon balance in FAD due to changes in biomass is then calculated as

$$\Delta C_{FF_{LB}} = \Delta C_{FF_G} - \Delta C_{FF_L}$$

With

$\Delta C_{FF_{LB}}$	annual change in carbon stocks (in Gg C) due to biomass change in forests in the Netherlands.
ΔC_{FF_G}	annual increase in carbon stocks (in Gg C) due to biomass increase in forests in the Netherlands.
ΔC_{FF_L}	annual decrease in carbon stocks (in Gg C) due to biomass decrease in forests in the Netherlands (for calculation see Annex A).

5.1.2 Trees outside Forest

For Trees outside Forest, no data on growth or increment are available. Similar to earlier years, it is assumed that Trees outside Forest grow with the same growth rate as Forests according to the Kyoto definition. The only difference between them is the size of the stand (< 0.5 ha for Trees outside Forest), so this seems a reasonable assumption. It is assumed that no building up of dead wood or litter occurs. It is also assumed that no harvesting takes place. Even if this assumption would not completely be met, the error would be negligible, as the harvested wood would be counted in the national harvest statistics and therefore would be counted under Forests according to the Kyoto definition.

5.2 Forest Land converted to other land use classes

5.2.1 Forest according to the Kyoto definition

The total emissions from the tree component after deforestation is calculated by multiplying the total area deforested with the average carbon stock in living biomass, above as well as below ground (Nabuurs et al., 2005) and the average carbon stock in dead organic matter. Thus it is assumed that with deforestation, all carbon stored in above and below ground biomass as well as in dead wood and litter is lost to the atmosphere. National averages are used as there is no record of the spatial occurrence of specific forest types.

The average carbon stock in living biomass follows the calculations from the gap filled NFI data (see Par. 5.1.1 and Annex A). The emission factors (in Mg C ha-1) are given in Table 5.1. The systematic increase in average standing carbon stock reflects the fact that annual increment exceeds annual harvests in the Netherlands.

Table 5.1.
Emission Factors for deforestation in Mg C ha^{-1}

NFI	Year	EF biomass	EF litter	EF dead wood
Hosp	1990	-60.4	28.97	0.45
Hosp	1991	-61.5	29.22	0.64
Hosp	1992	-63.0	29.78	0.79
Hosp	1993	-64.2	30.34	0.92
Hosp	1994	-65.7	30.90	1.03
Hosp	1995	-67.1	31.46	1.13
Hosp	1996	-68.5	32.02	1.21
Hosp	1997	-70.0	32.59	1.28
Hosp	1998	-71.4	33.15	1.35
Hosp	1999	-72.8	33.71	1.41
MFV	2000	-71.7	34.27	1.45
MFV	2001	-73.6	34.82	1.43
MFV	2002	-75.6	35.39	1.42
MFV	2003	-77.7	35.95	1.43
MFV	2004	-79.5	35.95	1.44
MFV	2005	-81.4	35.95	1.46
MFV	2006	-83.1	35.95	1.49
MFV	2007	-84.9	35.95	1.52
MFV	2008	-86.8	35.95	1.55
MFV	2009	-88.5	35.95	1.58
MFV	2010	-90.4	35.95	1.61

The average carbon stock in dead organic matter is the sum of two pools: dead wood and the litter layer (L+F+H) (IPCC, 2003). The average carbon in dead wood follows the calculations from the gap filled NFI data (see Par. 5.1.1 and Annex A). The systematic increase reflects the increasing attention for more nature oriented forest management. The average carbon in litter is based on a national estimate using best available data for the Netherlands as described in Chapter 7.

5.2.2 Trees outside Forest

For Trees outside Forest the same biomass is assumed as for Forest according to the Kyoto definition. However, no dead wood nor litter layer is assumed.

5.3 Land converted to Forest Land

5.3.1 Forest according to the Kyoto definition

The built up of carbon in land converted to Forest Land is only reported for biomass. It is assumed that building up of dead wood starts only after the initial twenty years. For litter, good data are lacking to relate the built up of carbon to age.

The current estimate is the outcome of the following steps/assumptions:

1. At time of regeneration, growth is close to zero.
2. Between regeneration and twenty years of age, the specific growth curve is unknown and is approximated by the simplest function, being a linear curve.
3. The exact height of this linear curve is best approximated by a linear regression on the mean growth rates per age as derived from the NFI. One mean value for each age is taken to avoid confounding effects of the age distribution of the NFI plots (some of which are not afforested but regenerating after a clear cut).
4. The emission factor is calculated for each annual set of afforested plots separately. Thus the specific age of the re/afforested plots is taken into account, and a general mean value is reached only at a constant rate of afforestation for more than twenty years.
5. Between 1990 and 2000, rates are based on the Hosp inventory. From 2000 onwards, rates are based on the MFV inventory (Figure 5.1). In Figure 5.2 the resulting emission factors that increase over time are compared to IPCC default values (min, max and mean).

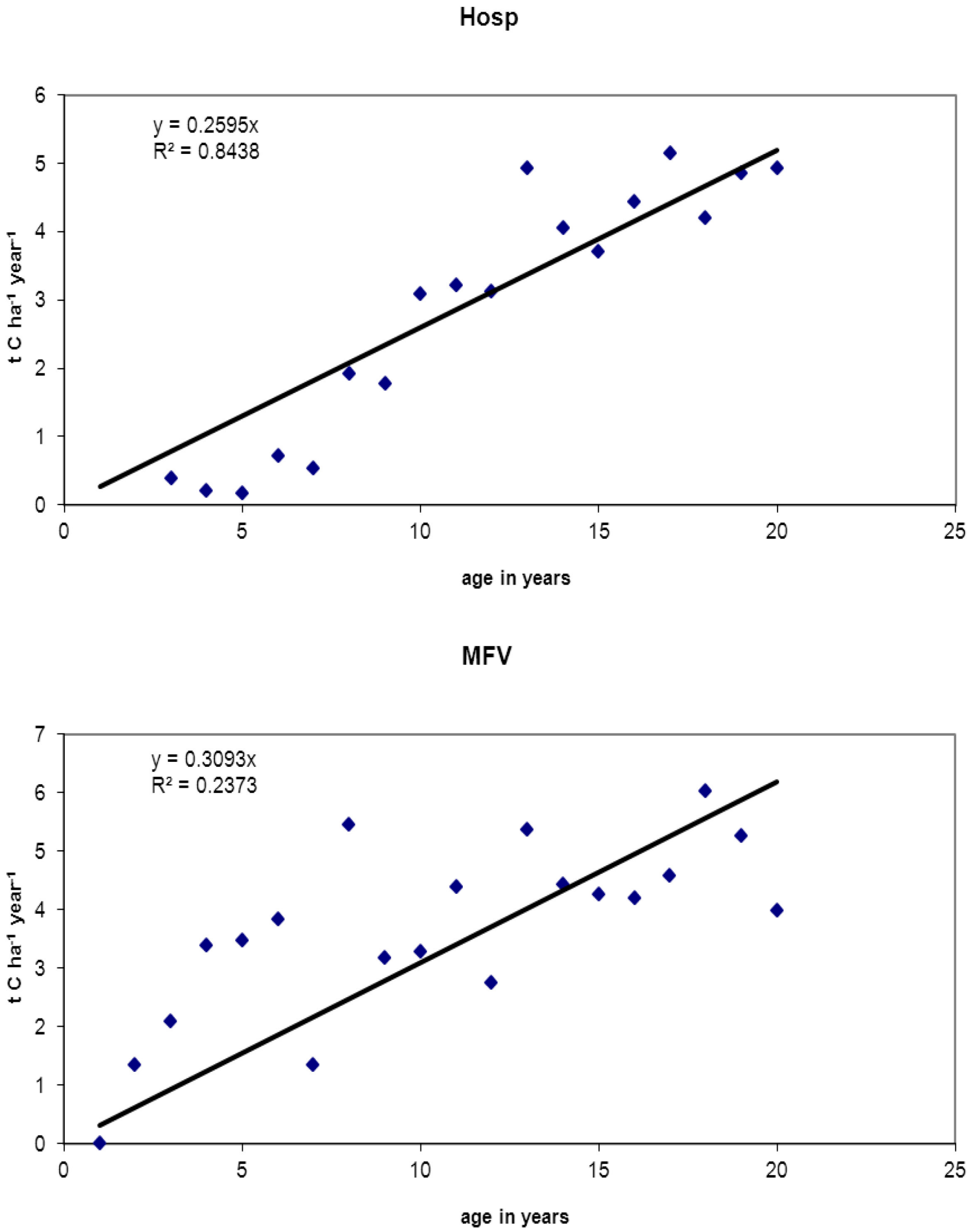

Figure 5.1
Regression between age and carbon emission (as calculated from increment data and IPCC expansion and conversion factors) for the Hosp and MFV data.

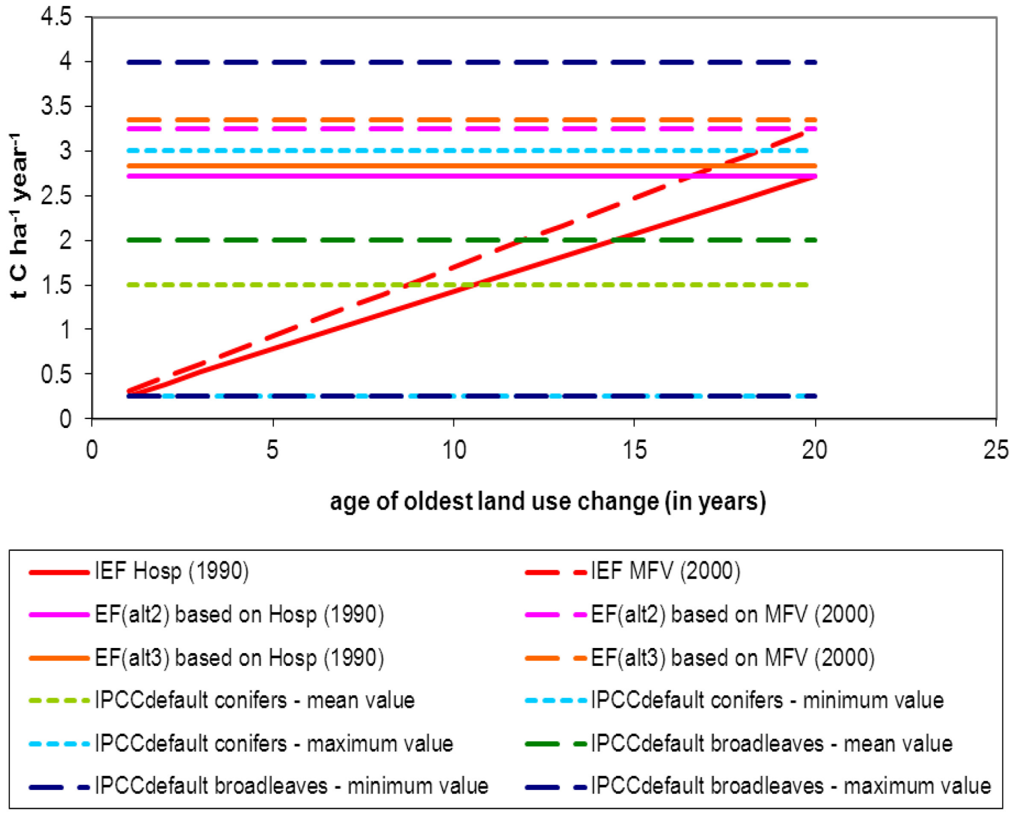

Figure 5.2
Country specific Emission Factor (EF) for afforestation in the Netherlands assuming a constant afforestation rate (IEF Hosp (1990) and IEF MFV (2000) in comparison to different IPCC default emission factors for afforestation.

5.3.2 Trees outside Forest

For Trees outside Forest the same biomass increase is assumed as for Forest according to the Kyoto definition. Similarly, no dead wood nor litter layer built up is assumed.

5.4 Land use conversions to and from Croplands and Grasslands

Carbon stock change due to changes in biomass in land use conversions to and from Croplands and Grasslands were calculated based on Tier 1 default carbon stocks (Table 5.2) for total biomass in combination with root-to-shoot ratios (Table 5.3) to allocate total carbon stock to above- and belowground compartments. Annual land use change rates were multiplied with the negative carbon stocks to calculate the loss in case of Croplands and Grasslands converted to other land use categories. Annual land use change rates were multiplied with the positive carbon stocks to calculate the gains in case of lands converted to Croplands and Grasslands.

Table 5.2
Tier 1 carbon stocks for croplands and grasslands used to calculate carbon stock changes due to changes in biomass associated with land use conversions.

Land use	C stock in biomass	Error	Reference
Croplands	5 tonnes C ha^{-1}	75%	GPG LULUCF table 3.3.8, value for land converted to annual croplands. Because according the GPG in annual croplands no net accumulation of biomass carbon stocks occurs, this is also the value used for afforestation)
Grasslands	13.6 tonnes DM ha^{-1} (= 6.8 tonnes C ha^{-1})	75%	GPG LULUCF table 3.4.9 (value for cold temperate wet)

Table 5.3
Tier 1 Root-to-Shoot values for croplands and grasslands used to calculate carbon stock changes due to changes in biomass associated with land use conversions.

Land use	R:S ratio	Error	Reference
Croplands	1.0		Assumption, no T1 value in GPG
Grasslands	4.0	150%	GPG LULUCF table 3.4.3 (value for cold temperate wet)

6 Carbon emissions from dead organic matter in forests

6.1 Forest according to the definition remaining Forest according to the definition

6.1.1 Dead wood

Dead wood volume was available from the Hosp and MFV forest inventory datasets. The change in dead wood was calculated using an average tree mortality of 0,4%, dead wood longevity from van Hees and Clerkx (1999) and a removal of 20% of the dead wood. The conversion of dead wood volume to carbon did not take into account anything but the volume of the logs. This was converted to mass using an average dead wood density half that of live trees. The equations are given in Annex A and a more detailed description is provided in Nabuurs et al. (2005). The method is updated for the 2011 submission and this is described in Annex B.

Similar to the case for living biomass, the following calculation is used to correct for missing data for carbon stock change due to change in dead wood:

$$\Delta C_{(1)} = V_{(1)} \frac{\Delta C_{(0)}}{V_{(0)}}$$

$$\Delta C_{(2)} = 0$$

$$\Delta C_{(3)} = \left(\Delta C_{(0)} + \Delta C_{(1)} + \Delta C_{(2)}\right) \cdot \frac{Area_{(3)}}{\sum_{x=0,1,2} Area_{(x)}}$$

$$\Delta C_{NL} = \Delta C_{(0)} + \Delta C_{(1)} + \Delta C_{(2)} + \Delta C_{(3)}$$

With

$\Delta C_{(x)}$	carbon budget in Gg C for category x
$Area_{(x)}$	total representative area for plots with missing data category x
$V_{(x)}$	total volume in m^3 for area represented by plots with missing data category x

6.1.2 Litter

The carbon stock change from changes in the litter layer was estimated using a stock change method at national level. Data for litter layer thickness and carbon in litter were available from five different datasets (data from Schulp and co-workers; De Vries and Leeters, 2001; Van den Burg, 1999; Forest Classification database; MFV litter inventory). The data from Van den Burg (1999) were collected between 1950 and 1990 and were used only to estimate bulk density based on organic matter content. The data from de Vries and Leeters

(2001) were collected in 1990 and their median was used until now as a generic national estimate. They also provide species specific values of (mostly) conifer species. However, they sampled sandy soils only. The Forest Classification dataset was designed to provide abiotic attributes for a forest classification in 1990, not to sample the mean litter in forests. However, it is the only database that has samples outside sandy areas. Schulp and co-workers intensively sampled selected forest stands in 2006 and 2007 on poor and rich sands with the explicit purpose to provide conversion factors or functions. They based their selection of species and soils on the MFV forest inventory. During the last two years (2004 and 2005) the litter layer thickness was measured for plots located on poor sands and loss (Daamen and Dirkse, 2005). For 1440 plots values were filled, but only 960 (951 on sands) plots had any non-zero values. As it could not be made likely that all-zero value plots were really measured, only plots with at least one of the litter layers present were selected.

None of these datasets could be used exclusively. Therefore, a stepwise approach was used to estimate the national litter carbon stock and change therein in a consistent way.
First the datasets were compared for (if available) bulk density and carbon or organic matter content of litter separately as well as these combined into conversion factors or functions between litter thickness and carbon stock. Based on appropriate conversion factors, litter carbon stock was calculated for the Forest Classification database and the MFV inventory. These were compared to each other and the available data from De Vries and Leeters (2001). From these, a hierarchy was developed to accord mean litter stock values to any of the sampled plots of the HOSP (1988-1992) and MFV (2001-2005) inventories.

The followed hierarchy was:

1) For non-sandy soils the only source of information was the Forest Classification database. Though sampled around 1990, it was used for 1990 and 2004 alike. As such it is considered a conservative estimate for any changes occurring. The use of the same dataset in 1990 and 2004 means that changes in total litter stock on non-sandy soils only occur through changes in forest area and tree species composition. Peaty soils were kept outside the analysis.
2) For sandy soils with measured litter layer thickness (i.e. only from the MFV in the years 2004 and 2005), regressions for rich and poor sands based on data from Schulp and co-workers were used to convert them into litter carbon stock estimates. For sand rich in chalk (five plots) the regression equation of rich sand was used.
3) For sandy soils in the MFV without measured litter layer thickness, but with all other information, a regression was developed from the 951 plots with measured litter layers to estimate the carbon stock from plot location and stand characteristics. However, as this estimate was completely based on data from the MFV alone, we did not use it for the HOSP plots.
4) For sandy soils with missing data for the regression equation mentioned in point 3 of this hierarchy, or for the sandy soils in the HOSP inventory, the following procedure was used:
   a) For reasons of consistency with the non-sandy soils, if a mean estimate was available for the tree species from the Forest Classification database, that was accorded to the plots.
   b) If no such estimate was available, the species specific estimate from the study of De Vries and Leeters (2001) was accorded. In this study, only median values were given and the mean value was taken as midway between the 5% and the 95% percentile.
   c) If no such estimate was available, the mean aspecific value for sandy soils from the Forest Classification database was accorded. This value was always available. However, the next option would have been to accord the mean aspecific value from De Vries and Leeters (2001).
   Though this implied using data from 1990 for 2004, this was thought of as a conservative estimate, i.e. underestimating rather than overestimating change. As the changes pointed to an increase of carbon in litter at the national level, an underestimate of change was considered to be conservative for the reporting of emissions.
5) For plots with missing soil information, the total area was summed and the total carbon litter stock in mineral soils was scaled up on an area basis.

The difference between 2004 (MFV litter layer thickness measurements) and 1990 (Forest Classification database; De Vries and Leeters, 2001) was estimated and a mean annual rate of carbon accumulation was calculated. A Monte Carlo uncertainty analysis was carried out with random carbon litter stocks assigned to plots from a distribution rather than from the mean values. The results of the Monte Carlo analysis consistently showed a carbon sink in litter, however the magnitude was very uncertain. As such, it was assumed to be the more conservative estimate to set the accumulation of carbon in litter in Forest Land - FAD remaining Forest Land-FAD to zero. The uncertainty was attributed largely to the fact that no litter information was collected in the HOSP inventory which was used for 1990. In future, when a new MFV inventory will be carried out, more certain estimates of the carbon accumulation in litter over time will be possible and will be reported.

6.2 Trees outside Forest remaining Trees outside Forests

For Trees outside Forest no dead wood nor litter layer build up is assumed. As the patches are smaller and any edge effects therefore larger, the uncertainty on dead wood and litter accumulation is much higher here. For very small patches and linear woody vegetation, the chance of dead wood removal may be very high. Disturbance effects on litter may prevent accumulation. Therefore the conservative estimate of no carbon accumulation in these pools is applied.

6.3 Land use conversions involving Forest Land

The calculations described in paragraph 6.1 yield an annual estimate both for the average carbon stock in litter and in dead wood in Forest Land - FAD. When Forest Land - FAD is converted to other land use categories (including Trees outside Forest) it is assumed that litter and dead wood are removed within one year of conversion. The resulting implied emission factors are given in Table 5.1. Emission factors for dead wood are based on the calculations described in paragraph 6.1.1. Emission factors for litter between 1990 and 2004 are based on the calculated litter values based on the Hosp (1990) and the MFV (2003) as described in paragraph 6.1.2. From 2004 on, data are missing and the litter values have been kept constant. Conversions of land towards Forest Land - FAD should yield an increase in both dead wood and litter, as no other land categories are assumed to have significant amounts. However, the current data do not permit an estimate of the amount of built-up in the first 20 years after conversion (see also Van den Wyngaert et al., 2011b, justification for not reporting carbon stock change in dead wood and litter for land under re/afforestation). Therefore, it was considered the most conservative approach not to report carbon stock built-up in dead organic matter for lands converted to Forest Land - FAD.

7 Carbon emissions from soils

Within the National Inventory Report the Netherlands has to report how carbon stocks are determined and how changes in the stocks are calculated as a part of internationally mandatory reporting. In 2002 and 2003 it was investigated how stocks can be determined and which databases are available for a Dutch monitoring system and which data are missing (see Kuikman et al., 2003; Nabuurs et al., 2003; Kuikman et al., 2004). Since 2009 the carbon stock change in mineral soils is conservatively reported to be zero, stating that mineral soils in the Netherlands as a whole are not a source for carbon. The motivation for this is described in this chapter.

The Netherlands has detailed soil information on its entire land area, which is derived from the soil map of the Netherlands at a scale of 1:50,000. The carbon content in the soil can therefore be expressed with a relatively high degree of accuracy. Kuikman et al. (2003) made a start on this topic using descriptions of profile details in the so-called LSK, a national sample survey of soil map units (Finke et al., 2001). A limited number of soil chemical parameters were quantified in the laboratory, including soil organic matter content. This sample survey was meant to provide further quantitative information for the existing soil maps.

The sample survey was implemented in the period 1990-2000 on a nationwide and stratified scale, where main soil categories were combined in order to produce a more homogeneous grouping with respect to landscape position, soil formation or parent material. Based on the ALBOS file, the land use 'nature' has been distinguished separately (see Nabuurs et al., 2005). In total about 1,200 locations were sampled at five different depths. Each of these sample points can be linked to a soil unit of the soil map of the Netherlands. The resulting soil carbon stock map based on the LSK survey is shown in Figure 7.1. More information about the quantification of the soil organic carbon stocks and its uncertainties is given in De Groot et al. (2005).

Although the total soil organic carbon stocks are well known, little information is available about the changes over time. Since the LSK sample survey was only performed once at each sample point, no temporal trends on soil organic matter can be obtained. Although the entire sampling survey was performed during the period 1990 to 2000, the results from different years cannot be used to establish trends in SOC levels, because the samples were stratified to soil mapping unit and groundwater class, and especially the last one was highly correlated to SOC level (De Groot et al., 2005). Besides, the stratification was not based on land use, which would be required for the assessment of SOC stocks for the different land use types for reporting to the UNFCCC.

However, recently two studies (Hanegraaf et al., 2009; Reijneveld et al., 2009) have been published, which used a different source of soil organic carbon data in the Netherlands. Additionally, these studies especially assessed the changes in soil organic carbon contents over time. Data were derived from a database with about two million results of soil analyses from farmers' fields. Within the database 304,000 data on SOC content were available. All samples were taken and analysed by one laboratory (BLGG in Oosterbeek) during the period 1984-2004.

Reijneveld et al. (2009) report on the changes in the mean SOC contents of the topsoil (0 - 5 cm) of grassland and the topsoil (0 - 25 cm) of arable land in the Netherlands during the period 1984 - 2004. The analyses were made for all agricultural land on mineral soils and for agricultural land in nine regions with distinct differences in mean soil textures and SOC contents, and for different land uses (arable land and permanent grassland). The study did not include samples from peat soils and samples with a SOC content of more than 125 g/kg. Mean SOC content of soils under arable land in 2003 ranged from 13 to 22 g kg^{-1} for sand, loess and clay soils to

59 g kg^{-1} for reclaimed peat soils. Mean SOC content of soils under permanent grassland in 2003 ranged from 22 to 56 g kg^{-1} for sand and clay soils. Mean SOC contents of all mineral soils under grasslands and arable land tended to increase annually by 0.10 and 0.08 g kg^{-1}, respectively (Figure 7.2). Large differences in mean trends were observed between regions. Regions with relatively low SOC contents tended to accumulate C by up to 0.37 g kg^{-1} year^{-1}, while regions with relatively high SOC contents (e.g., peaty clays) tended to lose C by up to 0.98 g kg^{-1} year^{-1}. They concluded that mean SOC contents of the topsoil of mineral soils of agricultural land in most regions in the Netherlands tended to increase slightly during the period 1984 - 2004.

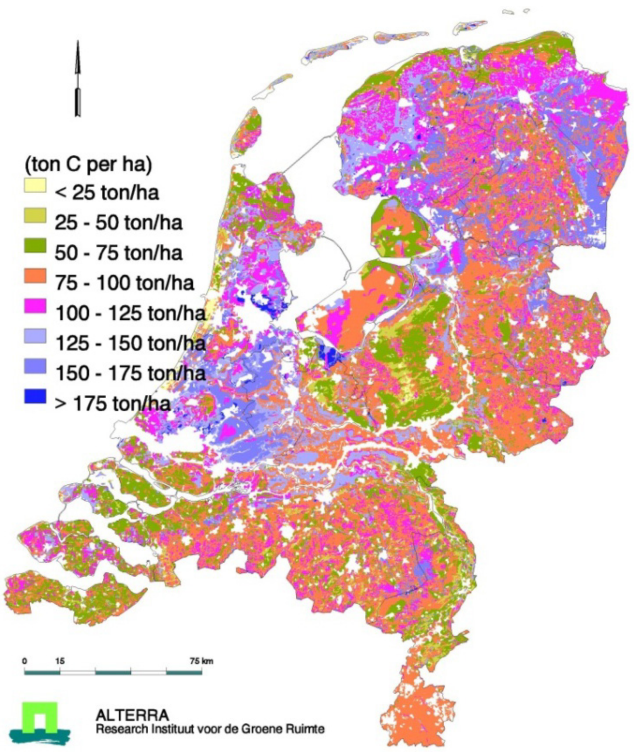

Figure 7.1
Soil carbon stocks (0-30 cm) for the Netherlands.

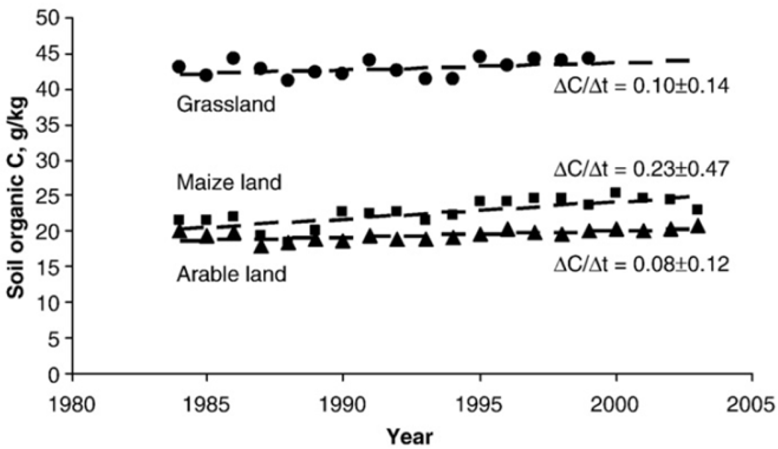

Figure 7.2
Changes in mean soil organic carbon contents of grassland (period 1984 - 2000), maize land (1984 - 2004) and arable land (1984 - 2004) in the Netherlands. The mean annual change in SOC is indicated as $\Delta C/\Delta t$, in g kg^{-1}year^{-1} (Source: Reijneveld et al., 2009).

Hanegraaf et al. (2009) performed a trend analysis of SOM contents in sandy soils, with data from grass, grass-maize rotation and maize fields in four adjacent provinces that had been sampled four to five times during the period 1984 - 2004. The mean SOM content showed a north-south gradient per cropping system. No single uniform trend in SOM contents over time was found for any of the three systems (Figure 7.3). Over the 20-year period, SOM declined in about 25% of all grasslands, whereas in increase was found in about 50% of the grassland fields. The area where a decrease in SOM was observed accounts for 185,000 out of the 635,000 hectares of land under grass and forage crops in the four provinces, whereas an increase in SOM was found for a total of 267,000 hectares. Carbon accumulation in grassland sandy soils was calculated at 39 g C m^{-2} $year^{-1}$ for the top 5 cm of the soil.

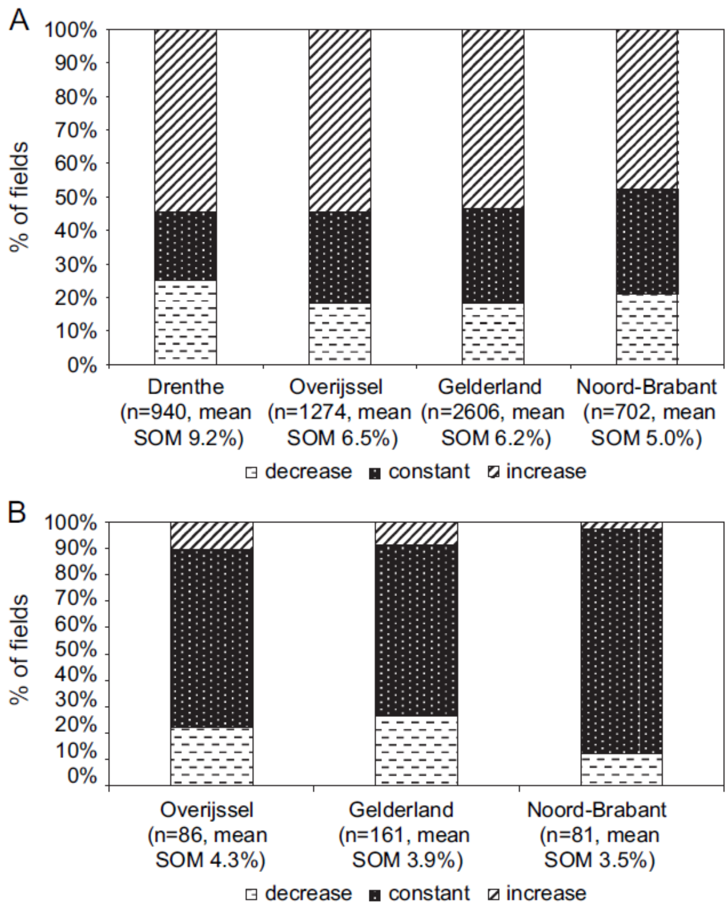

Figure 7.3

Absolute changes in SOM content (%) in sandy soils in four provinces in the Netherlands over 20 years (increase, + 1% or more; decrease, - 1% or more). (A) grassland; (B) continuous maize (no results for Drenthe due to lack of data) (Source: Hanegraaf et al., 2009).

From the data of Reijneveld et al. (2009) a small increase of 0.032 ton C $year^{-1}$ could be calculated for the six arable combinations of region and soil type. From the data on maize land in Noord-Brabant, published by Hanegraaf et al. (2009), a weighted average loss of 0.3 ton C ha^{-1} yr^{-1} can be calculated. Silage maize is a crop known to cause a decrease in SOC. From the data of Reijneveld et al. (2009) a small increase of 0.089 g kg^{-1} yr^{-1} could be calculated for the four grassland combinations of region and soil type. From the data on grassland in Noord-Brabant, published by Hanegraaf et al. (2009), a weighted average increase of 0.09 ton C

ha^{-1} year^{-1} can be calculated. Thus, both from Dutch studies indicate a small increase in SOC on grassland, but the increase is lower than the estimations made by IPCC and Janssens et al. (2004).
Both Reijneveld et al. (2009) and Hanegraaf et al. (2009) found a constant or increasing SOC level in most cases for the period between 1984 and 2004. This can possibly be explained by the large amount of manure applied in the Netherlands. Although the amount of manure that is allowed has reduced in the Netherlands during the last decades, it still amounts about 37 ton animal slurry ha^{-1} year^{-1} for arable land and up to 51 ton ha^{-1} year^{-1} on grassland. The application of animal manure leads to a build-up of SOC (Smith et al., 1997; Sleutel et al., 2006).

These two studies are further discussed in Chardon et al. (2009), who compare the results with other studies on temporal trends of soil organic carbon in Western Europe. Chardon et al. (2009) also reviewed the effects of manure application on the soil organic carbon levels from several studies and from a modelling approach with the Century model, which was calibrated for Dutch conditions (see also Heesmans and De Willigen, 2008).

It is thus concluded that for the majority of the mineral and non-organic agricultural soils (< 70 g C kg^{-1}), the SOC content is either constant or even increases, and in a few cases (soil type with specific land use) may decrease a little. The fact that agricultural soils in the Netherlands to a large extent maintain or even increase their SOC content is probably best explained by the relatively high amounts of animal manure that is applied on these soils. In the absence of a detailed monitoring system, it is considered fair and conservative to conclude that the SOC content of the Dutch agricultural soils overall does not change, so no net emission of CO_2 takes place due to changes in SOC stocks in the Netherlands. Therefore it was decided to report the emissions from carbon stock changes in mineral soils as a conservative zero aggregated at the national level.

Carbon emissions from cultivated organic soils
For carbon emissions from cultivated organic soils[1] the methodology is described in Kuikman et al. (2005). This method is based on subsidence as a consequence of oxidation of organic matter. Oxidation typically is caused by a low groundwater table, which also causes two other types of subsidence: (irreversible) shrinking of the peat as a consequence of drying and compaction due to changes in hydrostatic pressure (consolidation). However, the last two processes are of importance only a few years after a sudden decrease in groundwater level. Based on many series of long-term measurements, a relation was established between subsidence and either ditch water level or mean lowest groundwater level (Kuikman et al., 2005). For all peat soils in the Netherlands, the estimated subsidence could thus be predicted. The occurrence of peat soils was based on the application of the IPCC definition to the (updated) Dutch soil map (De Vries et al., 2003). This resulted in 223,147 ha of peat soils under agricultural land use in the Netherlands.

The carbon emissions per ha are calculated from the mean ground surface lowering using the following general equation:

$$C_{em} = R_{GSL} \cdot \rho_{peat} \cdot f_{ox} \cdot [OM] \cdot [C_{OM}] \cdot f_{conv} \quad (1)$$

With
C_{em} Carbon emission from oxidation of peat (kg C ha^{-1} year^{-1})
R_{GSL} Rate of ground surface lowering (m year^{-1})
ρ_{peat} Bulk density of lowest peat layer (kg soil m^{-3})

[1] N_2O is reported under land use category 4 Agriculture and not further considered here

f_{ox}	Oxidation status of the peat (-)
$[OM]$	Organic matter content of peat (kg OM kg^{-1} soil)
$[C_{OM}]$	Carbon content of organic matter (0.55 kg C kg^{-1} OM)
f_{conv}	Conversion from kg C m^{-2} $year^{-1}$ to kg C ha^{-1} $year^{-1}$ (10^4)

For deep peats (> 120 cm), the calculation is based on the properties of raw peat (bulk density of 140 kg soil m^{-3}, oxidation status of 1, and organic matter content of 0.80 kg OM kg^{-1} soil), which results in an emission of 616 kg C ha^{-1} $year^{-1}$ for each mm of annual ground surface lowering.

For shallow peat soils (40 < depth < 120 cm), the (higher) bulk density of half ripened peat should be used. During the process of oxidation of the peat and further ground surface lowering, the decomposability of the remaining peat decreases, resulting in a decreasing rate of ground surface lowering, an increasing bulk density and a decreasing organic matter content. Up to a peat layer depth of about 80 cm all values in equation (1) can be the same as for a deep peat soil, because the change in subsidence and bulk density of the raw peat below 60 cm depth is negligible. Also for peat soils thinner than 80 cm all values in equation (1) were used. This estimation is done because there is no data on subsidence of such shallow peat soils and because this would just cause a small error, because the fast majority of the Dutch peat soils are thicker than 80 cm. Besides, the underestimation of the bulk density will be compensated more or less by the overestimation of the subsidence.

In Table 7.1 the calculated ground surface lowering and the surface is shown for the different combinations of soil type of the upper soil layer, the peat type and drainage class. In the last column of the table the annual emission of Carbon is reported. The total annual loss of carbon from organic soils under agricultural land use is 1.158 Mton of C, which is an annual emission of 4.246 Mton of CO_2. This emission is reported under the category grassland remaining grassland.

Table 7.1
Carbon emissions as resulting from classification of peat soils in the Netherlands, estimated mean ground surface lowering (gsl) and surface (in ha)

Soil type upper soil layer	Peat type	Bad drainage		Reasonable drainage		Good drainage		Total	C-emission
		gsl	Surface (ha)	gsl	Surface (ha)	gsl	Surface (ha)	Surface (ha)	ton C $year^{-1}$
Clay	Eutrophic	3	16149	8	17250	13	531	33929	119100
	Mesotrophic	3	12780	8	22294	13	2863	37935	156403
	Oligotrophic	3	9421	8	10480	13	416	20315	72380
Peat	Eutrophic	6	16668	12	16846	18	206	33719	188415
	Mesotrophic	6	18668	12	31607	18	7169	57443	382118
	Oligotrophic	6	8688	12	10054	18	1168	19911	119381
Humus-rich sand	Mesotrophic	3	148	8	3184	13	4771	8102	54167
	Oligotrophic	3	27	8	760	13	2256	3041	21856
Sand	Mesotrophic	3	1365	8	3370	13	1318	6051	29681
	Oligotrophic	3	415	8	1450	13	836	2700	14604
Total			84325		117291		21531	223147	1158105

8 Submission 2012: values and comparison with previous submissions

8.1 Calculated values for the submission 2012

Table 8.1

Sector report for land use, land-use change and forestry of Net CO2 emissions or removals in 1990 and 2010 as submitted in the NIR2012. NE: not estimated. NA: not applicable. IE: included elsewhere.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Activity data (ha)		Net CO_2 emissions/ removals	
Reporting year	**1990**	**2010**	**1990**	**2010**
Total Land-Use Categories	**4,151.50**	**4,151.50**	**2,999.95**	**3,001.37**
A. Forest Land	**383.57**	**396.90**	**-2,355.94**	**-2,693.31**
1. Forest Land remaining Forest Land	380.61	341.15	-2,412.33	-2,146.22
2. Land converted to Forest Land	2.96	55.75	56.39	-547.09
B. Cropland	**1,013.66**	**918.96**	**122.34**	**164.06**
1. Cropland remaining Cropland	999.34	896.64	IE,NA,NE	IE,NA,NE
2. Land converted to Cropland	14.32	22.32	122.34	164.06
C. Grassland	**1,500.57**	**1,384.86**	**4,491.32**	**4,505.11**
1. Grassland remaining Grassland	1,485.04	1,355.23	4,246.00	4,246.00
2. Land converted to Grassland	15.52	29.63	245.32	259.11
D. Wetlands	**793.59**	**813.81**	**80.46**	**131.18**
1. Wetlands remaining Wetlands	791.36	810.38	NE	NE
2. Land converted to Wetlands	2.23	3.43	80.46	131.18
E. Settlements	**420.66**	**598.24**	**458.61**	**807.80**
1. Settlements remaining Settlements	408.27	586.30	NE	NE
2. Land converted to Settlements	12.39	11.94	458.61	807.80
F. Other Land	**39.45**	**38.72**	**20.00**	**26.82**
1. Other Land remaining Other Land	39.10	38.26		
2. Land converted to Other Land	0.35	0.46	20.00	26.82
G. Other			**183.15**	**59.72**
Harvested Wood Products			NE	NE
Lime application in all land use categories			183.15	59.72
Information items				
Forest Land converted to other Land-Use Categories			665.72	1,242.27
Grassland converted to other Land-Use Categories			305.48	104.41

Table 8.1 shows the integral set of values reported for main land use categories in the NIR 2012, including activity data, for 1990 (baseline year) and 2010 (t-2 year). Changes relative to the submission 2011 are identified and discussed in paragraph 8.2 for all categories A-F.

8.2 Comparison with submission 2011

Table 8.2
Submitted values for 1990 (dark colours) and 2009 (light colours) for main land use categories in the NIR 2011 and in the NIR 2012. Values are rounded to two decimals. Subcategories subject to changing values are printed in orange, subcategories not changing between submissions are printed in blue.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals in 1990 (Gg C)		Net CO_2 emissions/removals in 2009 (Gg C)	
Submission year	NIR 2011	NIR 2012	NIR 2011	NIR 2012
Total Land-Use Categories	**2,685.94**	**2,999.95**	**2,454.34**	**2,865.47**
A. Forest Land	**-2,436.99**	**-2,355.94**	**-2,849.69**	**-2,808.99**
1. Forest Land remaining Forest Land	-2,434.17	-2,412.33	-2,143.76	-2,253.03
2. Land converted to Forest Land	-2.82	56.39	-705.93	-555.96
B. Cropland	**34.39**	**122.34**	**47.97**	**163.39**
1. Cropland remaining Cropland	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE
2. Land converted to Cropland	34.39	122.34	47.97	163.39
C. Grassland	**4,637.02**	**4,491.32**	**4,790.16**	**4,496.25**
1. Grassland remaining Grassland	4,246.00	4,246.00	4,246.00	4,246.00
2. Land converted to Grassland	391.02	245.32	544.16	250.25
D. Wetlands	**39.94**	**80.46**	**55.55**	**130.04**
1. Wetlands remaining Wetlands	NE	NE	NE	NE
2. Land converted to Wetlands	39.94	80.46	55.55	130.04
E. Settlements	**210.48**	**458.61**	**294.36**	**798.58**
1. Settlements remaining Settlements	NE	NE	NE	NE
2. Land converted to Settlements	210.48	458.61	294.36	798.58
F. Other Land	**17.96**	**20.00**	**24.94**	**26.49**
1. Other Land remaining Other Land				
2. Land converted to Other Land	17.96	20.00	24.94	26.49
G. Other	**183.15**	**183.15**	**91.05**	**59.72**
Harvested Wood Products	NE	NE	NE	NE
Lime application in all land use categories	183.15	183.15	91.05	59.72
Information items				
Forest Land converted to other Land-Use Categories	693.78	665.72	966.98	1,222.05
Grassland converted to other Land-Use Categories	-1.53	305.48	-383.44	98.84

The changes in calculated values between the 2011 and 2012 submissions are shown for 1990 and 2009 in Table 8.2. Change in activity data occurred in all land use categories after 2003 as a result of the implementation of a new land use map (for 2009 (see Chapter 4). Changes in emissions occurred in all land use categories converted to other land use from 1990 on. This was the result of introducing emissions associated with biomass loss and gain during land use conversion to and from Croplands and Grasslands, as a response to the reviewers demand for a more complete inventory. From 2004 on, it was also the result of updated activity data.

8.3 Recalculations per land use category

8.3.1 Forest Land

8.3.1.1 Forest land remaining Forest Land

Changes in activity data

As a result of the new map overlay, there were the following changes in activity data:

- Difference of 0.5625 ha (on a total of 336.5 kha) of Forest Land remaining Forest Land between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the area converted away from Forest Land decreases from 2.3 kha year^{-1} to 1.7 kha year^{-1}, which is reflected in an increasingly higher area of Forest Land remaining Forest Land in the 2012 submission compared to the 2011 submission (see Figure 8-1).

The discontinuity in the decreasing trend between 2009 and 2010 (which is not a recalculation) is due to land converted to Forest Land in 1990 ageing beyond the transition period of 20 years (see Figure 8.1).

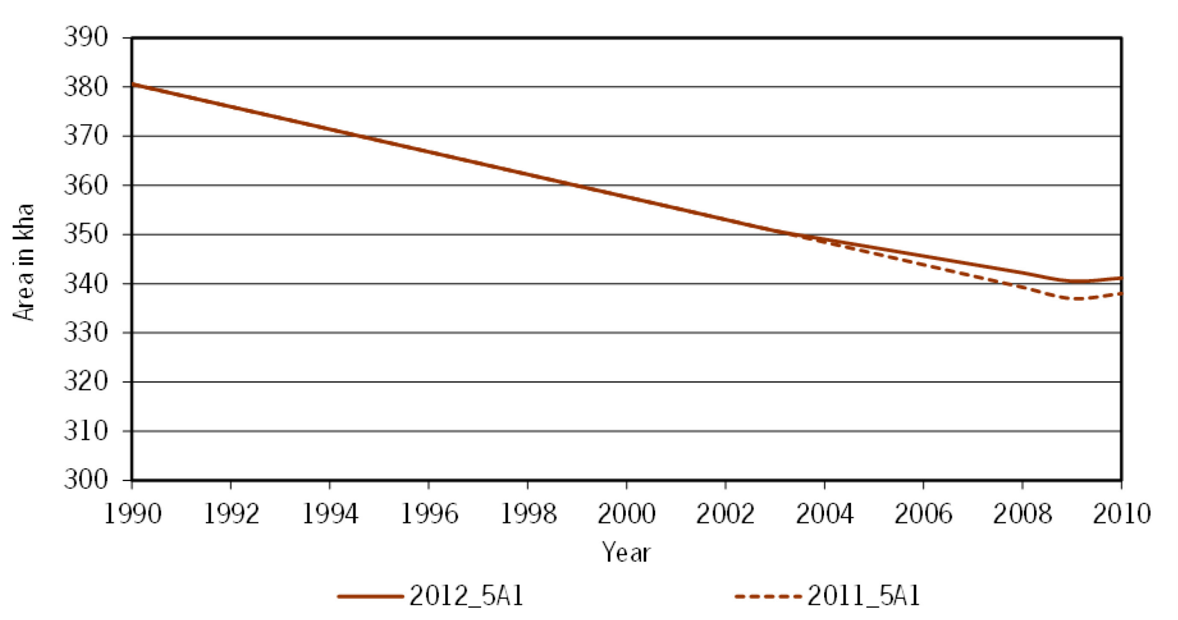

Figure 8.1

Area of Forest Land remaining Forest Land (5A1) in the 2011 and in the 2012 submission (note that y axis starts at 300).

Changes in emissions and (implied) emission factors

The difference in emissions between the 2012 and 2011 submission (Table 8.3) could be attributed to the following reasons:

- From 2012 on, a more consistent approach was followed to calculate dead wood in conversions between trees outside forests and forests according to the definition (see also par 6.3):
  - dead wood accumulation was not calculated anymore for trees outside forest converted to forests according to the definition in the first year of conversion
  - loss of dead wood was explicitly calculated for forests according to the definition converted to trees outside forests.

- The change in activity data due to the implementation of a new land use map was reflected in a proportional change in emissions from biomass changes.
- The national harvested volume for 2009 was updated, as the previous value was a preliminary one, copied from 2008. However, as the harvest value is corrected for the amount removed through deforestation before being used in FL remaining FL, this effect could not be distinguished from the change in activity data and was included there.

Table 8.3
Differences between the current and previous submission analysed

	Difference between submissions 2012 and 2011 for reporting years ($Gg\ CO_2$)		
	1990	**2003**	**2009**
CRF 2012	-2412.33	-2256.41	-2253.03
CRF 2011	-2434.17	-2284.44	-2143.76
CRF 2012 – CRF 2011 for	**21.84**	**28.03**	**-109.27**
Change in activity data	-0.01	-0.01	-149.74[a]
Change in DW for TOF to FAD	0.10	0.11	-1.25[b]
Change in DW for FAD to TOF	21.75	27.92	41.72[b]

[a] this includes the update of the harvested volume for 2009
[b] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data

8.3.1.2 Land converted to Forest Land

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:
- No difference in area converted to Forest Land between 1990 and 2003.
- From 2004 on, the annual area converted to Forest Land decreases from 2.96 kha $year^{-1}$ to 2.37 kha $year^{-1}$, resulting in a lower cumulative area in the 2012 submission compared to the 2011 submission (see Figure 8.2).

Changes in emissions and (implied) emission factors
The difference in emissions between the 2012 and 2011 submission () could be attributed to 2 main reasons:
- Implementation of Tier 1 defaults for biomass gains and losses associated with conversions to and from Croplands and Grasslands (see also Par. 5.4).
- The change in activity data due to the implementation of a new land use map was reflected in a proportional change in emissions from biomass changes from 2004 on.

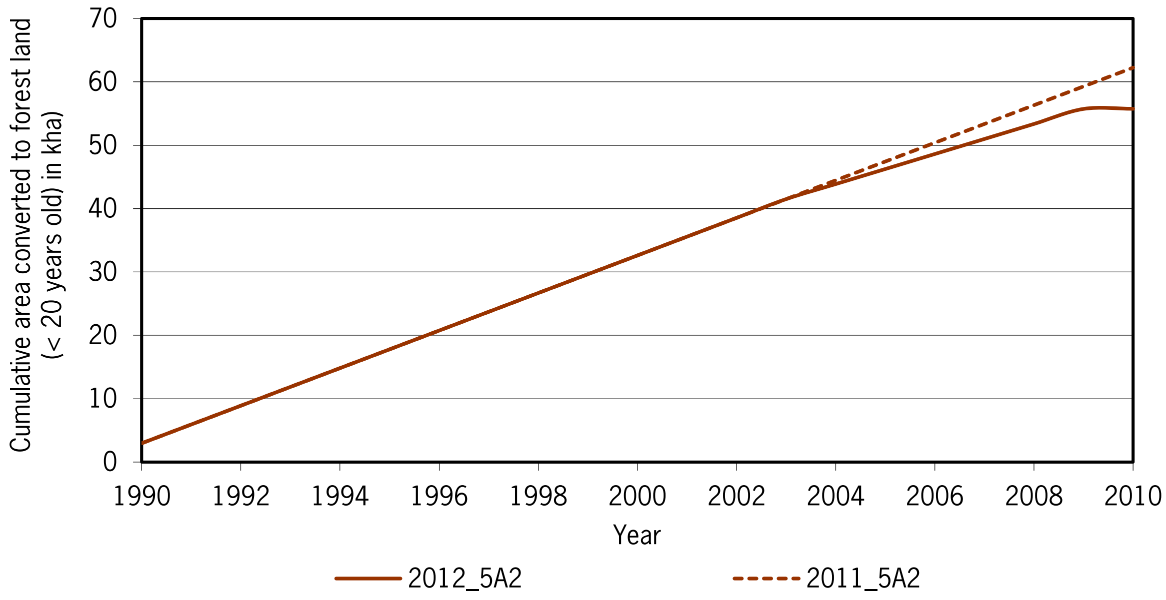

Figure 8.2
Cumulative area of land converted Forest Land (5A2) in the 2011 and in the 2012 submission.

Table 8.4
Differences between the current and previous submission analysed.

	Difference between submissions 2012 and 2011 for reporting years ($Gg\ CO_2$)		
	1990	**2003**	**2009**
CRF 2012	56.39	-293.76	-555.96
CRF 2011	-2.82	-352.90	-705.93
CRF 2012 – CRF 2011 for	**59.21**	**59.21**	**149.97**
Change in activity data	0.00	0.00	97.51
T1 Cropland conversion – biomass	19.07	19.07	8.45[a]
T1 Grassland conversion – biomass	40.14	40.14	44.01[a]

[a] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data.

8.3.2 Cropland

8.3.2.1 Cropland remaining Cropland

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:

- Difference of 0.3 ha (on a total of 999.3 kha) of Cropland remaining Cropland between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the area converted to Cropland increases from 14.3 kha year^{-1} to 22.3 kha year^{-1}, while the area converted away from Cropland increases from 20.0 to 25.3 kha year^{-1}. As a result, the

net loss decreases from 5.7 kha $year^{-1}$ for the period 1990-2003 to 3.0 kha $year^{-1}$ from 2004 on. Thus, from 2004 on the area under Cropland remaining Cropland is higher than in the previous submissions (see Figure 8.3).

- In 2004, the loss is much higher, as there is a one year delay on area increase (which is reported temporarily in land converted to Cropland) but no delay on area loss.

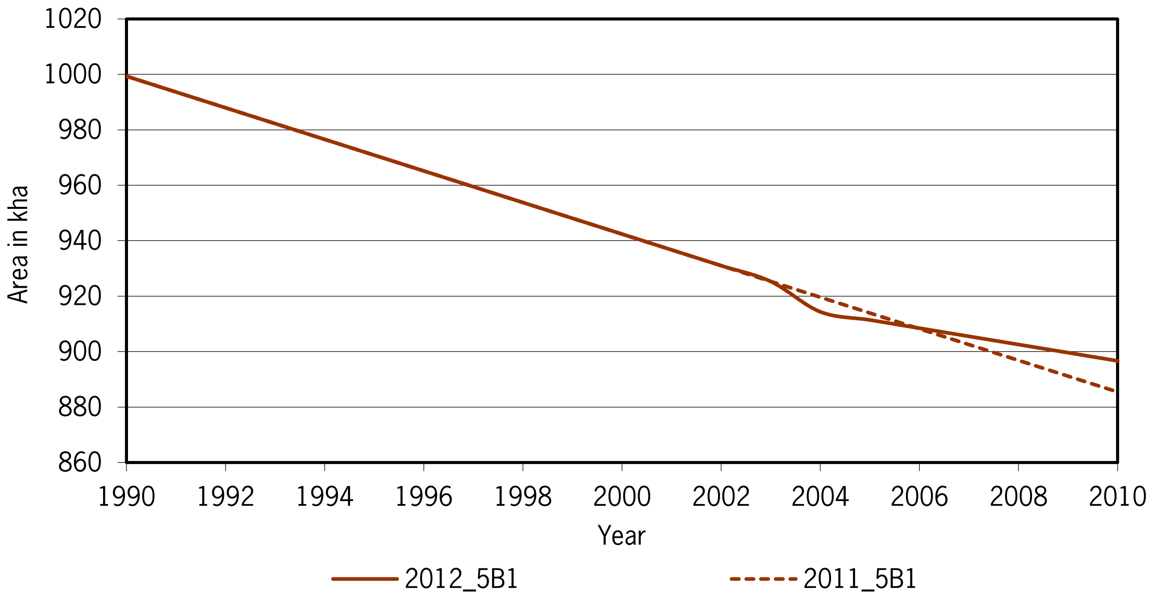

Figure 8.3
Cumulative area of Cropland remaining Cropland (5B1) in the 2011 and in the 2012 submission (note that y axis starts at 860).

8.3.2.2 Land converted to Cropland

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:

- No difference in area converted to Cropland between 1990 and 2003.
- From 2004 on, the annual area converted to Cropland increases from 14.3 kha $year^{-1}$ to 22.3 kha $year^{-1}$.

Changes in emissions and (implied) emission factors
The difference in emissions between the 2012 and 2011 submission (Table 8.5) could be attributed to two main reasons:

- Implementation of Tier 1 defaults for biomass gains and losses associated with conversions to and from Croplands and Grasslands (see also Par. 5.4).
- The change in activity data due to the implementation of a new land use map was reflected in a proportional change in emissions from biomass changes from 2004 on.

Table 8.5
Differences between the current and previous submission analysed.

	Difference between submissions 2012 and 2011 for reporting years ($Gg\ CO_2$)		
	1990	**2003**	**2009**
CRF 2012	122.34	132.23	163.39
CRF 2011	34.68	44.57	48.98
CRF 2012 – CRF 2011 for	**87.66**	**87.66**	**114.41**
Change in activity data	0.00	0.00	-7.78
T1 Cropland conversion - biomass	-262.46	-262.46	-409.13[a]
T1 Grassland conversion - biomass	350.13	350.13	531.32[a]

[a] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data

8.3.3 Grassland

8.3.3.1 Grassland remaining Grassland

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:

- Difference of about 1.5 ha (on a total of about 1400 kha) of Grassland remaining Grassland between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the area converted to Grassland increases from 15.5 kha $year^{-1}$ to 29.6 kha $year^{-1}$, while the area converted away from Grassland increases from 22.6 to 32.9 kha $year^{-1}$. As a result, the net loss decreases from 7.1 kha $year^{-1}$ for the period 1990-2003 to 3.3 kha $year^{-1}$ from 2004 on. Thus, from 2004 on the area under Grassland remaining Grassland is higher than in the previous submissions (see Figure 8.4).

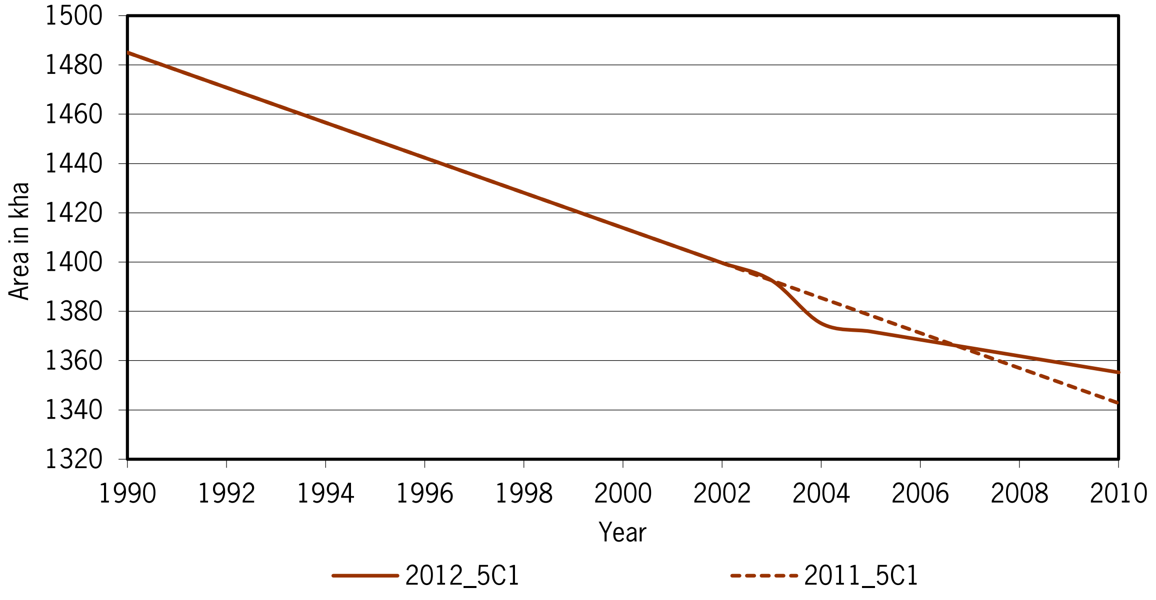

Figure 8.4
Cumulative area of Grassland remaining Grassland (5C1) in the 2011 and in the 2012 submission (note that y axis starts at 1320).

- In 2004, the loss is much higher, as there is a one year delay on area increase (which is reported temporarily in land converted to Grassland) but no delay on area loss.

8.3.3.2 Land converted to Grassland

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:
- Difference of about 0.03 ha land converted to Grassland between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the annual area converted to Grassland increases from 15.5 kha year^{-1} to 29.6 kha year^{-1}.

Changes in emissions and (implied) emission factors
The difference in emissions between the 2012 and 2011 submission (Table 8.6) could be attributed to two main reasons:
- Implementation of Tier 1 defaults for biomass gains and losses associated with conversions to and from Croplands and Grasslands (see also Par. 5.4).
- The change in activity data due to the implementation of a new land use map was reflected in a proportional change in emissions from biomass changes from 2004 on.

Table 8.6
Differences between the current and previous submission analysed.

	Difference between submissions 2012 and 2011 for reporting years ($Gg\ CO_2$)		
	1990	**2003**	**2009**
CRF 2012	245.32	357.87	250.25
CRF 2011	394.47	507.01	556.21
CRF 2012 – CRF 2011 for	**-149.14**	**-149.14**	**-305.97**
Change in activity data	0.00	0.00	3.90
T1 Cropland conversion – biomass	231.52	231.52	397.76[a]
T1 Grassland conversion – biomass	-380.66	-380.66	-707.63[a]

[a] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data.

8.3.4 Wetland

8.3.4.1 Wetland remaining Wetland

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:

- Difference of about 0.7 ha (on a total of about 790 kha) of Wetland remaining Wetland between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the area converted to Wetland increases from 2.2 kha $year^{-1}$ to 3.4 kha $year^{-1}$, while the area converted away from Wetland increases from 1.6 kha $year^{-1}$ to 2.3 kha $year^{-1}$. As a result, the net area gain decreases from 0.6 kha $year^{-1}$ for the period 1990-2003 to 1.2 kha $year^{-1}$ from 2004 on. Thus, from 2004 on the area under Wetland remaining Wetland is higher than in the previous submissions.
- In 2004, the loss is slightly lower, as there is a one year delay on area increase (which is reported temporarily in land converted to Wetland) but no delay on area loss.

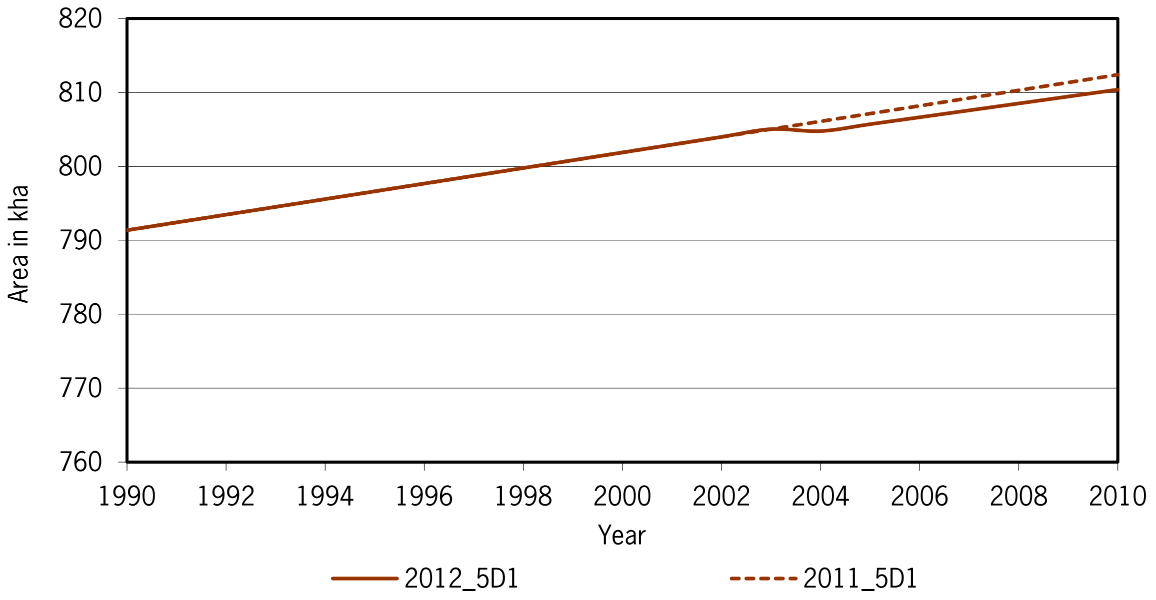

Figure 8.5
Cumulative area of Wetland remaining Wetland (5D1) in the 2011 and in the 2012 submission (note the y-axis starts at 760).

8.3.4.2 Land converted to Wetland

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:

- Difference of less than 0.01 ha in land converted to Wetland between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the annual area converted to Wetland increases from 2.2 kha $year^{-1}$ to 3.4 kha $year^{-1}$.

Changes in emissions and (implied) emission factors
The difference in emissions between the 2012 and 2011 submission (Table 8.7) could be attributed to two main reasons:

- Implementation of Tier 1 defaults for biomass gains and losses associated with conversions to and from Croplands and Grasslands (see also Par. 5.4).
- The change in activity data due to the implementation of a new land use map was reflected in a proportional change in emissions from biomass changes from 2004 on.

Table 8.7
Differences between the current and previous submission analysed

	Difference between submissions 2012 and 2011 for reporting years ($Gg\ CO_2$)		
	1990	**2003**	**2009**
CRF 2012	80.46	91.95	130.04
CRF 2011	40.29	51.78	56.80
CRF 2012 – CRF 2011 for	**40.16**	**40.16**	**73.24**
Change in activity data	0.00	0.00	15.72
Copying error	-1.97	-1.97	-1.97
T1 Cropland conversion – biomass	8.93	8.93	6.58[a]
T1 Grassland conversion – biomass	33.20	33.20	52.91[a]

[a] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data

8.3.5 Settlements

8.3.5.1 Settlements remaining Settlements

Changes in activity data

As a result of the new map overlay, there were the following changes in activity data:

- Difference of about 0.7 ha (on a total of about 408 kha) of Settlements remaining Settlements between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the area converted to Settlements decreases slightly from 12.4 kha $year^{-1}$ to 11.9 kha $year^{-1}$, while the area converted away from Settlements increases from 1.2 kha $year^{-1}$ to 7.4 kha $year^{-1}$. As a result, the net area gain decreases from 11.2 kha $year^{-1}$ for the period 1990-2003 to 4.6 kha $year^{-1}$ from 2004 on. Thus, from 2004 on the area under Settlements remaining Settlements is lower than in the previous submissions (see Figure 8.6).
- In 2004, the increase is intermediate, as there is a one year delay on area increase (which is reported temporarily in land converted to Settlements) but no delay on area loss.

8.3.5.2 Land converted to Settlements

Changes in activity data

As a result of the new map overlay, there were the following changes in activity data:

- Difference of about 0.01 ha land converted to Settlements between 1990 and 2003 (difference between current and previous overlay of 1990 and 2004 maps).
- From 2004 on, the annual area converted to Settlements decreases slightly from 12.4 kha $year^{-1}$ to 11.9 kha $year^{-1}$.

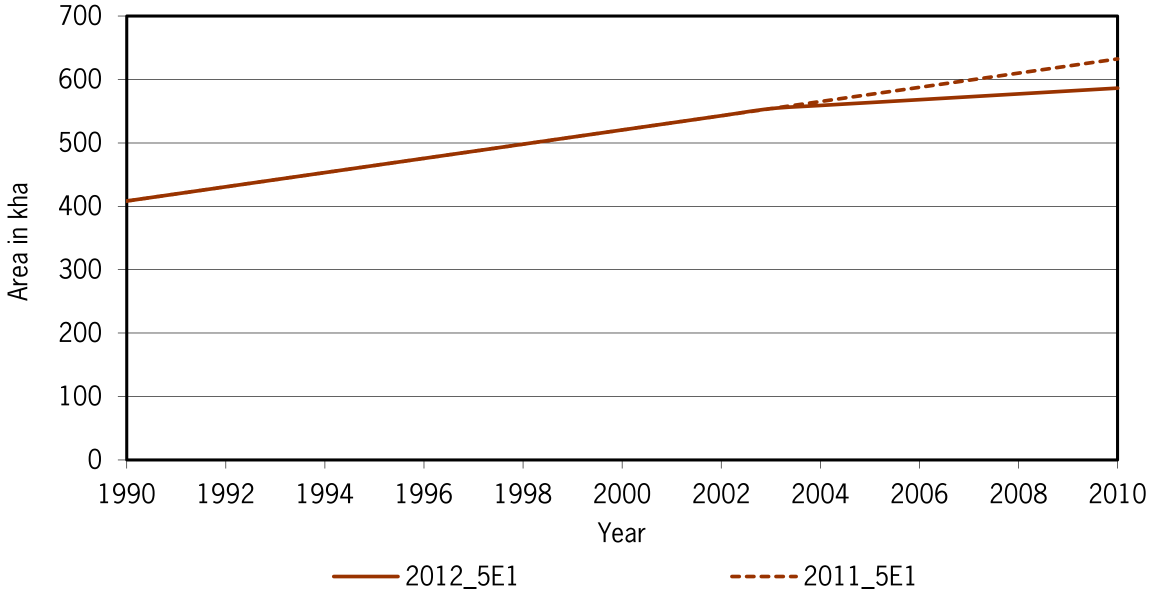

Figure 8.6

Cumulative area of Settlements remaining Settlements (5E1) in the 2011 and in the 2012 submission.

Changes in emissions and (implied) emission factors

The difference in emissions between the 2012 and 2011 submission (Table 8.8) could be attributed to two main reasons:

- Implementation of Tier 1 defaults for biomass gains and losses associated with conversions to and from Croplands and Grasslands (see also Par. 5.4).
- The change in activity data due to the implementation of a new land use map was reflected in a proportional change in emissions from biomass changes from 2004 on.

Table 8.8

Differences between the current and previous submission analysed.

	Difference between submissions 2012 and 2011 for reporting years ($Gg\ CO_2$)		
	1990	**2003**	**2009**
CRF 2012	458.61	519.68	798.58
CRF 2011	212.14	272.68	300.17
CRF 2012 – CRF 2011 for	**246.48**	**246.48**	**166.05**
Change in activity data	0.00	0.00	260.81
T1 Cropland conversion – biomass	107.10	107.10	50.34[a]
T1 Grassland conversion – biomass	139.37	139.37	188.02[a]

[a] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data

8.3.6 Other Land

8.3.6.1 Other Land remaining Other Land

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:

- No difference in area of Other Land remaining Other Land between 1990 and 2003.
- From 2004 on, the area converted to Other Land increases slightly from 0.35 kha year^{-1} to 0.46 kha year^{-1}, while the area converted away from Other Land decreases slightly from 0.46 kha year^{-1} to 0.35 kha year^{-1}. As a result, the net area loss of 0.11 kha year^{-1} for the period 1990-2003 changes into a net gain of 0.11 kha year^{-1} from 2004 on. Thus, from 2004 on the area under Other Land remaining Other Land is higher than in the previous submissions.
- In 2004, there is hardly any effect, as there is a one year delay on area increase (which is reported temporarily in land converted to Other Land) but no delay on area loss.

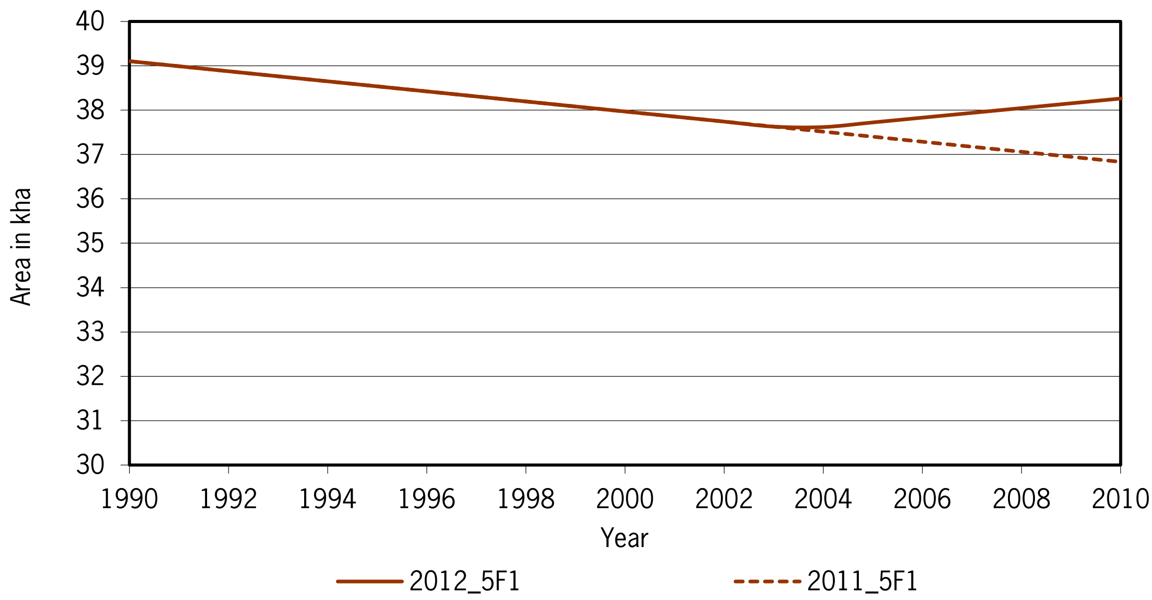

Figure 8.7
Cumulative area of Other Land remaining Other Land (5F1) in the 2011 and in the 2012 submission (note the y-axis starts at 30).

8.3.6.2 Land converted to Other Land

Changes in activity data
As a result of the new map overlay, there were the following changes in activity data:

- No difference in area of land converted to Other Land between 1990 and 2003.
- From 2004 on, the annual area converted to Other Land increases slightly from 0.35 kha year^{-1} to 0.46 kha year^{-1}.

Changes in emissions and (implied) emission factors
The difference in emissions between the 2012 and 2011 submission (Table 8.9) could be attributed to two main reasons:

- Implementation of Tier 1 defaults for biomass gains and losses associated with conversions to and from Croplands and Grasslands (see also Par. 5.4).
- The change in activity data due to the implementation of a new land use map was reflected in a proportional change in emissions from biomass changes from 2004 on.

Table 8.9
Differences between the current and previous submission analysed.

	Difference between submissions 2012 and 2011 for reporting years ($Gg\ CO_2$)		
	1990	**2003**	**2009**
CRF 2012	20.0	25.17	26.49
CRF 2011	18.13	23.30	25.52
CRF 2012 – CRF 2011 for	**1.88**	**1.88**	**0.97**
Change in activity data	0.00	0.00	-0.46
T1 Cropland conversion – biomass	0.26	0.26	0.10[a]
T1 Grassland conversion – biomass	1.61	1.61	5.22[a]

[a] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data

8.4 Aggregation of recalculations over the categories

Aggregating all categories, the difference in emissions between the 2011 and the 2012 submission can be explained by the following changes that were implemented (Table 8.10):

Table 8.10

Specification of the quantitative differences between submission 2011 and submission 2012 (Gg CO2). The year 2003 is included as the last year with unchanged activity data.

	Difference between submissions 2012 and 2011 for reporting years (Gg CO_2)		
	1990	**2003**	**2009**
CRF 2012	2999.95	2908.63	2865.47
CRF 2011	2691.86	2594.32	2475.03
CRF 2012 – CRF 2011 for	**308.08**	**314.30**	**390.44**
Change in activity data	104.42	104.42	54.10[a]
T1 Cropland conversion – biomass	183.79	183.79	113.85[a]
T1 Grassland conversion – biomass	0.00	0.00	368.95
Change in activity data – FL remaining FL	-0.01	-0.01	-149.74[b]
Changes in DOM in FL remaining FL (conversions between FAD and TOF)	21.85	28.04	40.47
Liming	0.00	0.00	-31.33
Error	-1.97	-1.97	-1.97

[a] this value reflects the difference between the 2011 and the 2012 submission and is thus is also affected by the change in activity data.

[b] this includes the update of the harvested volume for 2009.

9 QA/QC process

This chapter describes the route towards and during the 2012 submission for the LULUCF sector to the UNFCCC.

9.1 Planning and process management

Meetings	Date	Actions
Meeting WG[a] LULUCF	06-07-2011	Preparations for in-country review of September 2011
		Decisions on new land-use matrix resulting from inclusion of 2009 map
Meeting WG LULUCF	05-09-2011	Preparations for in-country review of September 2011
		Discussion on planning uncertainty analysis
Meeting WG LULUCF	17-11-2011	Evaluation of in-country review
		Discussion on uncertainty analysis
		Planning new forest inventory to commence in 2012
		Planning of points for improvements in 2012 (taking effect in 2013 submission)
Meeting WG LULUCF	12-01-2012	Evaluation EU review results
		Checks on CRF tables for LULUCF
		Establish work plan for 2012
Meeting WG LULUCF	06-03-2012	Concept NIR text for LULUCF

[a] Working group LULUCF

9.2 Changes/recalculations for the submission 2012

For the 2012 submission a number of changes and recalculations were identified (see Chapter 8). These are listed:

Change in activity data

T1 Cropland conversion – biomass

T1 Grassland conversion – biomass

Change in activity data – FL remaining FL

Changes in DOM in FL remaining FL (conversions between FAD & TOF)

Liming

Error

9.3 Calculations

Table 9.1
Overview of calculations supporting the LULUCF submission 2012.

Category	What	Who	Description
Activity data: area	Land use change matrix based on topographical maps	CGI, Alterra	Kramer et al., 2009; Chapter 2
C emissions from changes in biomass for 'Forest Land remaining Forest Land'	Simple bookkeeping model based on NFI data	Forest Ecology, Alterra	Nabuurs et al., 2005; Van den Wyngaert et al., 2007; Van den Wyngaert et al., 2009; Protocol 5A: CO2: Forest land (NIR 2012); Chapter 5
C emissions from changes in DOM-dead wood for 'Forest Land remaining Forest Land'	Simple bookkeeping model based on NFI data	Forest Ecology, Alterra	Nabuurs et al., 2005; Van den Wyngaert et al., 2007; Van den Wyngaert et al., 2009; Protocol 5A: CO2: Forest land (NIR 2012); Chapter 6
C emissions from changes in DOM-litter for 'Forest Land remaining Forest Land'	Stock change at national level using a combination of several data sets	Forest Ecology, Alterra	Van den Wyngaert et al., 2009; Protocol 5A: CO2: Forest land (NIR 2012); Chapter 6
C emissions from changes in biomass for 'Land converted to Forest Land'	Based on mean growth of young forest calculated from NFI data	Forest Ecology, Alterra	Nabuurs et al., 2005; Van den Wyngaert et al., 2009; Protocol 5A: CO2: Forest land (NIR 2012); Chapter 5
C emissions from changes in biomass for 'Forest Land converted to other category Land'	Based on mean C stock in forest biomass from the model based on NFI data	Forest Ecology, Alterra	Nabuurs et al., 2005; Van den Wyngaert et al., 2009; Protocol 5A: CO2: Forest land (NIR 2012); Chapter 5
C emissions for cultivation of organic soils	Based on groundwater level map and soil surface lowering	Soil Quality and Nutrients, Alterra	Kuikman et al., 2005; Protocol 5B-G: CO2 emissions for total land-use categories; Chapter 7
C emissions from use of calcareous fertilizers	Based on national use and default emission values	RIVM	NIR

9.4 Process for calculating and reporting emissions

The Dutch land use matrix is derived from an overlay between land use maps for 1990 and 2004. Both are made by CGI (Alterra) based on the topographical maps (Kramer et al., 2009). The land use change maps are delivered to Soil Centre (Alterra). At the Soil Quality and Nutrients team (Alterra) an overlay is made between the land use maps, the soil carbon map and the soil peat map. The land use change matrix for land on mineral soils and for land on peat soils is delivered to the sectoral expert at Forest Ecology (Alterra).
The emission factor of emissions associated with Forest land or conversions to and from Forest Land (Gg C ha^{-1}) are calculated by Forest Ecology (Alterra). Emissions associated with use of organic soils are calculated by Soil Quality and Nutrients (Alterra). Emissions or emission factors are sent to the sectoral expert at Forest Ecology (Alterra).

Carbon emissions associated with the agricultural use of chalk ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) on croplands or grasslands is calculated by RIVM and sent to the sector expert at Forest Ecology (Alterra).

Once all values for the submission are available, a series of actions is performed to check for typing or copying errors, internal consistency, international consistency, completeness, etc.

9.5 Submission route

The reported values are entered in a copy of the CRF reporter by the sector expert at Alterra (Figure 9.1, A t/m D). After completely filling the LULUCF sector, a CRF is generated and checked by Alterra. After accordance a XML file is generated and sent to TNO (Figure 9.1, D t/m F).
Then the draft CRF tables for LULUCF are generated from the CRF reporter by TNO and sent to Alterra and RIVM for checking (Figure 9.1, G t/m I).
Alterra sends the spread sheet for internal checking class 5A (Forest) and for classes 5B to 5F (Cropland, Grassland, Wetland, Settlements, Other Land). After checking and commenting Alterra reports back to TNO. RIVM checks independently whether the values in the CRF are right.
This is a check on all actions between calculating the values and the actual submission.

TNO generates the final CRF tables (Figure 9.1, H t/m J). This loop is followed until there is full accordance. The final tables are sent to RIVM who actually performs the official submission (Figure 9.1, K).

Based on the CRF and the different reports, RIVM writes the LULUCF chapter for the NIR. This chapter is read by Alterra.

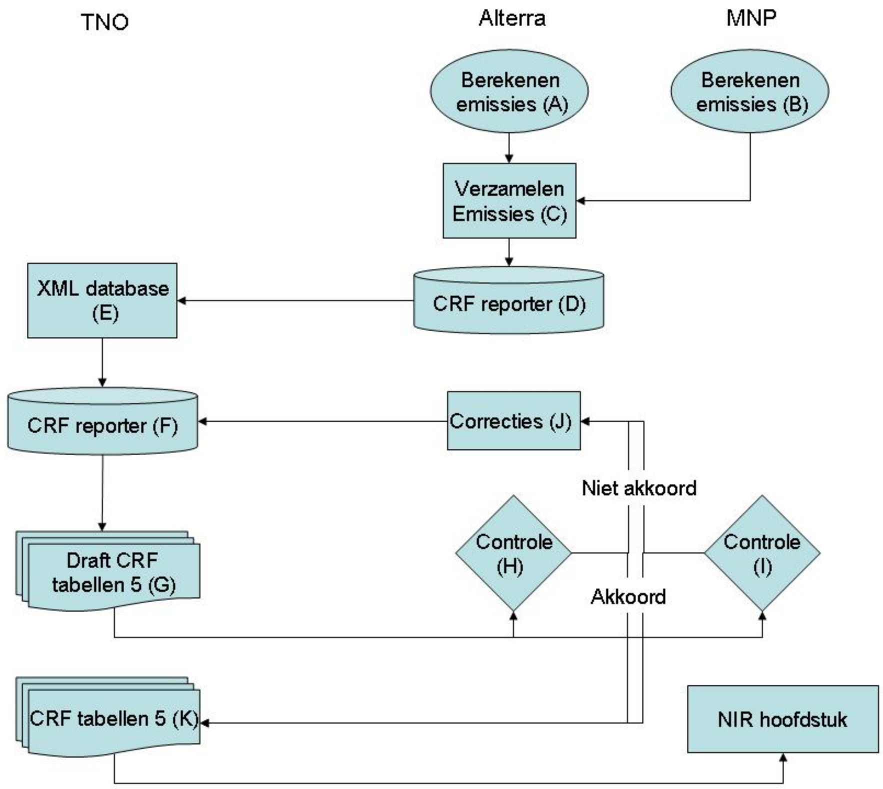

Figure 9.1
Flow of information from calculation to submission.

10 Possibilities for future updates

When the current system was implemented for the LULUCF sector, it was already envisaged that there would be regular improvements over time. In Van den Wyngaert et al. (2011) a short list of proposed improvements were given that need further attention. These do not have a fixed data tied to them, and are repeated here for reasons of completeness.

Installation of subcategories in Grassland, i.e. distinction between rotational grassland, permanent grassland and natural grasslands

More than half of the land use conversions occurs between Grassland and Cropland, in either direction. The use of area as grasslands as part of a full rotational cycle is part of the agricultural system in many parts of the Netherlands. However, as such it is not possible to discriminate between 'permanent' land use changes, and its related emissions, and 'temporary' land use changes between Cropland and Grassland. Currently, it is possible to distinguish natural grasslands with a management directed towards the conservational value from grassland with a mostly agricultural purpose using a dataset on subsidies. In future it may be possible to add a further distinction between rotational grasslands and permanent agricultural grasslands. For the moment this is a conceptual idea. Due to financial reasons it is not expected to progress further in the coming years.

Update of the forest model used in Forest Land remaining Forest Land

Until now, the gap in data between two NFI's (HOSP and MFV) and after an NFI cycle was filled based on the data from the NFI previous to the calculated years, assuming no change in net annual increment and converted to carbon stock changes using a very simple bookkeeping model. The validity of this assumption was tested in Van den Wyngaert et al. (2007) and accepted. However, as the time of extrapolation increases, this may change. Due to financial reasons an update of the National Forest Inventory has been delayed, but currently a new cycle is being initiated to start in 2012. This provides a good opportunity to update the forest growth functions and to adapt the current bookkeeping model to address the shortcomings the 2012 peer-review has identified. Also with obligatory reporting of forest management expected for the near future, a thorough update of the forest calculations, along with an analysis on how to proceed with irregular data in time is needed.

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Annex A. Carbon emission calculations for Forest Land remaining Forest Land (I) and fluxes associated with changes in biomass associated with the conversion of land to and from Forest (II)

A(I). Forest remaining forest

The carbon budget of forests in the Netherlands is based on a simulated annual carbon stock change budget for each of the NFI plots, which are then aggregated to the country scale based on the representative areas of the plots. The calculated biomass values are used for the calculation of an emission factor for deforestation.

Plot level simulation model to calculate annual plot scale carbon stock and carbon stock change

1. Calculate age from recording year and regeneration year

$$T_{it} = t_{rcd} - t_{reg}$$

where

T_{it}	Age of NFI plot *i* at time t (years)
t_{rcd}	Year of recording of NFI plot *i*
t_{reg}	(Estimated) year of regeneration of NFI plot *i*

2. Calculate maximal height from age and measured dominant height

$$h_{it} = SI_i \cdot (1 - e^{-c_7 T_{it}})^{c_8}$$
$$\Leftrightarrow SI_i = h_{it} / (1 - e^{-c_7 T_{it}})^{c_8}$$

where

T_{it}	Age of NFI plot *i* at time *t* (years)	
h_{it}	Dominant height of NFI plot *i* at time *t* (m)	
SI_i	Site index of NFI plot *i*, i.e. asymptote of hdom→ ∞ (m)	[MFV]
c7, c8	Tree species specific constants (year-1 , -)	

3. Calculate current mean tree volume and dbh from total standing stock, tree density and dominant height

$$\overline{V_{it}} = \frac{V_{it}}{nt_{it}}$$

where

V_{it}	Stand volume of NFI plot *i* at time *t* (m^3 ha^{-1})
nt_{it}	Living tree density of NFI plot *i* at time *t* (ha^{-1})
$\overline{V_{it}}$	Average tree volume of NFI plot *i* at time *t* (m^3)

$$\overline{V_{it}} = \overline{dbh_{it}}^{a} \times h_{it}^{b} \times e^{c}$$
$$\Leftrightarrow \ln(\overline{V_{it}}) = a \times \ln(\overline{dbh_{it}}) + b \times \ln(h_{it}) + c$$
$$\Leftrightarrow \ln(\overline{dbh_{it}}) = \frac{1}{a} \times (\ln(\overline{V_{it}}) - b \times \ln(h_{it}) - c)$$

where

$\overline{V_{it}}$	Average tree volume of NFI plot *i* at time *t* (m^3)
$\overline{dbh_{it}}$	Average tree diameter of NFI plot *i* at time *t* (cm)
h_{it}	Dominant height of NFI plot *i* at time *t* (m)
a, b, c	Type-specific constants

4. Calculate current mean tree mass and total plot biomass and carbon from current tree dimensions

$$\overline{B_{it}} = \overline{B_{AG_{it}}} + \overline{B_{BG_{it}}}$$
$$\overline{B_{AG_{it}}} = bf_{AG}\left(\overline{dbh}_{it}, h_{it}\right)$$
$$\overline{B_{BG_{it}}} = bf_{BG}\left(\overline{dbh}_{it}, h_{it}\right)$$

where

$\overline{B_{it}}$	Average tree biomass of NFI plot *i* at time *t* (kg DW)	
$\overline{B_{AG_{it}}}$	Above ground mean tree biomass of NFI plot *i* at time *t*	(kg DW)
$\overline{B_{BG_{it}}}$	Below ground mean tree biomass of NFI plot *i* at time *t*	(kg DW)
$bf_{AG}(\ )$	Biomass function relating mean tree above ground biomass to mean DBH and height	
$bf_{BG}(\ )$	Biomass function relating mean tree below ground biomass to mean DBH and height	

5. Calculate next year's stand dominant height and volume from age and volume increment:

$$h_{i(t+1)} = SI_i \cdot (1 - e^{-c_7(T_{it}+1)})^{c_8}$$

where

T_{it}	Age of NFI plot *i* at time t (years)	
$h_{i(t+1)}$	Dominant height of NFI plot *i* at time $t+1$ (m)	
SI_i	Site index of NFI plot *i*, i.e. asymptote of $h_{dom} \rightarrow \infty$ (m)	[MFV]
c_7, c_8	Tree species specific constants ($year^{-1}$, -)	

$$V_{i(t+1)} = V_{it} + I_{V_{it}}$$

where

$V_{i(t+1)}$	Volume of standing stock for plot *i* at time $t+1$ (m^3 ha^{-1})	
V_{it}	Volume of standing stock for plot *i* at time t (m^3 ha^{-1})	[HOSP/MFV]
$I_{V_{it}}$	Annual volume increment for plot *i* at time t (m^3 ha^{-1} $year^{-1}$)	[HOSP/MFV]

$$nt_{i(t+1)} = (1 - f_{mort}) \cdot nt_{it}$$

$nt_{i(t+1)}$	Living tree density of NFI plot *i* at time *t*+1 (ha^{-1})
nt_{it}	Living tree density of NFI plot *i* at time t (ha^{-1})
f_{mort}	Annual mortality fraction (-)

6. Calculate next year's mean tree dimensions from new total standing stock, tree density and dominant height

$$\overline{V}_{i(t+1)} = \frac{V_{i(t+1)}}{nt_{i(t+1)}}$$

where

$V_{i(t+1)}$	Stand volume of NFI plot *i* at time *t*+1 (m^3 ha^{-1})
$nt_{i(t+1)}$	Living tree density of NFI plot *i* at time *t*+1 (ha^{-1})
$\overline{V}_{i(t+1)}$	Average tree volume of NFI plot *i* at time *t*+1 (m^3)

$$\ln(\overline{dbh_{i(t+1)}}) = \frac{1}{a} \times (\ln(\overline{V_{i(t+1)}}) - b \times \ln(h_{i(t+1)}) - c)$$

where

$\overline{V_{i(t+1)}}$	Average tree volume of NFI plot *i* at time *t*+1 (m^3)
$\overline{dbh_{i(t+1)}}$	Average tree diameter of NFI plot *i* at time *t*+1 (cm)
$h_{i(t+1)}$	Dominant height of NFI plot *i* at time $t+1$ (m)
a,b,c	Type-specific constants

7. Calculate next year's mean tree mass and total plot biomass and carbon from new tree dimensions

$$\overline{B_{i(t+1)}} = \overline{B_{AG_{i(t+1)}}} + \overline{B_{BG_{i(t+1)}}}$$
$$\overline{B_{AG_{i(t+1)}}} = bf_{AG}\left(\overline{dbh}_{i(t+1)}, h_{i(t+1)}\right)$$
$$\overline{B_{BG_{i(t+1)}}} = bf_{BG}\left(\overline{dbh}_{i(t+1)}, h_{i(t+1)}\right)$$

where

$\overline{B_{i(t+1)}}$	Average tree biomass of NFI plot i at time t (kg DW)	
$\overline{B_{AG_{i(t+1)}}}$	Above ground mean tree biomass of NFI plot *i* at time *t*	(kg DW)
$\overline{B_{BG_{i(t+1)}}}$	Below ground mean tree biomass of NFI plot *i* at time *t*	(kg DW)
$h_{i(t+1)}$	Dominant height of NFI plot *i* at time $t+1$ (m)	
$bf_{AG}(\ )$	Biomass function relating mean tree above ground biomass to mean DBH and height	
$bf_{BG}(\ )$	Biomass function relating mean tree below ground biomass to mean DBH and height	

8. Distribute national harvest values over plots

$$p_{it}(H) = \begin{bmatrix} 0 | V_{it} < 300 \wedge T_{it} < 110 \\ 1 | V_{it} > 300 \vee T_{it} > 110 \end{bmatrix}$$

$$f_H = \frac{H_{NL}}{\sum \left[p_{it}(H) \cdot V_{it} \right]}$$

$$B_{L_{it}} = f_H \cdot p(H) \cdot nt_{it} \cdot \overline{B_{it}}$$

where

$p_{it}(H)$	Chance of a harvest occurring in plot *i* at time *t* (-)
V_{it}	Stand volume of NFI plot *i* at time *t* (m^3 ha^{-1})
T_{it}	Age of NFI plot *i* at time *t* (years)
f_H	Fraction of plot *i* that is harvested at time *t* (-)
H_{NL}	Annually harvested volume at national scale (m^3)
$B_{L_{it}}$	Biomass harvested in plot *i* at time *t* (kg DW)
nt_{it}	Living tree density of NFI plot *i* at time *t* (in ha^{-1})

9. Calculate carbon gain from tree growth and carbon loss from harvest

$$\Delta C_{FF_G} = \sum_1^n \left(A_i \bullet G_{TOTALi} \right) \bullet CF$$

$$G_{TOTALi} = \left(\overline{B_{it+1}} - \overline{B_{it}} \right) \cdot nt_{it}$$

where

ΔC_{FF_G}	Total net carbon emission due to biomass increase for Forest land remaining Forest land - FAD in the Netherlands	kg C ha^{-1}
A_i	Area represented per NFI plot	ha
CF	Carbon fraction of living biomass	0.5

and

G_{TOTALi}	Biomass increase for NFI plot *i*	kg DW
$\overline{B_{i\,t}}$	Average tree biomass of NFI plot *i* at time *t*	kg DW
$\overline{B_{i\,t+1}}$	Average tree biomass of NFI plot *i* at time *t*+1	kg DW
nt_{it}	Living tree density of NFI plot *i* at time *t*	ha^{-1}

$$\Delta C_{FF_L} = \sum_{i=1}^{n} \left(B_{L_{it}} \cdot CF \right)$$

$$\Delta C_{FF_{LB}} = \Delta C_{FF_G} - \Delta C_{FF_L}$$

with

$\Delta C_{FF_{LB}}$	annual change in carbon stocks (in Gg C) due to biomass change in forests in the Netherlands
ΔC_{FF_G}	annual increase in carbon stocks (in Gg C) due to biomass increase in forests in the Netherlands
ΔC_{FF_L}	annual decrease in carbon stocks (in Gg C) due to biomass decrease in forests in the Netherlands (for calculation see Annex A)

10. Carbon stock change on dead wood

$$\Delta C_{FF_{DW}} = \sum \left(A_i \bullet \left(B_{DW\,\mathrm{into}_i} - B_{DW\,out_i} \right) \right) \bullet CF$$

$$B_{DW\,\mathrm{into}_i} = B_{it} \bullet f_{mort}$$

$$B_{DW\,out_i} = \left(\frac{V_{SD\,i}}{L_{SDi}} + \frac{V_{LDi}}{L_{LDi}} \right) \bullet D_{DW} + f_{removal} \bullet D_{DW}$$

$\Delta C_{FF_{DW}}$	Total net carbon emission due to change in dead wood for Forest land remaining Forest land - FAD in the Netherlands
$B_{DW\,\mathrm{into}_i}$	Annual mass transfer into dead wood pool of NFI plot *i*
$B_{DW\,out_i}$	Annual mass transfer out of dead wood pool of NFI plot *i*
B_{it}	Stand living biomass of NFI plot *i* at time *t*
f_{mort}	Mortality fraction (0.4% $year^{-1}$)
$V_{SD\,i}$	Volume of standing dead wood of NFI plot *i*
V_{LDi}	Volume of lying dead wood of NFI plot *i*
L_{SDi}	Species specific longevity of standing dead wood
L_{LDi}	Species specific longevity of standing lying wood
D_{DW}	Species specific average wood density of dead wood
$f_{removal}$	Removal fraction of dead wood (0.2 $year^{-1}$)

A(II). Afforestation & deforestation

Following calculations are carried out to derive the annual carbon balance from the live tree compartment through afforestation and deforestation

1. Afforestation

$$\Delta C_{LF_{Growth}} = \sum_{t=1}^{20} \left(EF_t \cdot A_{LF_t} \right)$$

Where

$\Delta C_{LF_{Growth}}$	Change in carbon stock in living biomass in land annually converted to forest land (Gg C)
EF_t	Emission factor for young plots of age t (see par. 5.3.1) (Gg C ha^{-1})
A_{LF_t}	Area of land converted to forest of age t (ha)

2. Deforestation

$$\Delta C_{FL_{Loss}} = A_{FL_t} \cdot \frac{\sum \left(A_i \cdot B_{it} \right)}{\sum A_i} \cdot CF$$

$\Delta C_{FL_{Loss}}$	change in carbon stocks in living biomass due to conversion of Forest land to other land use categories (Gg C)
A_{FL_t}	Area of land deforested annually (ha)
A_i	Area of land represented by plot i (ha)
B_{it}	Stand biom

Annex B. Biomass expansion equations

The selection of biomass expansion equations used for the calculations of aboveground biomass (Table B-1) and belowground biomass (Table B-2), for more information see Appendix I in Nabuurs et al., 2005.

Table B-1
Allometric equations used to calculate for single trees their aboveground biomass (in kg) from inventory data (D in cm, H in m).

Species group	Equation	Developed for	Country	Reference
Acer spp	$0.00029*(D*10)^{2.50038}$	*Betula pubescens*	Sweden	Johansson, 1999a
Alnus spp	$0.00309*(D*10)^{2.022126}$	*Alnus glutinosa*	Sweden	Johansson, 1999b
Betula spp	$0.00029*(D*10)^{2.50038}$	*Betula pubescens*	Sweden	Johansson, 1999a
Fagus sylvatica	$0.0798*D^{2.601}$	*Fagus sylvatica*	The Netherlands	Bartelink, 1997
Fraxinus excelsior	$0.41354*D^{2.14}$	*Quercus robur* and *Quercus petraea*	Austria	Hochbichler, 2002
Larix spp	$0.0533*(D^2*H)^{0.8955}$	*Picea abies*	European Russia	Hamburg et al., 1997
Picea spp	$0.0533*(D^2*H)^{0.8955}$	*Picea abies*	European Russia	Hamburg et al., 1997
Pinus other	$0.0217*(D^2*H)^{0.9817}$	*Pinus sylvestris*	European Russia	Hamburg et al., 1997
Pinus sylvestris	$0.0217*(D^2*H)^{0.9817}$	*Pinus sylvestris*	European Russia	Hamburg et al., 1997
Populus spp	$0.0208*(D^2*H)^{0.9856}$	*Populus tremula*	European Russia	Hamburg et al., 1997
Pseudotsuga menziesii	$0.111*D^{2.397}$	*Pseudotsuga menziesii*	The Netherlands	Van Hees, 2001
Quercus spp	$0.41354*D^{2.14}$	*Quercus robur* and *Quercus petraea*	Austria	Hochbichler, 2002
Coniferous other	$0.0533*(D^2*H)^{0.8955}$	*Picea abies*	European Russia	Hamburg et al., 1997
Broadleaved other	$0.41354*D^{2.14}$	*Quercus robur* and *Quercus petraea*	Austria	Hochbichler, 2002

Table B-2
Allometric equations used to calculate for single trees their biomass (in kg) from inventory data (D in cm, H in m).

Species group	Equation	Species	Country	Reference
Acer spp	$0.0607*D^{2.6748}*H^{-0.561}$	*Betula pubescens*	European Russia	Hamburg et al., 1997
Alnus spp	$0.0607*D^{2.6748}*H^{-0.561}$	*Betula pubescens*	European Russia	Hamburg et al., 1997
Betula spp	$0.0607*D^{2.6748}*H^{-0.561}$	*Betula pubescens*	European Russia	Hamburg et al., 1997
Fagus sylvatica	$e^{-3.8219}*D^{2.5382}$	*Fagus sylvatica*	France	Le Goff & Ottorini, 2001
Fraxinus excelsior	$-1.551*0.099*D^2$	*Quercus petraea*	France	Drexhage et al., 1999
Larix spp	$0.0239*(D^2*H)^{0.8408}$	*Picea abies*	European Russia	Hamburg et al., 1997
Picea spp	$0.0239*(D^2*H)^{0.8408}$	*Picea abies*	European Russia	Hamburg et al., 1997
Pinus other	$0.0144*(D^2*H)^{0.8569}$	*Pinus sylvestris*	European Russia	Hamburg et al., 1997
Pinus sylvestris	$0.0144*(D^2*H)^{0.8569}$	*Pinus sylvestris*	European Russia	Hamburg et al., 1997
Populus spp	$0.0145*(D^2*H)^{0.8749}$	*Populus tremula*	European Russia	Hamburg et al., 1997
Pseudotsuga menziesii	$0.0239*(D^2*H)^{0.8408}$	*Picea abies*	European Russia	Hamburg et al., 1997
Quercus spp	$-1.551*0.099*D^2$	*Quercus petraea*	France	Drexhage et al., 1999
Coniferous other	$0.0239*(D^2*H)^{0.8408}$	*Picea abies*	European Russia	Hamburg et al., 1997
Broadleaved other	$-1.551*0.099*D^2$	*Quercus petraea*	France	Drexhage et al., 1999

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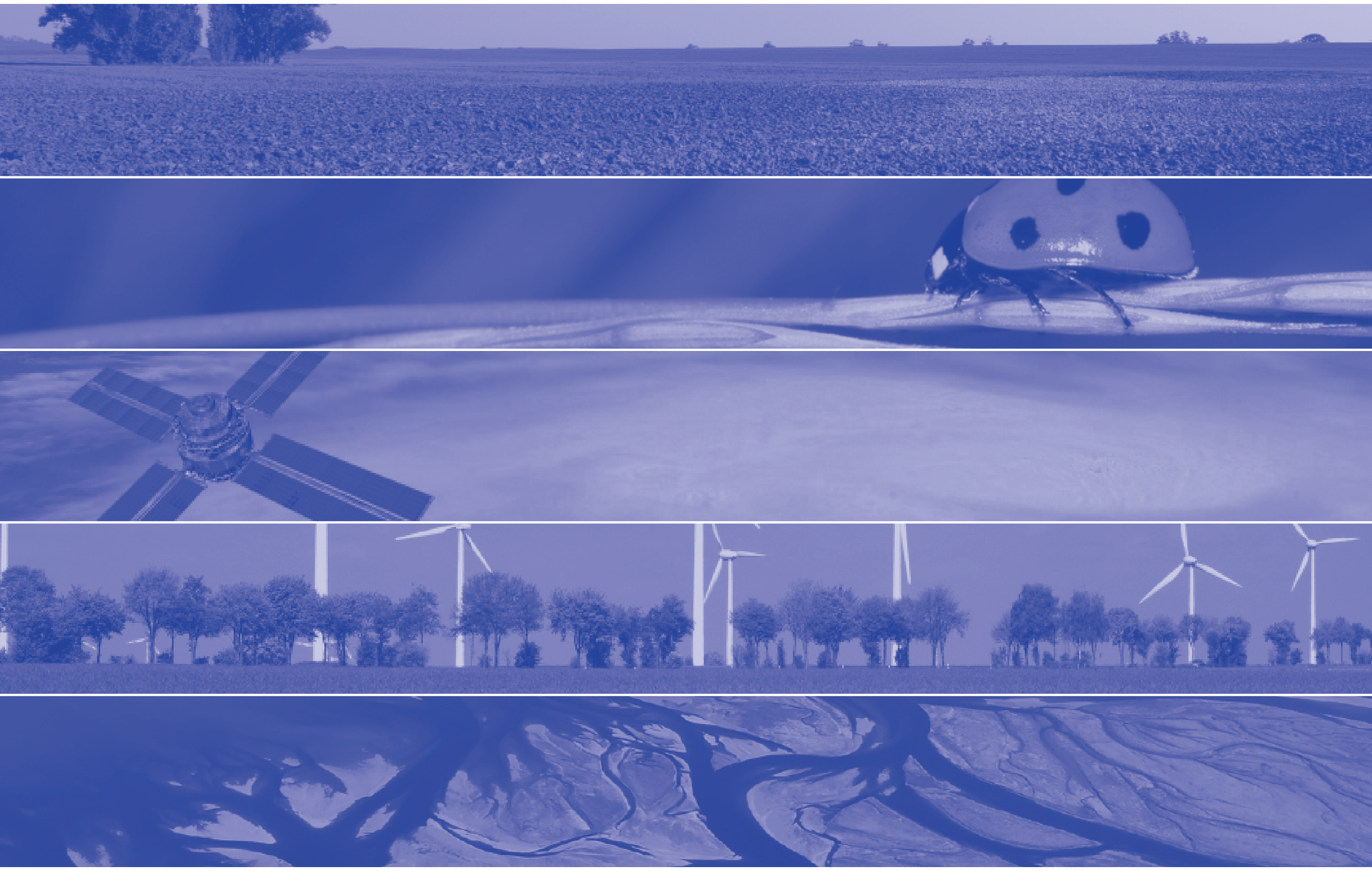

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