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Greenhouse gas reporting of the LULUCF sector for the UNFCCC and Kyoto Protocol

Background to the Dutch NIR 2013

WOt Technical report 1

E.J.M.M. Arets, K.W. van der Hoek, H. Kramer, P.J. Kuikman and J.P. Lesschen

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Statutory Research Tasks Unit for Nature & the Environment

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Abstract
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This report provides a complete description and background information of the Dutch National System for Greenhouse gas Reporting of the LULUCF sector and the Dutch LULUCF submission under the Kyoto Protocol for the 2013 submission of The Netherlands. The 2013 submission reports greenhouse gas emissions over the year 2011. It includes detailed description of the methodologies used to calculate activity data and emissions and it gives the full text of the NIR-II for KP-LULUCF, as well as a description of the table-by-table methodologies, choices and motivations. In 2011 afforestation and reforestation activities produced a sink of 458.66 Gg CO_2 equivalents while deforestation caused an emission of 838.67 Gg CO_2 equivalents. These values were based on changes in above-and belowground biomass, dead wood, litter and soil (mineral as well as organic), and agricultural lime application on deforested areas.

Keywords: Greenhouse Gas Reporting, Kyoto Protocol, LULUCF, National Inventory report, National system greenhouse gases, the Netherlands, UNFCCC

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Preface

This report provides a complete description and background information of the Dutch National System for Greenhouse gas Reporting of the LULUCF sector for the UN Framework Convention on Climate Change (UNFCCC) and the Dutch LULUCF submission under the Kyoto Protocol for its 2013 submission. It is the first background document that combines the submission under the UNFCCC and the submission under the Kyoto Protocol. Previous background documents to the submissions under the UNFCCC, dealing with similar topics, were published as Alterra reports, mostly but not exclusively in the 1035.x series (e.g. Nabuurs *et al.* (2003, 2005), De Groot *et al.* (2005), Kuikman *et al*. (2003; 2005) and Van den Wyngaert *et al.* (2007, 2008, 2009, 2011a,b and 2012)). Two previous background reports for the submission under the Kyoto Protocol have been published in a WOt publication series.

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Contents

Summary

This report provides a detailed description of the Dutch Greenhouse gas calculations and reporting of the LULUCF sector for the 2013 submission to the UNFCCC and Kyoto Protocol (KP). 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, 2011a,b, & 2012). 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.

The development of the Land use maps and corresponding land use change matrices are elaborated in Chapter 4. Procedures to produce the land use maps and matrices are discussed in detail in Kramer *et al.* (2009). Chapter 4 includes a summary of the development of the 1990 and 2004 maps and land use matrix. For the submission in 2012 a new land use map for 2009 was introduced that enabled the development of a new land use change matrix covering the years 2004-2009. As this new land use map has not been published in a separate report more detailed information on the methodology is also provided in Chapter 4. Additionally, the overlays of the land use maps with a soil carbon map and a peat soil map, are 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. Chapter 5 focuses on carbon emissions from biomass, while Chapter 6 gives details on carbon emissions from dead organic matter and litter. Chapter 5 also describes the method used to calculate changes in carbon stocks in biomass in land use conversions to and from Croplands and Grasslands based on default carbon stocks for total biomass.

In Chapter 7 greenhouse gas emissions (CO_2, CH_4 en N_2O) from wildfires in forests (forest fires) are estimated according the Tier 1 method. These are reported for the first time in the NIR 2013. Previously these emissions were not reported because no recent data on the extent of forest fires are available and because the total area is estimated to be very small. Following repeated comments on this assumption during subsequent reviews it was decided to include Tier 1 estimates with area burned forest based on a historical series of 1980-1992 for which annual number of forest fires and the total area burned were available.

In Chapter 8 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 calculation of the carbon emissions from organic soils.

In Chapter 9 the values submitted in the NIR 2013 are compared with the values submitted in the NIR 2012. Differences in net CO_2 emissions and removals between the NIR 2012 and NIR 2013 were observed in forest land remaining forest land, in land converted to grassland and in emissions form lime application. These differences were the results of several re-calculations resulting from the first time reporting of forest fires (re-calculations for the whole time series 1990-2013), correcting an error in the used Tier 1 emission factor for conversion from settlements to grassland and from other land to grassland and an update of the 2010 emissions for liming.

Chapter 10 describes in detail the methods behind the filling of the KP LULUCF tables. Reporting under the Kyoto Protocol deals with the same type of pools and gases as the Convention and is

complementary to and partly overlapping with the background information provided in the previous chapters. Emissions occurring from LULUCF, however, are reported in more detail under the Kyoto Protocol, while at the same time, the KP tables do not cover the full LULUCF sector.

The Netherlands has chosen to define forests as having a minimum area of 0.5 ha, a minimum crown cover of 20% and a minimum height of 5 m. This is in line with our national forest definition as well as FAO reporting since 1984. The definition matches the subcategory 'Forests according to the Kyoto definition' (abbreviated as 'FAD') of Forest Land in the inventory under the Convention on Climate Change. Units of land that did not comply to the forest definition on 1st January 1990 and do so at any moment (that can be measured) before 31st December 2012 are reported as re/afforested. Units of land that did comply to the forest definition on or after 1st January 1990 and do not anymore so at any moment (that can be measured) before 31st December 2012 are reported as deforested. Once land is classified as deforested, it remains in this category, even if it is reforested and thus complies to the forest definition again later in time.

The identification of units of land subject to re/afforestation and deforestation (ARD) corresponds with the wall-to-wall approach used for reporting under the Convention (approach 3 in GPG-LULUCF Chapter 2) and is described as reporting method 2 in GPG-LULUCF for Kyoto (section 4.2.2.2). It is explained and motivated in detail in Kramer *et al.*, 2009 and Chapter 4.

Chapter 11 compares the Convention and KP tables. The linkage between AR the reporting based on land use (sub)categories for the Convention are:

- 5.A.2.1 Cropland converted to Forest Land – Forests according to the Kyoto definition;
- 5.A.2.2 Grassland converted to Forest Land – Forests according to the Kyoto definition;
- 5.A.2.3 Wetland converted to Forest Land – Forests according to the Kyoto definition;
- 5.A.2.4 Settlement converted to Forest Land – Forests according to the Kyoto definition;
- 5.A.2.5 Other Land converted to Forest Land – Forests according to the Kyoto definition;
- as well as the conversion from 5.1.1. Trees outside Forest to Forests according to the Kyoto definition, included in 5.1.1. Forests according to the Kyoto definition.

The linkage between D and the reporting based on land use (sub)categories for the Convention are:

- 5.B.2.1 Forest Land – Forests according to the Kyoto definition converted to Cropland;
- 5.C.2.1 Forest Land – Forests according to the Kyoto definition converted to Grassland;
- 5.D.2.1 Forest Land – Forests according to the Kyoto definition converted to Wetland;
- 5.E.2.1 Forest Land – Forests according to the Kyoto definition converted to Settlement;
- 5.F.2.1 Forest Land – Forests according to the Kyoto definition converted to Other Land;
- as well as the conversion from Forests according to the Kyoto definition to Trees outside Forest and, included in 5.1.1. Trees outside Forest.

Changes in carbon pools in land changing between Kyoto forest and cropland, grassland, wetlands, settlements or other lands are calculated as described for land use changes involving Forest land under the Convention. A distinction into above- and below ground biomass is made using appropriate R values, and only biomass gains (AR) or only biomass losses (D) are reported.

Changes in carbon pools in Kyoto forest changing to and from Trees outside Forest does not involve a discontinuity in woody cover and is calculated using the simple NFI based bookkeeping model applied for Forest land remaining Forest Land in Convention reporting (Chapter 5). Changes in litter and dead wood pools are reported only for D, using national means resulting from the same simple bookkeeping model also used for living biomass stocks (Chapter 5).

In Chapter 12 the QA/QC for both the reporting under the Convention and Kyoto Protocol is presented. Finally, in Chapter 13 some foreseen future improvements in calculations are presented.

1 Introduction

1.1 UNFCCC

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, i.e. Nabuurs *et al.* (2003, 2005), Van den Wyngaert *et al.* (2007, 2008, 2009, 2011a,b & 2012), 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 2013 submission under the Convention. For the first time this reporting is combined with the reporting under the Kyoto Protocol, which still is presented in different chapters. In future background reports it is expected that the two parts will be further integrated.

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. In Chapter 7 for the first time greenhouse gas emissions from forest fires (wildfires) are estimated. Chapter 8 deals mainly with reporting of carbon emissions from soils. Chapter 9 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 12. The report concludes with a plan of future improvements to the National System for LULUCF (Chapter 13).

1.2 Kyoto Protocol

The Netherlands has also ratified the Kyoto Protocol and thereby has committed itself to additional yearly reporting on its greenhouse gas emissions. Whereas the Convention on Climate Change is mostly directed to accurate monitoring of greenhouse gas emissions, the Kyoto Protocol (KP) contains quantified targets for the reduction of greenhouse gas emissions. Both agreements require countries to design and implement a system for reporting of greenhouse gases (GHG) (Article 5 of the UNFCCC).

In 2010 The Netherlands reported for the first time to the Kyoto Protocol (KP). Negotiations have led to different reporting rules for the LULUCF sector under the Convention and under KP. Whereas under the Convention land based reporting ideally covers the complete national surface, under KP activity based reporting was chosen. Only two types of activities, i.e. re/afforestation and deforestation have mandatory reporting. Other activities can be elected but The Netherlands has chosen not to do so. The difference in emissions to be reported and in accountability under the KP have led to a difference between reporting practice under KP and under the Convention. The LULUCF sector is the only sector that has two types of tables in the Common Reporting Format (CRF, i.e. tables used to harmonize the structure of the reported emissions), one for the Convention and one for KP.

In this technical report the background for the reported emissions under the KP for the NIR 2013 (KP reporting years 2008, 2009, 2010 and 2011) is described. The 2013 submission is the 4th submission under KP. Chapter 10 provides basic information on the Kyoto tables and how it is based on background information. It presents the underlying sources of data and gives the equations used for estimating greenhouse gas emissions from LULUCF. In Chapter 11 the link is made between the values submitted under the Convention and under the KP. Special issues arising from the methodology used are further elaborated. Results of the QA/QC process followed are reported in Chapter 12. The report concludes with plan of future improvements to the KP-LULUCF reporting (Chapter 13).

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 topographic maps (see also De Groot *et al.* (2005) for motivation of topographic 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; Van den Wyngaert *et al.*, 2012) 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 living 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 1). 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 6). Land use changes from forests according to the definition to trees outside forests involve a loss of dead wood and litter (Chapter 6).

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 5). 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 5).

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 2013 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 for the 2013 submission.

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: Biomass Loss; DW: Dead Wood; Litt: Litter. Land use types are: FL: Forest Land; FAD: Forest According Kyoto Definition; TOF: Trees Outside Forests; CL: Cropland; GL: Grassland; WL: Wetland; Sett: Settlement; OL: Other Land.

3 Definition of land use categories

3.1 Background

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.

3.2 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. clear-cut areas to be replanted, young afforestation). 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 topographic map classes (Chapter 4) 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.

3.3 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 topographic map is leading, with land 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.

Under Cropland the class 'arable land' as well as the class 'tree nurseries' of the used topographic maps (Chapter 4) are reported. 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.

3.4 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 topographic maps, Chapter 4). 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 topographic map (Chapter 4) 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.

3.5 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 topographic 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 topographic 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.

3.6 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 land use classes included under Settlements are urban areas, 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.

3.7 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).

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.

3.8 Overview of land use allocation

The basis of allocation for IPCC land use (sub)categories are the land use/cover classifications of the national topographic maps (see Chapter 4), TOP25, TOP10Vector and TOP10NL. For most of the topographic classes, there was only one IPCC land use (sub)category where it could be unambiguously included. For other topographic 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 topographic 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 topographic class best.

The resulting classification is summarized in Table 3.1.

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

Topographic class	**Dutch 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

General
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 topographic 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 topographic maps at 1:25,000 scale and digital topographic maps at 1:10,000	Digital topographic maps at 1:10,000 and additional sources to distinguish specific nature types	Digital topographic 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

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 was available (Van den Wyngaert *et al.*, 2012). 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.

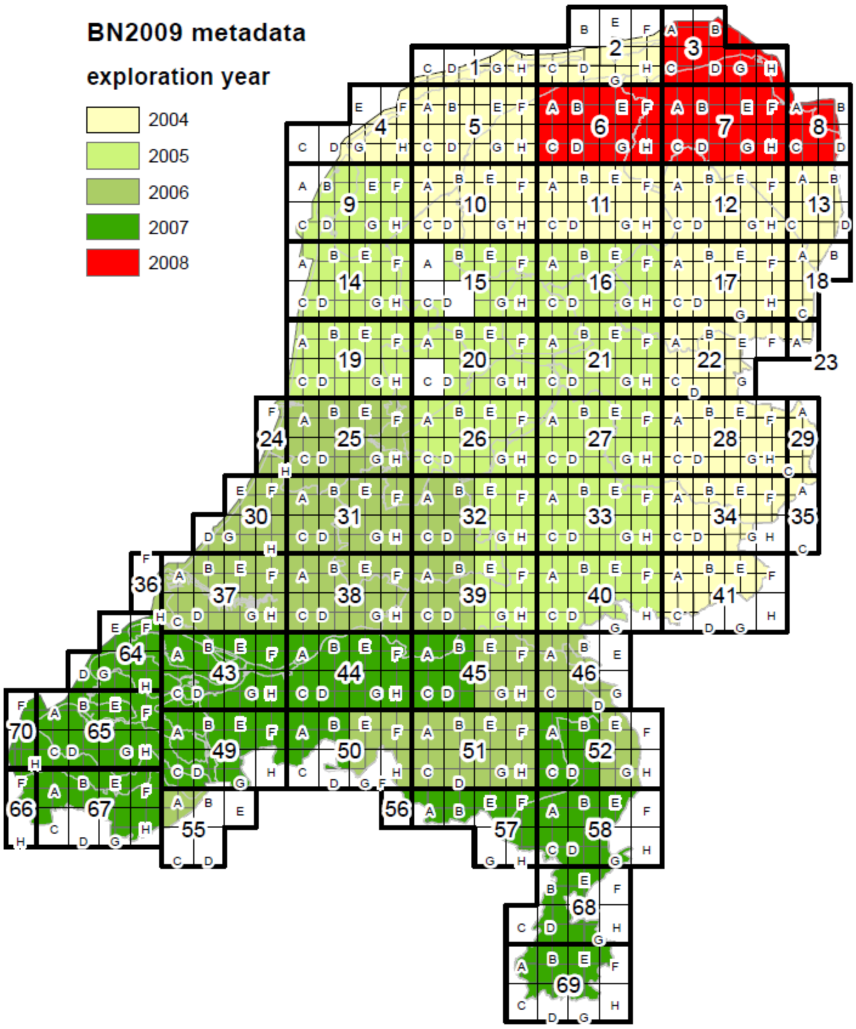


Figure 4.1 Exploration year by map sheet used for BN2009.

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 *et al.*, 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.

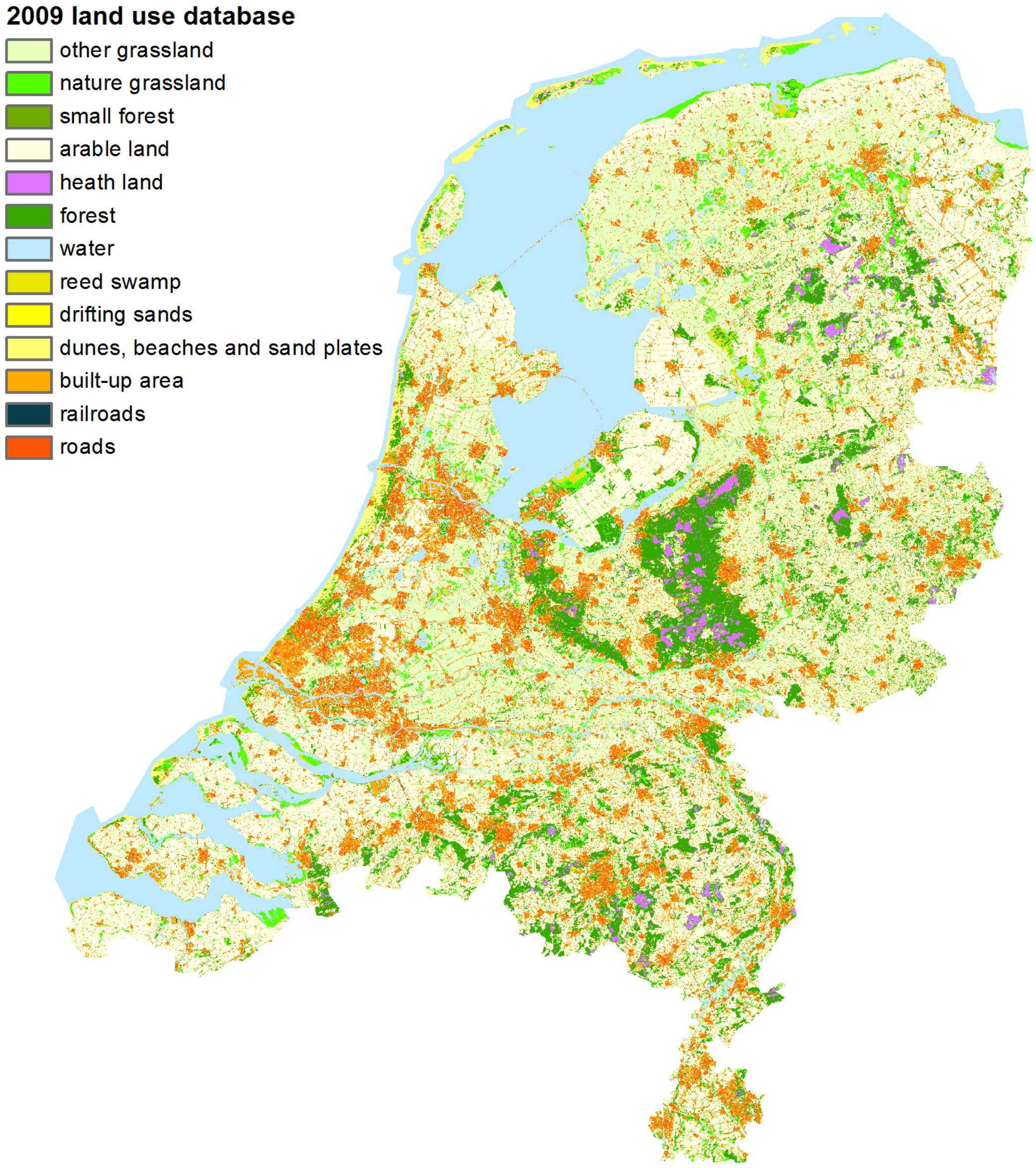


Figure 4.2. Land use map of 2009.

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 definitions of the UNFCCC land use categories are 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 was made between the new land use maps and the Dutch soil map (De Vries *et al.*, 2003) indicating the peat areas. The results are presented in Table 4.7. 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**	**Peat area 2004**	**Total area 2004**	**% total**	**% total**
	(ha)	**(ha)**	**(ha)**	**land 1990**	**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	939,617	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 topographic 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

5.1.1 General

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 sections 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.

5.1.2 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). 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 2). 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 1(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 1).

5.1.3 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 Section 5.1.2 and Annex 1). 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
MFV	2011	-92.1	35.95	1.65

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 Section 5.1.2 and Annex 1). 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.

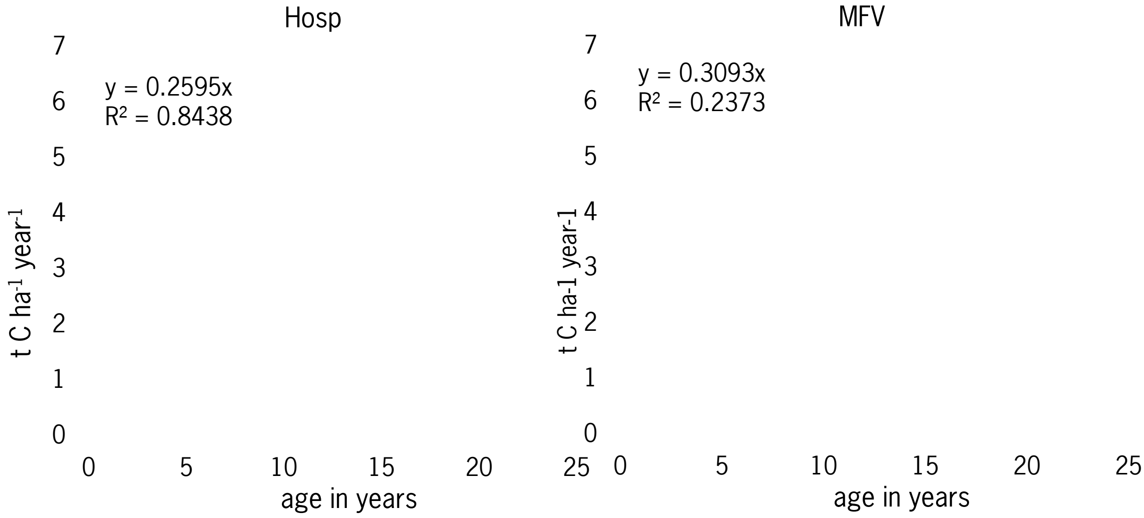


Figure 5.1. Regression between age and carbon emission (as calculated from increment data and IPCC expansion and conversion factors) for the Hosp and MFV data.

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.

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)
6. In Figure 5.2 the resulting emission factors that increase over time are compared to IPCC default values (min, max and mean).

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 5.2Table 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 ton 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 ton DM ha^{-1} (= 6.8 ton 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 1 and a more detailed description is provided in Nabuurs *et al.* (2005). The method was further updated for the 2011 submission as described in Annex 2.

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 and considered to be 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.

   This value was always available.
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 Section 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 Section 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 Section 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 Greenhouse gas emissions from forest fires

7.1 Wildfires on forest land

After previous reviewer's comments, for the NIR 2013 an effort has been made to include wild fires for the first time in our emission reporting. Recent data on occurrence and extent of wild fires is lacking. Due to decreasing occurrence of wild fires the monitoring of these fires ceased in 1996. Between 1980 and 1992 besides the number of fires, also the area of forest fires was monitored (see Wijdeven *et al.*, 2006). The average area of forest that burns annually was based on the historical data series (1980 to 1992, Table 7.1). This was 37.8 ha (or 0.1 ‰ of the total forest land in the Netherlands) and was used from 1993 onwards. For 1990-1992 the real area burned was used (Table 7.1).

Table 7.1. Annual number and total area of forest fires in the Netherlands (from Wijdeven et al., 2006)

Year	Number of forest fires	Total area burned
1980	153	153
1981	40	12
1982	103	40
1983	77	20
1984	102	65
1985	41	14
1986	65	15
1987	58	27
1988	52	26
1989	67	22
1990	48	**40**
1991	51	**33**
1992	42	**24**
Average 1980-1992	69	**37.8** ± 10.3 (s.e.)

In the Netherlands no country specific information on intensity of forest fires and emissions of Greenhouse gases is available. Therefore from the submission of the 2013 NIR onwards emissions of CO_2, CH_4 en N_2O from forest fires are reported using the Tier 1 method as described in the GPG 2003.

GPG 2003 equation 3.2.20 was used to calculate total carbon released from forest fires (Table 7.2) based on the average annual carbon stock in living biomass, litter and dead wood. These values change yearly depending on forest growth and harvesting. (Table 5.1; the emission factors for deforestation). The default combustion efficiency (fraction of the biomass combusted) for "all other temperate forests" is used (0.45, GPG 2003 Table 3A.1.12).

For calculation of non-CO_2 emissions (GPG 2003 equation 3.2.19) default emission ratios were used (0.012 for CH_4 and 0.007 for N_2O, GPG 2003 Table 3A.1.15).

Table 7.2. Total annual C released in forest fires, and associated annual CO_2, CH_4 and N_2O emissions from forest fires in the Netherlands. GHG emissions in Gg gas and Gg CO_2 equivalents.

Year	Total C released	CO_2 (Gg)	CH_4 (Gg)	CH_4 (Gg CO_2 eq)	N_2O (Gg)	N_2O (Gg CO_2 eq.)	Total (Gg CO_2 eq.)
1990	1617	5.50	0.026	0.54	0.00018	0.055	6.10
1991	1357	4.64	0.022	0.46	0.00015	0.046	5.14
1992	1011	3.23	0.016	0.34	0.00011	0.034	3.61
1993	1622	5.23	0.026	0.55	0.00018	0.055	5.83
1994	1659	6.08	0.027	0.56	0.00018	0.057	6.70
1995	1694	6.21	0.027	0.57	0.00019	0.058	6.84
1996	1729	6.34	0.028	0.58	0.00019	0.059	6.98
1997	1765	6.47	0.028	0.59	0.00019	0.060	7.13
1998	1800	6.60	0.029	0.60	0.00020	0.061	7.27
1999	1834	6.73	0.029	0.62	0.00020	0.063	7.40
2000	1826	6.69	0.029	0.61	0.00020	0.062	7.37
2001	1867	6.85	0.030	0.63	0.00021	0.064	7.54
2002	1911	7.01	0.031	0.64	0.00021	0.065	7.71
2003	1956	7.17	0.031	0.66	0.00022	0.067	7.90
2004	1987	7.28	0.032	0.67	0.00022	0.068	8.02
2005	2019	7.40	0.032	0.68	0.00022	0.069	8.15
2006	2049	7.51	0.033	0.69	0.00023	0.070	8.27
2007	2080	7.63	0.033	0.70	0.00023	0.071	8.40
2008	2113	7.75	0.034	0.71	0.00023	0.072	8.53
2009	2142	7.85	0.034	0.72	0.00024	0.073	8.65
2010	2175	7.97	0.035	0.73	0.00024	0.074	8.78
2011	2204	8.08	0.035	0.74	0.00024	0.075	8.90

Currently there are discussions in the Netherlands to resume monitoring of forest fires but it is not certain yet if and when this will happen. As soon as new information on area and extent of forest fires becomes available this will be used to update the current estimates.

7.2 Controlled biomass burning

Controlled biomass burning does not occur in the Netherlands, and therefore is reported as not occurring (NO).

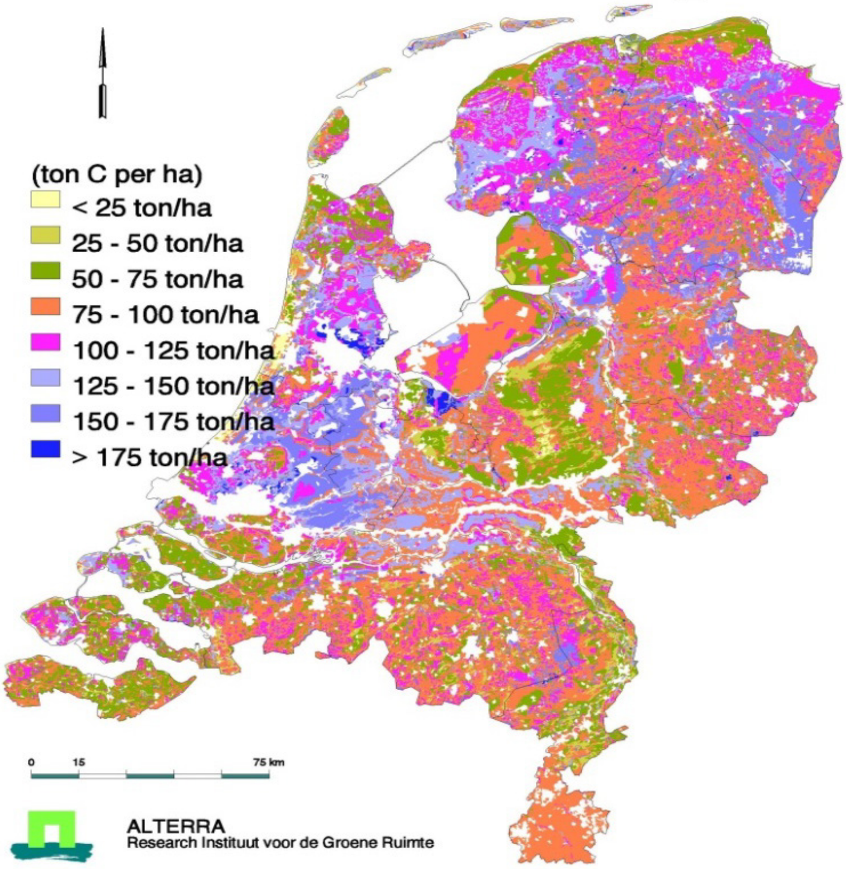
8 Carbon emissions from soils

8.1 Carbon stock changes in mineral soils in the Netherlands

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 8.1. 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 8.2). 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.

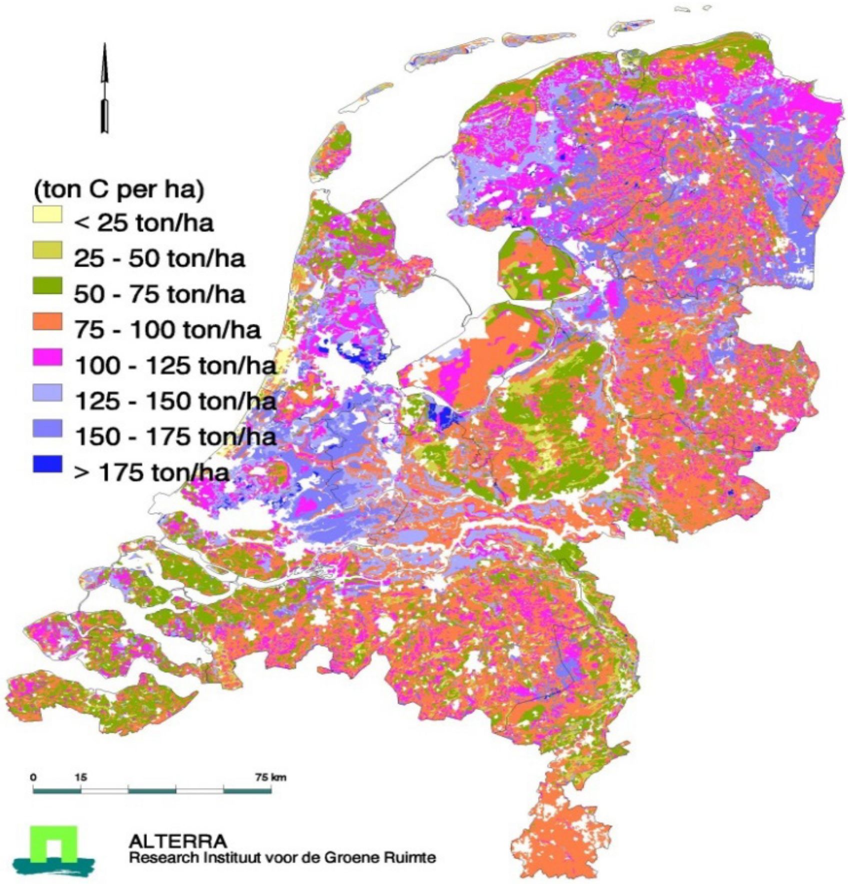


Figure 8.1. Soil carbon stocks (0-30 cm) for the Netherlands

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 8.3). 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.

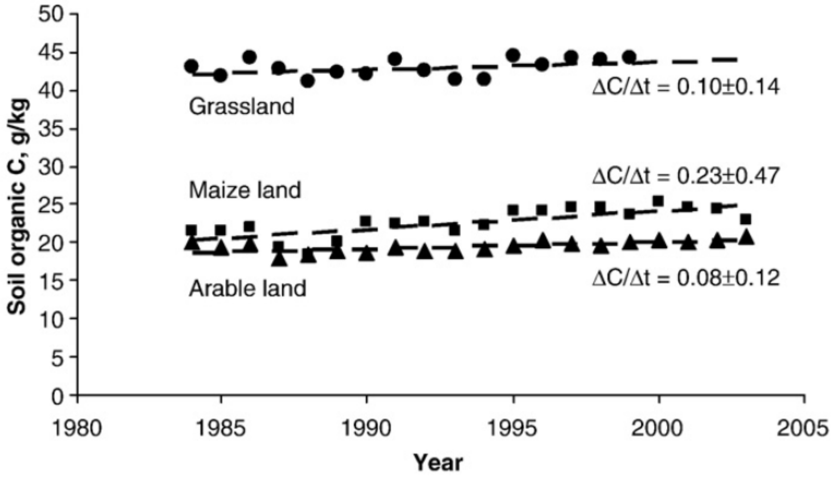


Figure 8.2. Changes in mean soil organic carbon contents of grassland (period 1984 - 2000), maize land (1984 - 2004) and arable land (1984 - 2004) in the Netherlands. The mean annual change in SOC is indicated as ΔC/Δt, in g kg^{1} year^{1} (Source: Reijneveld et al., 2009)

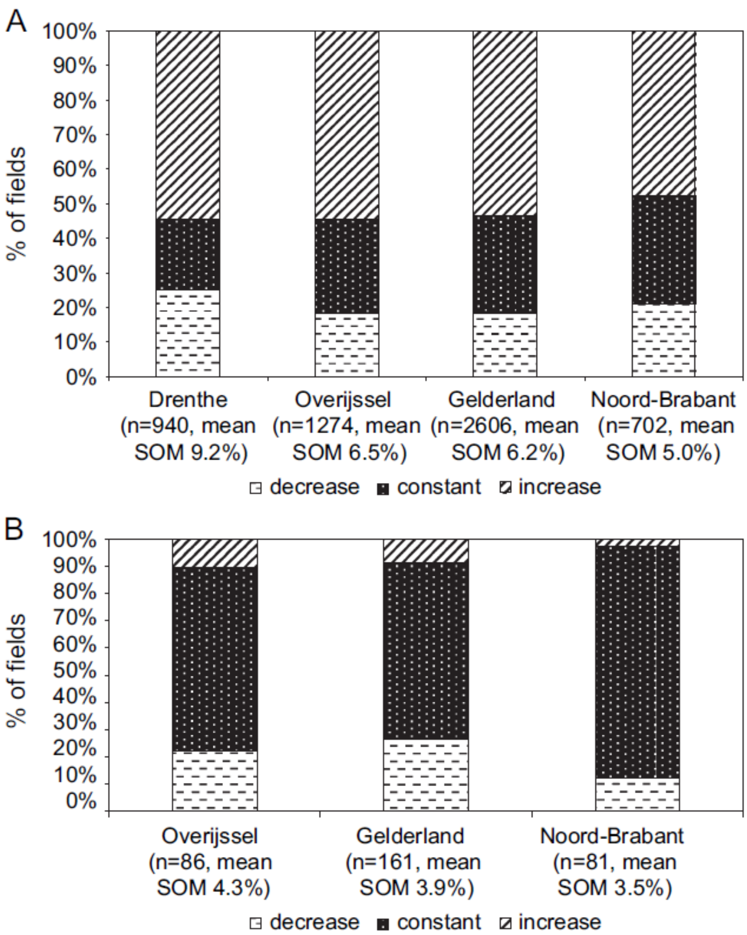


Figure 8.3. Absolute changes in SOM content (%) in sandy soils in four provinces in the Netherlands over 20 years (increase, + 1% or more; decrease, - 1% or more). (A) grassland; (B) continuous maize (no results for Drenthe due to lack of data) (Source: Hanegraaf et al., 2009)

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} $year^{-1}$ 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} $year^{-1}$ 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.

8.2 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:

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

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

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})
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 8.1 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 8.1. 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	16,149	8	17,250	13	531	33,929	119,100
	Mesotrophic	3	12,780	8	22,294	13	2863	37,935	156,403
	Oligotrophic	3	9,421	8	10,480	13	416	20,315	72,380
Peat	Eutrophic	6	16,668	12	16,846	18	206	33,719	188,415
	Mesotrophic	6	18,668	12	31,607	18	7169	57,443	382,118
	Oligotrophic	6	8,688	12	10,054	18	1168	19,911	119,381
Humus-rich sand	Mesotrophic	3	148	8	3,184	13	4771	8,102	54,167
	Oligotrophic	3	27	8	760	13	2256	3,041	21,856
Sand	Mesotrophic	3	1,365	8	3,370	13	1318	6,051	29,681
	Oligotrophic	3	415	8	1,450	13	836	2,700	14,604
Total			84,325		117,291		21531	223,147	1,158,105

9 Submission 2013: values and comparison with previous submissions

9.1 Calculated values for the 2013 submission to the UNFCCC

Table 9.1 shows the integral set of values reported for main land use categories in the NIR 2013, including activity data, for 1990 (baseline year) and 2011 (t-2 year). Changes relative to the submission 2012 are identified and discussed in Section 9.2 for all categories A-F.

Table 9.1. Sector report for land use, land use change and forestry of Net CO_2 emissions or removals in 1990 and 2011 as submitted in the NIR2013. NE: not estimated. NA: not applicable. IE: included elsewhere.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Activity data (1000 ha)		Net CO_2 emissions/ removals (Gg C)	
Reporting year	**1990**	**2011**	**1990**	**2011**
Total Land Use Categories	**4,151.50**	**4,151.50**	**2,999.95**	**3,265.12**
A. Forest Land	**383.57**	**397.57**	**-2,355.94**	**-2,433.87**
1. Forest Land remaining Forest Land	380.61	341.62	-2,412.33	-1,892.75
2. Land converted to Forest Land	2.96	55.95	56.39	-541.12
B. Cropland	**1,013.66**	**916.01**	**122.34**	**164.70**
1. Cropland remaining Cropland	999.34	893.69	IE,NA,NE	IE,NA,NE,NO
2. Land converted to Cropland	14.32	22.32	122.34	164.70
C. Grassland	**1,500.57**	**1,381.54**	**4,491.32**	**4,482.37**
1. Grassland remaining Grassland	1,485.04	1,351.91	4,246.00	4,246.00
2. Land converted to Grassland	15.52	1,302.56	245.32	236.37
D. Wetlands	**793.59**	**814.75**	**80.46**	**134.85**
1. Wetlands remaining Wetlands	791.36	811.32	NE	NE
2. Land converted to Wetlands	2.23	3.43	80.46	134.85
E. Settlements	**420.66**	**602.80**	**458.61**	**816.60**
1. Settlements remaining Settlements	408.27	590.86	NE	NE
2. Land converted to Settlements	12.39	11.94	458.61	816.60
F. Other Land	**39.45**	**38.83**	**20.00**	**27.13**
1. Other Land remaining Other Land	39.10	38.37		
2. Land converted to Other Land	0.35	0.46	20.00	27.13
G. Other			**183.15**	**73.32**
Harvested Wood Products			NE	NE
Lime application in all land use categories			183.15	73.32
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

9.2 Comparison with submission 2012

Differences in net CO_2 emissions and removals between the NIR 2012 and NIR 2013 can be observed in forest land remaining forest land, in land converted to grassland (**Fout! Ongeldige bladwijzerverwijzing.**) and in emissions form lime application. These differences were the results of the following re-calculations (see next page).

Table 9.2. Net CO_2 emissions and removals in the main land use categories for the years 1990 and 2010 as submitted in the NIR 2012 and in the NIR 2013. Values are rounded to two decimals. Cells of subcategories subject to changing values are shaded in light red.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		Net CO_2 emissions/removals in 1990 (Gg C)		Net CO_2 emissions/removals in 2010 (Gg C)	
	Submission year	NIR 2012	NIR 2013	NIR 2012	NIR 2013
Total Land Use Categories		**2,999.95**	**2,999.07**	**3,001.37**	**2,991.77**
A. Forest Land		**-2,355.94**	**-2,350.44**	**-2,693.31**	**-2,685.33**
1. Forest Land remaining Forest Land		-2,412.33	-2,406.83	-2,146.22	-2,138.25
2. Land converted to Forest Land		56.39	56.39	-547.09	-547.09
B. Cropland		**122.34**	**122.34**	**164.06**	**164.06**
1. Cropland remaining Cropland		IE,NA,NE	IE,NA,NE,NO	IE,NA,NE	IE,NA,NE,NO
2. Land converted to Cropland		122.34	122.34	164.06	164.06
C. Grassland		**4,491.32**	**4,484.94**	**4,505.11**	**4,473.92**
1. Grassland remaining Grassland		4,246.00	4,246.00	4,246.00	4,246.00
2. Land converted to Grassland		245.32	238.94	259.11	227.92
D. Wetlands		**80.46**	**80.46**	**131.18**	**131.18**
1. Wetlands remaining Wetlands		NE	NE	NE	NE
2. Land converted to Wetlands		80.46	80.46	131.18	131.18
E. Settlements		**458.61**	**458.61**	**807.80**	**807.80**
1. Settlements remaining Settlements		NE	NE	NE	NE
2. Land converted to Settlements		458.61	458.61	807.80	807.80
F. Other Land		**20.00**	**20.00**	**26.82**	**26.82**
1. Other Land remaining Other Land					
2. Land converted to Other Land		20.00	20.00	26.82	26.82
G. Other		**183.15**	**183.15**	**59.72**	**73.32**
Harvested Wood Products		NE	NE	NE	NE
Lime application in all land use categories		183.15	183.15	59.72	73.32
Information items					
Forest Land converted to other Land Use Categories		665.72	665.72	1,242.27	1,242.27
Grassland converted to other Land Use Categories		305.48	305.48	104.41	104.41

1. To increase completeness, CO_2, CH_4 and N_2O emissions from wildfires in forests (forest fires) were included this year for the first time. This resulted in a decreased sink of CO_2 and increased emissions of CH_4 and N_2O in Forest land. The inclusion of forest fires in the NIR 2013 fully accounts for the differences observed in Forest land remaining forest land Emissions from these fires in the NIR 2013 were estimated at 5.50 Gg C for 1990 and 7.79 Gg C (see CRF tables 5(V)). In the NIR 2012 the CO_2 emissions from forest fires were not yet estimated.
2. During a QA/QC check an error was found in the 2012 submission in the EF applied to carbon stock change (gain) in living biomass for conversion from settlements to grassland and from other land to grassland. Instead of applying the default EF for grasslands (i.e. 6.8 Mg C ha^{-1}), the EF for cropland was applied (5 Mg C ha^{-1}) (see Table 5.2). This correction resulted in minor recalculations for all inventory years. It involved 0.96 kha grassland in 1990 and 4.72 kha grassland in 2010 and fully accounts for the observed differences in net CO_2 emissions.
3. Fertiliser data to assess emissions from the liming of agricultural soils in Other, which covers lime application in all land use categories, were not yet available for 2010 at the time the previous NIR (2012) was prepared. Therefore 2010 emissions were set equal to 2009 emissions in the 2012 submission. Fertiliser data have since become available and have been used to re-calculate the 2010 emissions for the 2013 submission..

10 Kyoto tables –detailed information

This chapter describes in detail the methods behind the filling of the KP LULUCF tables. The main aim is to provide background information on the values and notation keys that were used in the CRF tables.

The structure of this chapter follows the structure of the CRF tables and discusses the information submitted table by table: first the three tables with overview information on the submission (Section 10.1), then the tables that contain the changes in carbon stock due to article 3.3 activities (Section 10.2), a short note on information to be reported under article 3.4 (Section 10.3) and finally the tables with information on other greenhouse gas emissions to be reported under article 3.3 (Section 10.4).

10.1 NIR-tables

The KP LULUCF tables NIR1 to NIR3 summarize the status of the submission by giving information on completeness and forest definition (NIR-1), the land use (changes) matrix (NIR-2) and to what extent the KP-LULUCF tables contain emission sources that are to be considered as key sources (NIR-3). These three NIR tables are also included in the NIR II.

10.1.1 NIR-1 – completeness of reporting

Changes in carbon pools for re/afforested areas are reported for biomass (gains and losses) and soil (mineral as well as organic). Carbon stock changes in litter and dead wood in re/afforested areas are an unknown sink and as such are not reported. In deforested areas carbon stock change is reported for all pools (Table 10.1).

Table 10.1. Completeness of reporting (R – reported, NR – not reported) for the changes in carbon pools. How they are reported is discussed with in the respective sections.

Activity	Change in carbon pool reported				
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil
Re/Afforestation	R	R	NR	NR	R
Deforestation	R	R	R	R	R

Fertilization in re/afforested areas does not occur in The Netherlands and is reported NO. Nitrous oxide emissions associated with disturbance of soils when deforested areas are converted to cropland are estimated from carbon stock changes in mineral soils converted to croplands (Table 10.2).

Liming of forest in the Netherlands might occur occasionally but no statistics are available. All liming based on quantities of product sold is attributed to agricultural land (Cropland, Grassland) which is the main sector where liming occurs. Liming is thus reported only for deforested land that is converted to any of these categories (Table 10.2).

Greenhouse gas emissions (CO_2, CH_4 and N_2O) due to controlled biomass burning in areas that are afforested or reforested (AR) does not occur as no slash burning etc is allowed. However, greenhouse gas emissions (CO_2, CH_4 and N_2O) from wildfires in forests (on AR land), i.e. forest fires, are from this 2013 submission onwards estimated using the Tier 1 method in combination with average annual carbon stock in living biomass, litter and dead wood in FAD. Because no recent statistics on occurrence of wildfires are available an average annual area burned was estimated based on a historic series (1980-1992, Wijdeven *et al.*, 2006). Estimates are reported in Table 5 (KP-II)5.

Table 10.2. Completeness of reporting for other greenhouse gases. How they are reported is discussed with in the respective sections.

Activity	**Greenhouse gas sources reported**					
	Fertilization	Disturbance associated with land use conversion to croplands	Liming	Biomass burning		
	N_2O	N_2O	CO_2	CO_2	CH_4	N_2O
Afforestation and Reforestation	NO		NO	R	R	R
Deforestation		R	R	NE	NE	NE

10.1.2 NIR-2 – land use and land use change matrix

The land use changes in The Netherlands are based on a map overlay between land use maps with map dates 1st January 1990, 1st January 2004 and 1st January 2009. Land use change rates between 1990 and 2003 are derived from maps dated 1st January 1990 and 1st January 2004, between 2004 and 2008 they are derived from the maps dated maps dated 1st January 2004 and 1st January 2009. Actual surveys for some map sheets may have been carried out in earlier or later years (Kramer *et al.*, 2009). The land use matrix on the basis of these maps shows changes for 13 land use categories that can be aggregated to the 6 IPCC categories for LULUCF (IPCC, 2003): Forest Land, Cropland, Grassland, Wetland, Settlement and Other Land (see Kramer *et al.*, 2009 and Van den Wyngaert *et al.*, 2012 for the explanation on the 13 categories and how they are aggregated). As the Kyoto definition of forest does not match exactly with the definition of Forest Land used for Convention reporting, aggregation for reporting under the Kyoto protocol results in 7 land use categories: Kyoto forests (reported in Forest Land), Trees outside Forest (reported in Forest Land), Cropland, Grassland, Wetland, Settlement and Other Land. Forests according to the Kyoto definition (FL-FAD) and Trees outside forest (FL-TOF) together sum up to the Convention land use category Forest Land (see also par 3.1). The land use matrix between 1990 and 2004 and between 2004 and 2009 is shown in Table 10.3, and the land use change matrix (showing annual rates of change between land use categories) is presented in Table 10.4. For background information on calculation of the land use (change) matrix and a discussion on the results in a broader framework the reader is referred to Kramer *et al.* (2009). In Van den Wyngaert *et al.* (2012) it is explained how the distribution of land use classes over organic and mineral soils is calculated.

Not all land use changes are considered under the Kyoto Protocol. The coloured cells in Table 10.3 and Table 10.4 indicate land use conversions that need to be reported under article 3.3, with green cells indicating afforestation and orange cells indicating deforestation. For the land use (change) matrix 2004-2009 the green cells also include the area that was deforested between 1990 and 2004 and is reforested again between 2004 and 2009, and which is therefore NOT reported under AR land. This explains the difference between the AR value in Table 10.4 (3201 $ha.year^{-1}$) and in Table 10.5 (2527 $ha.year^{-1}$ or 2.53 $kha.year^{-1}$). The assumption is that all land use changes to and from Kyoto forests are human induced.

Table 10.3. Land use and land use change matrix showing changes between 1990 and 2004 in ha. Orange cells are areas reported under KP article 3.3 deforestation, green cells are areas reported under KP article 3.3 re/afforestation (FAD = Forests according to the Kyoto Definition; TOF = Trees outside Forest; FL = Forest land; CL = Cropland; GL = Grassland; WL = Wetland; Sett = Settlements; OL = Other land)

				BN 1990				
BN 2004	FL-FAD	FL-TOF	CL	GL	WL	Sett	OL	Total
FL-FAD	334211	2352	12520	18066	888	1452	552	370041
FL-TOF	2852	11336	2039	4475	328	1078	98	22207
CL	1218	386	739190	196595	596	1623	8	938399
GL	14586	3316	176797	1190740	9092	10987	2547	1393479
WL	1503	319	6821	18641	776007	1390	2583	805762
Sett	7031	2988	81783	78259	2836	392805	630	559301
OL	699	110	201	907	2791	122	33144	37275
Total	362100	20806	1019353	1507682	792539	409457	39563	4151500

				BN 2004				
BN 2009	FL-FAD	FL-TOF	CL	GL	WL	Sett	OL	Total
FL-FAD	357474	1701	2007	7119	374	4597	209	373480
FL-TOF	1516	16893	297	1708	92	1558	29	22092
CL	350	137	813282	106547	177	4367	2	924863
GL	5219	1198	108480	1243329	9633	23123	506	1391488
WL	703	126	1794	10610	794785	3033	890	811941
Sett	4572	2122	13729	37705	1441	529417	137	589123
OL	208	30	27	1047	762	237	36200	38512
Total	370041	22207	939617	1408064	807265	566332	37974	4151500

Table 10.4 Land use change matrix (in ha per year). Orange cells are annual deforestation rates reported under KP article 3.3 deforestation, green cells are annual re/afforestation rates reported under KP article 3.3 re/afforestation (1990-2004) or reported partly under re/afforestation and partly remaining under deforestation (2004-2009). Abbreviations as in Table 10.3.

				BN 1990				
BN 2004	FL-FAD	FL-TOF	CL	GL	WL	Sett	OL	Total
FL-FAD		168	894	1290	63	104	39	2559
FL-TOF	204		146	320	23	77	7	777
CL	87	28		14042	43	116	1	14316
GL	1042	237	12628		649	785	182	15523
WL	107	23	487	1332		99	184	2233
Sett	502	213	5842	5590	203		45	12395
OL	50	8	14	65	199	9		345
Total	1992	676	20012	22639	1181	1189	459	48148

				BN 2004				
BN 2009	FL-FAD	FL-TOF	CL	GL	WL	Sett	OL	Total
FL-FAD		340	401	1424	75	919	42	3201
FL-TOF	303		59	342	18	312	6	1040
CL	70	27		21309	35	873	0	22316
GL	1044	240	21696		1927	4625	101	29632
WL	141	25	359	2122		607	178	3431
Sett	914	424	2746	7541	288		27	11941
OL	42	6	5	209	152	47		462
Total	2513	1063	25267	32947	2496	7383	355	72024

The information in Table NIR-2 table does not distinguish between land use categories and only considers annual rates of re/afforestation and deforestation. As such, the only values of importance for NIR-2 are total annual deforestation (lower row, orange cell, in Table 10.4, i.e. 1992 ha year^{-1} between 1990 and 2004 and 2513 ha year^{-1} between 2004 and 2009) and total annual re/afforestation. The latter is more difficult to extract from the land use matrices, as reforestation of deforested land is not reported under re/afforestation. Thus, between 1990 and 2004 a constant annual re/afforestation of 2559 ha year^{-1} is reported (last column, green cell, in Table 10.4), while for the period 2004-2009 a constant value of 2527 ha year^{-1} is reported. This is the net result of ha 3201 year^{-1} (last column, green cell, in Table 10.4) minus 674 ha year^{-1} (this is the area of re/afforestation that is reported under deforestation and cannot be derived directly from the individual land use change matrices). Between 1990 and 2009, these values should be considered as final, while values for 2009 and 2010 are based on extrapolation and will be updated as the 2012 land use map becomes available. The technical aspects of filling NIR 2 are summarized in Annex 43.

Table 10.5. Results of the calculations of the area change (in kha) of re/afforestation (AR) and deforestation (D) in the period 1990-2012.

Year	AR land remaining AR land	land converted to AR land	AR land converted to D land	D land remaining D land	land converted to D land	Other (not in KP article 3.3)	Land in KP article 3.3 ARD
1990	0.00	2.56	0.00	0.00	1.99	4,146.95	4.55
1991	2.56	2.56	0.00	1.99	1.99	4,142.40	9.10
1992	5.12	2.56	0.00	3.98	1.99	4,137.85	13.65
1993	7.68	2.56	0.00	5.98	1.99	4,133.29	18.21
1994	10.24	2.56	0.00	7.97	1.99	4,128.74	22.76
1995	12.80	2.56	0.00	9.96	1.99	4,124.19	27.31
1996	15.36	2.56	0.00	11.95	1.99	4,119.64	31.86
1997	17.92	2.56	0.00	13.94	1.99	4,115.09	36.41
1998	20.47	2.56	0.00	15.94	1.99	4,110.54	40.96
1999	23.03	2.56	0.00	17.93	1.99	4,105.99	45.51
2000	25.59	2.56	0.00	19.92	1.99	4,101.43	50.07
2001	28.15	2.56	0.00	21.91	1.99	4,096.88	54.62
2002	30.71	2.56	0.00	23.91	1.99	4,092.33	59.17
2003	33.27	2.56	0.00	25.90	1.99	4,087.78	63.72
2004	34.96	2.53	0.88	27.89	1.64	4,083.61	67.89
2005	36.61	2.53	0.88	30.40	1.64	4,079.45	72.05
2006	38.26	2.53	0.88	32.92	1.64	4,075.28	76.22
2007	39.91	2.53	0.88	35.43	1.64	4,071.12	80.38
2008	41.57	2.53	0.88	37.94	1.64	4,066.95	84.55
2009	43.22	2.53	0.88	40.46	1.64	4,062.79	88.71
2010	44.87	2.53	0.88	42.97	1.64	4,058.62	92.88
2011	46.52	2.53	0.88	45.48	1.64	4,054.45	97.05

10.1.3 NIR-3 – key source analysis

Key category analysis is performed by comparing matching categories between KP reporting and Convention reporting (IPCC, 2003 Section 4.2.1) as well as by comparing KP reporting categories with the smallest Convention key categories for level (both including and excluding LULUCF). In 2011 2, LULUCF categories were key category.

10.2 KP(5-I) tables

The data tables for Carbon Stock Changes under article 3.3: KP(5-I)A are filled according to the same structure:
- Aboveground biomass
- Belowground biomass
- Litter
- Dead Wood
- Organic soil
- Mineral soil

This structure is followed for each of the categories A.1.1 (units of land not harvested since the beginning of the commitment period) and A.2 (Units of land deforested). Category A.1.2 currently does not occur in The Netherlands, and is not expected to occur within the commitment period.
In The Netherlands, Kyoto forest does not include all land with woody cover. Therefore a distinction is made between land use conversions that imply a discontinuity in land cover of the land units under consideration (conversions to and from cropland, grassland, wetland, settlement and other land) and conversions that change land use but not land cover (conversion to and from trees outside forest).

10.2.1 KP(5-I)A.1.1 Units of land not harvested since the beginning of the commitment period

Aboveground and belowground biomass

Re/afforestation from land use without woody cover
For cropland, grassland, wetland, settlement and other land, conversion to Kyoto forest involves creating a growing carbon stock in living biomass. This carbon sink in biomass in re/afforested areas is calculated using the same assumptions and emission factors as for land converted to Forest according to the Kyoto definition under the Convention (see Chapter 5), with assumptions and their justification for KP presented in Annex 4. It is valid for forests up to 20 years old, consistent with Convention reporting. The calculated carbon sink in biomass is distinguished into above- and below ground biomass based on the mean ratio in the plots (each plot based on the respective IPCC default). This resulted in 69% of the carbon sink in the aboveground biomass and 31% in the below ground biomass. This ratio was applied consistently over all AR-forests.

For forests older than 20 years of age, the methodology for Forests according to the Kyoto definition remaining Forests according to the Kyoto definition under the Convention (Chapter 5) was used.

Biomass loss from harvesting was assumed to be negligible, as harvesting is not a regular practice in young forests. Data to relate harvesting to forest age are currently lacking, and will not become available during this first commitment period.

Biomass loss from biomass removal in croplands and grasslands converted to forests was calculated in the same way as under the convention (see Section 5.4) and is based on Tier 1 defaults for biomass stocks (see Table 5.2) and R values (Table 5.3). The values were taken from tables with T1 values for biomass after conversion, but are assumed to be valid before as well after conversion (consistent with our assumption that there is no net change in biomass in croplands remaining croplands and grasslands remaining grasslands).

Re/afforestation from land use with woody cover
Small units of lands with woody cover that do not meet the Kyoto forest definition may start to meet this definition when adjacent land is re/afforested. This does not involve a discontinuity in land cover for the units of land with woody cover, though the connection to a larger unit does involve a change

in land use. The annual per ha carbon stock change of such units of article 3.3 AR land is calculated as the mean aboveground and belowground carbon sink due to volume increment calculated from inventory data using a simple bookkeeping model (Chapter 5). This method corresponds to the method used for Forest Land remaining Forest Land (Chapter 5).

Litter and dead wood

The national forest inventory provides an estimate for the average amount of litter (in plots on sandy soils only) and the amount of dead wood (all plots). The data do provide the age of the trees and assume that the plots are no older than the trees. As such the age of the plot does not take into account any litter accumulation from previous forests on the same location and does not necessarily represent time since re/afforestation. This is reflected in a very weak relation between tree age and carbon in litter (Figure 10.110.2), and a large variation in dead wood even for plots with young trees (Figure 10.1).

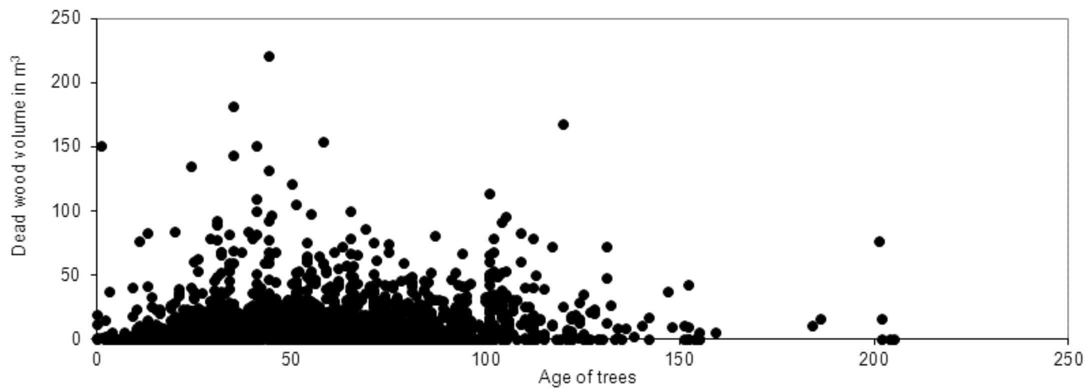


Figure 10.1: Volume of dead wood (standing and lying) in Dutch NFI plots in relation to tree age.

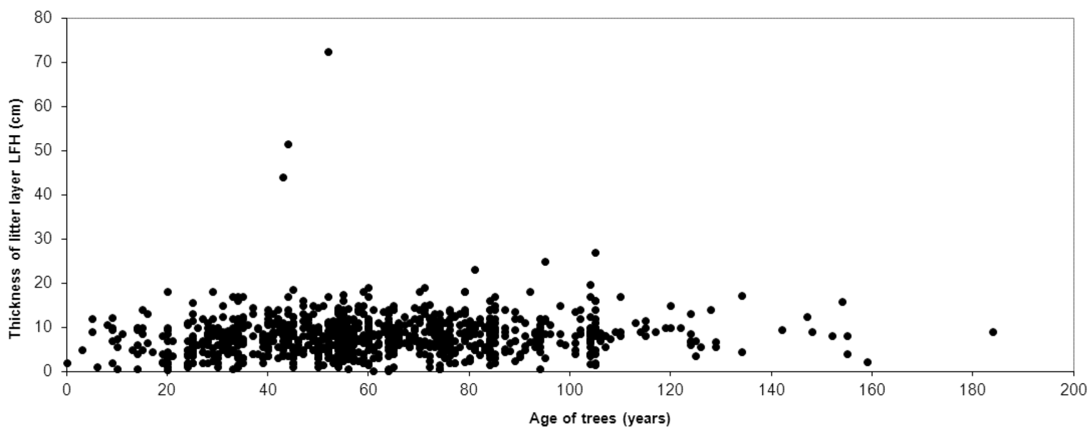


Figure 10.2: Thickness of litter layer (LFH) in Dutch NFI plots in relation to tree age. LFH measurements were conducted only in plots on sandy soils.

Apart from forests, no land use has a similar carbon stock in litter (in Dutch grasslands, management prevents the build-up of a significant litter layer). Thus, the conversion of non-forest to forest always involves a build-up of carbon in litter. However, as good data are lacking to quantify this sink, we conservatively report the accumulation of carbon in litter for re/afforestation conservatively as zero. Similarly, no other land use has carbon in dead wood. Thus, the conversion of non-forest to forest involves a build-up of carbon in dead wood. However, as it is unlikely that much dead wood will accumulate in very young forests (regenerating in 1990 or later), accumulation of carbon in dead wood in re/afforested plots is most likely a very tiny sink that is too uncertain to quantify reliably. Thus we report this carbon sink conservatively as zero.

Mineral soils

Under the Convention, The Netherlands reports that as a whole, including all land uses and land use changes but leaving out the cultivation of organic soils for agricultural use, the soil of The Netherlands is most probably a sink of a highly uncertain magnitude. As such, no soil emissions are reported for mineral soils. The loss of C from cultivation of organic soils is reported separately under grassland (see Chapter 8). For KP land, CSC in mineral soils need to be reported per pool/activity and cannot be reported at an aggregated level. A methodology was developed to calculate the effect of land use on carbon stock in mineral soils based on data from the LSK survey (De Groot *et al.*, 2005) and IPCC GPG methodology. This is described in Annex 5.

This method starts from a soil in equilibrium at the moment of land use change, and this assumption is maintained for soils under re/afforestation (which change once - to forest- when entering AR land and once –away from forest- when leaving AR land to D land). However, for deforestation land use may change further once units of land are under KP reporting. In those cases, the time since the previous land use change is taken into account in the soil C calculations:

(1) the estimated carbon stock at time of land use change was calculated based on

$$C_{\Delta yi_t} = C_{xi} + t \cdot \frac{C_{yi} - C_{xi}}{T}$$

With:

$C_{\Delta yi_t}$	Carbon stock of land converted from land use *x* to land use *y* on soil type *i* at time *t* years after conversion (Gg C ha^{-1})
C_{yi}, C_{xi}	Carbon stocks of land use *x* respectively y on soil type I (Gg C.ha^{-1})
t	years since land use change to land use *y*

(2) this carbon stock was filled in the first formula to calculate the mineral soil emissions involved in another land use change:

$$E_{\min\_xy} = \sum_{1}^{i}\left(\frac{C_{yi} - C_{xi}}{T} \cdot A_{\min\_xyi}\right)$$

With symbols as above and:

$E_{\min\_xy}$	Annual emission for land converted from land use *x* to land use y on soil type *I* (Gg C year^{-1})
$A_{\min\_xy}$	Area of land converted from land use *x* to land use *y* on soil type *I* in years more recent than the length of the transition period (= less than 20 years ago) (ha)

Organic soils
About 8% of re/afforested land units and 5% of deforested land units is on organic soils. The majority of this is involved in a conversion between Kyoto forest and agricultural land (cropland or grassland). The emissions as calculated for cultivation of organic soils are based on an overlay with a map with water level regimes and assumptions typically valid for agricultural peat soils in The Netherlands. How these can be translated to the effects of conversion to other land use types is described in Annex 5. This was based on the 1990 and 2004 land use maps, and the emission factors for AR and D land were extrapolated for land under KP from 2004 on.

10.2.2 KP(5-I)A.1.2 Units of land harvested since the beginning of the commitment period

None of the afforested or reforested land as of 1990 was harvested within the commitment period. This category of harvested forest will not be reported here.

10.2.3 KP(5-I)A.1.3 Units of land otherwise subject to elected activities under Article 3.4

The Netherlands has not elected any activities under Article 3, paragraph 4, of the Kyoto protocol.

10.2.4 KP(5-I)A.2 Deforestation

In The Netherlands, the definition of forest that was chosen for the Kyoto Protocol does not include all land with woody cover. Therefore a distinction is made between land use conversions that imply a discontinuity in woody cover (conversions to and from cropland, grassland, wetland, settlement and other land) and conversions that imply a discontinuity in land use but not in land cover (conversion to and from trees outside forest). See also Section 11.1.

Aboveground and belowground biomass

Deforestation to a land use category without woody cover
A unit of land that is converted to a land use category without woody cover loses all carbon stock in the same year of deforestation. The emission factor for deforested areas changing to cropland, grassland, wetland, settlement or other land is the outcome of the following steps/assumptions:

- In the year of deforestation, all carbon in standing above- and belowground biomass is lost instantaneously. This standing carbon stock is equal to the average amount of carbon stored in aboveground biomass in Dutch forests in that particular year. The latter is derived from a simple bookkeeping model that extrapolates NFI measurements (Nabuurs *et al.*, 2005; Van den Wyngaert *et al.*, 2012). The emission factor increases over time, reflecting the built-up of C stocks in standing biomass with continuation of current management practices.
- In the years following deforestation, no additional carbon losses are calculated. Carbon gains are calculated for land uses that have a GPG 2003 Tier 1 default value, i.e. Cropland and Grassland, according to Table 5.2 and Table 5.3, Section 5.4).
- As a result of reporting of the accumulated area of deforested area, whereas emissions occur only in the year of deforestation itself, the IEF for biomass from deforestation decreases over time.

Deforestation to a land use category with woody cover
Small units of lands with woody cover that do not meet the Kyoto forest definition may remain after deforestation of adjacent land. This does not involve a discontinuity in land cover for the units of land with woody cover, though the loss of connection to a larger unit does involve a change in land use. The annual per ha carbon stock change of such units of article 3.3 AR land is calculated as the mean

aboveground and belowground carbon sink due to volume increment calculated from inventory data using a simple bookkeeping model corresponding to the method used for Forest Land remaining Forest Land (Chapter 5).

Litter

The loss of carbon from litter was calculated from the national average amount of carbon stored in litter as estimated from the NFI litter layer measurements and additional sources (Van den Wyngaert *et al.*, 2012). Between 1990 and 2003, an interpolation was made between the litter carbon stock estimate for the HOSP inventory and the MFV inventory. After 2003, the litter carbon stock was kept constant as the best estimate based on MFV data.

It was assumed that after deforestation, all carbon stored in litter was lost in the same year. This matches the methodology for the loss of carbon in biomass and dead wood upon deforestation. The emission factors for litter increases between 1990 and 2003, illustrating that Dutch forests accumulate carbon in litter, and remains stable from 2003 onwards as no data are available after 2003.

Dead wood

The loss of carbon from dead wood was calculated in a similar way as the loss of carbon from biomass. The national average amount of carbon stored in dead wood (lying as well as standing for years after 2000) was available from a simple bookkeeping model (Nabuurs *et al.*, 2005; Van den Wyngaert *et al.*, 2012) and it was assumed that all carbon stored in dead wood was lost in the year of deforestation.

Mineral soils

See Section 10.2.1 “Re/afforestation of land without woody cover” under “Mineral soils”.

Organic soils

See Section 10.2.1 ‘Re/afforestation of land without woody cover’ under ‘Organic soils’.

10.3 Data tables for CSC under article 3.4: KP(5-I)B tables

The Netherlands has not elected any 3.4 articles.

10.4 Data tables for other gases under article 3.3: KP(5-II) tables

10.4.1 KP(5-II)1 Direct N_2O emissions from nitrogen fertilisation

Nitrogen fertilization of forests does not occur in The Netherlands. Therefore, NO is reported here.

10.4.2 KP(5-II)2 N_2O emissions from drainage of soils for areas under FM

The Netherlands has not elected any 3.4 articles.

10.4.3 KP(5-II)3 N_2O emissions from disturbance associated with land use conversion to cropland

Nitrous oxide emissions associated with disturbance of soils when deforested areas are converted to Croplands were calculated based on the activity data and the emission factor calculated for the 2011 submission. This was based on the equations 3.3.14 and 3.3.15 of Good Practice Guidance for LULUCF (IPCC, 2003) for each aggregated soil type separately (for a description of soil types see Annex 5), in combination with the land use changes based on the period 1990-2004.

The N_2O emissions from disturbance associated with the conversion of forest to cropland were then calculated as follows:

$$N_2O - N_{conv} = N_2O_{net-\min} - N$$
$$N_2O_{net-\min} - N = EF_1 \cdot N_{net-\min}$$

The amount of C lost as a consequence of land use conversion of forest to cropland was calculated according to Annex 5 (based on the rates of land use conversions 1990-2004 for each aggregated soil type). The default EF1 of 0.0125 kg N_2O-N/kg N was used. For 3 aggregated soil types calculated C:N ratios were available and used, for all other aggregated soil types we used the default C:N ratio of 15 (GPG p. 3.94 , IPCC, 2003). For aggregated soil types where conversion to cropland lead to a net gain of carbon the nitrous oxide emission was set to zero.

10.4.4 KP(5-II)4 Carbon emissions from lime application

Activity data for lime are available only per type of lime applied (limestone and dolomite), not per land use category where they are applied. It is assumed that almost all of it is applied in agricultural grasslands and cropland. Liming of forests does not occur in The Netherlands, therefore liming is reported as NO for re/afforested areas.

As lime is applied on grasslands and cropland, it is most likely also applied on units of land that are deforested towards grasslands and cropland. However, there is no information how much of the liming is applied on croplands and grasslands that are reported under article 3.3 deforestation. Therefore an estimate is made. A mean national application rate is calculated for dolomite and limestone from the total amount applied and the total area where it can potentially be applied (i.e. the total area of croplands and grasslands reported under 5B and 5C of LULUCF). This mean application rate was then multiplied with the total area grassland and cropland reported under article 3.3 deforestation to calculate the amount of dolomite and limestone applied on article 3.3 deforestation land (Table 10.6). Lime application is converted to CO_2 emissions using default emission factors.

Table 10.6: Liming of deforested land converted to cropland and grassland

Year	National totals			Mean lime application rate			Lime applied in D land	
	Dolomite	Limestone	Area CL + GL	Dolomite	Limestone	Area de-forested to CL and GL	Dolomite	Limestone
	Mg	Mg	kha	Mg kha^{-1}	Mg kha^{-1}	kha	Mg	Mg
2008	101,964	49,953	2316	44.02	21.57	21.37	940.80	460.91
2009	85,465	43,065	2310	37.00	18.64	22.49	831.92	419.20
2010	100,668	57,514	2304	43.70	24.96	23.60	1031.24	589.17
2011	100,668*	57,514*	2298	43.82	25.03	24.71	1082.85	618.65

* same values as for 2010. These will be replaced when actual data for 2011 become available.

10.4.5 KP(5-II)5 Greenhouse gas emissions from biomass burning

In The Netherlands, controlled burning does not occur, nor for forests nor for any other land use types. Therefore greenhouse gas emissions related to controlled burning are reported as NO.

After previous reviewer's comments in the NIR 2013 an effort has been made to include wild fires for the first time in our emission reporting. Recent data on occurrence and extent of wild fires is lacking. Based on a historical series ranging from 1980 to 1992 with annual number of forest fires and the total area burned (see Chapter 7, Wijdeven *et al.*, 2006) an average annual area of forest fire was estimated. In this period on average 37.8 ha (0.1 ‰) of the total forest land in the Netherlands was burned annually.

For AR Land, which is a fraction of the total forest area, GHG emissions are estimated based on the this fraction of the area of AR land to total area of forest land in the same year (Table 10.7). The method for estimating emissions from wild fires from the total forest area is presented in Chapter 7.

Table 10.7. For each year the area AR land as a fraction of total forest land and the estimated area AR land burned by wild fires with associated CO_2, CH_4 and N_2O emissions, in Gg GHG and Gg CO_2 equivalents.

Year	Area AR land as fraction of total forest land	AR area burned (ha)	CO_2 (Gg)	CH_4 (Gg)	CH_4 (Gg CO_2 eq.)	N_2O (Gg)	N_2O (Gg CO_2 eq.)	Total (Gg CO_2 eq.)
2008	0.111	4.21	0.863	0.004	0.079	0.000026	0.0080	0.95
2009	0.115	4.36	0.907	0.004	0.083	0.000027	0.0084	1.00
2010	0.119	4.51	0.952	0.004	0.087	0.000029	0.0088	1.05
2011	0.123	4.66	0.997	0.004	0.091	0.000030	0.0092	1.10

Historic data indicate that the occurrence of, and area affected by forest fires steadily decreased over time until 1992 (Wijdeven *et al.*, 2006)). Hence, using the average over the period 1980 – 1992 most likely results in an overestimation of the total forest area burned and hence the AR area burned. Additionally for the emission factor for forest fires, it was assumed that all biomass on the burned forest area is affected, whereas most forest fires mainly affect the vegetation in the understorey and trees are generally affected to a lesser extent. There are, however, no data available to support this observation, but in addition the likely overestimation of annually burned forest area, this leads to an overestimation of emissions from forest fires and therefore should be considered a conservative estimate with a high level of uncertainty.

There is no spatial information on the occurrence of wild fires and also other data are lacking to make even a rough estimate for wild fires on Deforested land. Therefore currently there is no sound scientific basis to support estimates of wild fires on land that was deforested before. This would predominantly involve wild fires on land converted from forest to grassland, which includes heathlands and involves relatively small amounts of biomass and consequently very low CO_2 and non-CO_2 GHG emissions.

In the Netherlands wild fires in general do not lead to deforestation. Wild fires usually affect only the vegetation in the forest understorey, while trees are affected only to a lesser extent, allowing forest recovery after a fire.

11 Comparison between Kyoto and Convention tables 2008-2012

The information required under the Kyoto Protocol for LULUCF is partly overlapping and partly supplementary to the information submitted under the Convention. In this section we make explicit how both reporting requirements relate to one another, and where differences emerge on the basis of the calculation made.

11.1 Definitions and matching of (sub)categories

Under the Convention, all land is classified in six land use categories, that are described in Good Practice Guidance for LULUCF (IPCC, 2003). Countries are free to choose the exact definition of these categories, depending on national circumstances, as long as they fit the descriptions. The Netherlands chose to define Forest Land in a rather broad way, including also mapped wooded ecosystems that did not match the area and width criteria of the Kyoto forest definition. Therefore all submissions to the Convention distinguish two subcategories: forests according to the Kyoto definition (FAD) and trees outside forest (TOF). The latter category is defined without minimum area and minimum width, and as such can include shelterbelts, groups of trees, forest remnants after fragmentation, etc., all if large enough to show on the 25 m x 25 m raster land use map (Kramer *et al.*, 2009).

There is an exact match between the 'forests according to the Kyoto definition' (FAD) under the Convention and forests reported under the Kyoto Protocol. Thus, any change in area of FAD emerges as either re/afforestation or deforestation under article 3.3 reporting and vice versa. However, under the Convention conversions between FAD and TOF are not singled out and are included in the respective categories where the land use is converted into. Furthermore, under the Convention a transition period of maximally 20 years is applied, while under KP all respective land use changes since 1990 are included (Table 11.1).

Table 11.1. Crossover between LULUCF (sub)categories under the KP (AR = Afforestation and reforestation; D = Deforestation) and under the Convention. (FAD = Forests according to the Kyoto Definition; TOF = Trees outside Forest; CL = Cropland; GL = Grassland; WL = Wetland; Sett = Settlements; OL = Other land)

Kyoto Subcategory	Matching subcategory in Convention
AR from Cropland	5.A.2. CL- FAD
AR from Grassland	5.A.2. GL- FAD
AR from Wetland	5.A.2. WL- FAD
AR from Settlements	5.A.2. Sett- FAD
AR from Other Land	5.A.2. OL- FAD
AR from Trees Outside Forest	Included in 5.A.1. FAD
D to Cropland	5.B.2. FL-FAD
D to Grassland	5.C.2. FL-FAD
D to Wetland	5.D.2. FL-FAD
D to Settlements	5.E.2. FL-FAD
D to Other Land	5.F.2. FL-FAD
D to Trees Outside Forest	Included in 5.A.1. TOF

11.2 Areas

Both under the Convention and under the KP land use conversions to and from FAD are reported. Both are based on the same set of land use maps and the same land use change matrix (Kramer *et al.*, 2009) and annual conversion rates for the same years are equal under both reporting agreements.

Re/afforestation

Under the Convention, The Netherlands chose to report in sector 5.A.2 on emissions from land converted to Forest Land not more than 20 years ago, but no earlier than 1st January 1990. Thus, for 2008 emissions are reported that occur between 1st January 2008 and 31st December 2008 on land converted to Forest land between 1st January 1990 and 31st December 2008. For 2012 emissions are reported that occur between 1st January 2012 and 31st December 2012 on land converted to Forest land between 1st January **1993** and 31st December 2012.

Under the Kyoto Protocol, The Netherlands is obliged to report on annual emissions from land converted to FAD since 1st January 1990. Thus, for 2008 emissions are reported that occur between 1st January 2008 and 31st December 2008 on land converted to Forest land between 1st January 1990 and 31st December 2008. For 2012 emissions are reported that occur between 1st January 2012 and 31st December 2012 on land converted to Forest land between 1st January **1990** and 31st December 2012.

As a result, in 2008 and 2009, equal areas show up in both CRF tables. However, from 2010 on, land is moved from A.2. (land converted to FL) to A.1. FL remaining FL under the Convention, and a difference will emerge between the matching subcategories in Table 11.1. The differences during the first CP will be one (2010), two (2011) or three (2012) times the mean annual re/afforestation rate for the period 1990-2004 minus the annual deforestation rate between 2004-2009 of areas that were re/afforested in the period 1990-2004 (**Fout! Verwijzingsbron niet gevonden.**; Figure 11.1).

Table 11.2. Relation between ARD area reported under the Convention (AR_{Conv} and D_{Conv}) and ARD area reported under KP (AR_{KP} and D_{KP}) for matching subcategories other than TOF from Table 11.1

Year	Re/Afforestation	Deforestation
2008	$AR_{KP} = AR_{Conv(2008)}$	$D_{KP} = \sum_{1990}^{2008} D_{Conv(i)}$
2009	$AR_{KP} = AR_{Conv(2009)}$	$D_{KP} = \sum_{1990}^{2009} D_{Conv(i)}$
2010	$AR_{KP} = AR_{Conv(2010)} + (AR_{Conv(1990)} - D_{AR(1990)})$	$D_{KP} = \sum_{1990}^{2010} D_{Conv(i)}$
2011	$AR_{KP} = AR_{Conv(2010)} + AR_{Conv(1991)} - D_{AR(1991)})$	$D_{KP} = \sum_{1990}^{2011} D_{Conv(i)}$
2012	$AR_{KP} = AR_{Conv(2010)} + AR_{Conv(1992)} - D_{AR(1992)})$	$D_{KP} = \sum_{1990}^{2012} D_{Conv(i)}$

Deforestation

Deforestation rates are reported on an annual basis under the Convention, and cumulative since 1990 under the KP (**Fout! Verwijzingsbron niet gevonden.**). As no land can leave Deforestation, the total amount reported under KP is the sum of all land that is reported for any year under the Convention (**Fout! Verwijzingsbron niet gevonden.**).

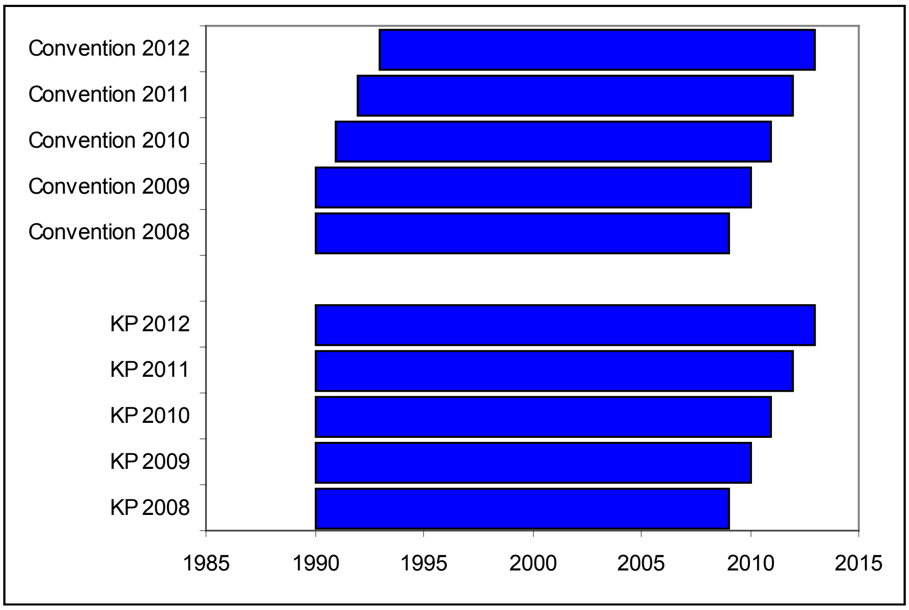


Figure 11.1: Years of conversion of land converted to Forest Land reported in sector 5.A.2 under the Convention (upper) and of re/afforested land under the Kyoto Protocol (lower). Note that in 2008 and 2009, the bars are equal under the Convention and the KP.

11.3 Emissions

11.3.1 Carbon stock changes under re/afforestation

Carbon stock changes due to changes in biomass, dead wood and litter are calculated using consistently the same methodology under KP and under the Convention. Both litter and dead wood are reported conservatively 'not a source' under the Convention as well as KP. However, for the remaining pools there are a number of differences in the two reporting systems that cause emissions to be different:

- Under the Convention there is a transition period with a maximum of 20 years, whereas under KP all land changing since 1990 is reported (see also Section 11.2) with the emission factor for 'older than 20 years' based on the calculations for forests remaining forests.
- Under the Convention, land changing from trees outside forests to forests according to the definition (equivalent to KP forest) is reported under the 'Forest Land remaining Forest Land' category (subcategory forests according to the definition).
- Under the Convention, all carbon stock changes in mineral soils are reported aggregated at the national scale to a conservative zero, whereas under KP carbon stock changes from mineral soils are reported explicitly.
- Under the Convention, carbon stock changes from land use changes on organic soils are not reported explicitly (and only implicitly if they are included in cultivation of organic soils), whereas under KP carbon stock changes from land use changes on organic soils are reported explicitly.

11.3.2 Carbon stock changes under deforestation

All differences in biomass, dead wood and litter C due to deforestation are assumed to occur only in the year of deforestation under the Convention as well as under KP, and calculated in the same way for biomass, litter and dead wood. However, there are a number of differences in the two reporting systems that cause emissions to be different:

- Under the Convention, only land changing away from forest is reported under "forests converted to …". However, as land cannot leave deforestation, the implementation of a third land use map has caused other land use changes that follow deforestation to be reported under deforestation as well. From this year on, this has implications for all land converted to or from cropland and grassland.
- Under KP, there are agreements on how to report on re/afforested land that is then deforested. This was singled out for KP, but not for reporting under the Convention.
- Under the Convention, land changing from forests according to the definition to trees outside forests is reported under the 'Forest Land remaining Forest Land' category (subcategory trees outside forests).
- Under the Convention, all carbon stock changes in mineral soils are reported aggregated at the national scale to a conservative zero, whereas under KP carbon stock changes from mineral soils are reported explicitly.
- Under the Convention, carbon stock changes from land use changes on organic soils are not reported explicitly (and only implicitly if they are included in cultivation of organic soils), whereas under KP carbon stock changes from land use changes on organic soils are reported explicitly.

12 QA/QC

12.1 QA/QC for UNFCCC reporting

This chapter describes the route towards and during the 2013 submission for the LULUCF sector to the UNFCCC. For the 2013 submission a number of changes and recalculations were identified (see Section 9.2). These are listed:

- Inclusion of Greenhouse gas emissions from forest fires.
- Correction of error in T1 emission factors used for conversions from Settlement to Grassland and from Other Land to Grassland.
- Liming, update based on availability of fertiliser data for 2010.

12.2 Calculations

Table 12.1 gives an overview of calculations supporting the LULUCF submission for 2012.

Table 12.1. Overview of calculations supporting the LULUCF submission 2012.

Category	**What**	**Who**	**Description**
Activity data: area	Land use change matrix based on topographic maps	CGI, Alterra	Kramer *et al.*, 2009; Van den Wyngaert *et al.* 2012. Chapters 3, 4.
C emissions from changes in biomass for 'Forest Land remaining Forest Land'	Simple bookkeeping model based on NFI data	Team Vegetation, Forest and Landscape Ecology, Alterra	Nabuurs *et al.*, 2005; Van den Wyngaert *et al.*, 2007; Van den Wyngaert *et al.*, 2009; Protocol 5A: CO_2: 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	Team Vegetation, Forest and Landscape Ecology, Alterra	Nabuurs *et al.*, 2005; Van den Wyngaert *et al.*, 2007; Van den Wyngaert *et al.*, 2009; Protocol 5A: CO_2: 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	Team Vegetation, Forest and Landscape Ecology, Alterra	Van den Wyngaert *et al.*, 2009; Protocol 5A: CO_2: 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	Team Vegetation, Forest and Landscape Ecology, Alterra	Nabuurs *et al.*, 2005; Van den Wyngaert *et al.*, 2009; Protocol 5A: CO_2: Forest land (NIR 2012); Chapter 5.3
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	Team Vegetation, Forest and Landscape Ecology, Alterra	Nabuurs *et al.*, 2005; Van den Wyngaert *et al.*, 2009; Protocol 5A: CO_2: Forest land (NIR 2012); Chapter 5.2
C emissions for cultivation of organic soils	Based on groundwater level map and soil surface lowering	Team Sustainable Soil Use, Alterra	Kuikman *et al.*, 2005; Protocol 5B-G: CO_2 emissions for total land use categories; Chapter 8
C emissions from use of calcareous fertilizers	Based on national use and default emission values	RIVM	NIR

12.3 Process for calculating and reporting emissions

The Dutch land use matrix is derived from an overlay between land use maps for 1990, 2004 and 2009. All three are made by the team Earth Informatics of Alterra (part of Wageningen University and Researchcentre) based on the topographic maps (Kramer *et al.*, 2009, Van den Wyngaert *et al.,* 2012). The land use change maps are delivered to the Team Sustainable Soil Use of Alterra who prepare an overlay 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 sector expert at the Team Vegetation, Forest and Landscape 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 the sector expert. Emissions associated with use of organic soils are calculated by the Team Sustainable Soil Use (Alterra). Emissions or emission factors are sent to the sector expert at the Team Vegetation, Forest and Landscape 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 The National Institute for Public Health and the Environment (RIVM) and sent to the sector expert at the Team Vegetation, Forest and Landscape Ecology of 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.

12.4 Submission route

The reported values were entered in a copy of the CRF reporter by the sector expert at Alterra in collaboration with the CRF specialist of the Netherlands Organisation for Applied Scientific Research (TNO). After completely filling the LULUCF sector, a draft of the CRF tables for LULUCF are generated from the CRF reporter by TNO and sent to Alterra and RIVM for checking.

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. This loop is repeated until everyone involved agrees with the data in the CRF tables. The final tables are sent to RIVM who actually performs the official submission.

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

12.5 QA/QC for the Kyoto reporting

The submission route is the same as for the Convention submission. Consistency with the values submitted for the Convention was assured by using the same base data and calculation structure, and apply different calculations only where applicable as formulated in Chapter 4. The data and calculations were thus subject to the same QA/QC (Van den Wyngaert *et al.*, 2012).

Verification with other international statistics was performed only with FAO. The area of forest is systematically lower for FAO. This may be due to a different methodology, for discussion on different outcomes of different estimates of forest cover in The Netherlands the reader is referred to Nabuurs *et al.*, 2005. The net increase in forest area in the FAO statistics (1.5 kha per year between 1990 and 2000, 1 kha per year between 200 and 2005) is higher than in our estimates (0.567 kha per year between 1990 and 2004. These values indicate a conservative estimate of the net forest are increase in The Netherlands.

The mean C stock in Dutch forests (used as emission factor for deforestation under the KP) is slightly higher in the UNFCCC estimates than in the FAO estimates (Table 12.2). Considering that different conversion factors were used, the estimates are close together, while the difference has the tendency to increase. These values indicate a conservative estimate of C emissions from deforestation.

Table 12.2. Comparison between FAO and UNFCCC values for the mean C stock in living biomass in Dutch forests in t ha^{-1}

Year	**FAO (biomass / area * 0.5)**	**UNFCCC**
1990	59.4	60.4
2000	68.1	71.7
2005	71.1	81.3

No values from FAO are available on young forests. FAO statistics also provide no information on fires or disturbances for the Kyoto period, since at the national level, these statistics are not kept any more. The same accounts for EFFIS, the European Forest Fires Information System.

13 Foreseen improvements

13.1 UNFCCC

When the current system was implemented for the LULUCF sector, it was already envisaged that there would be regular improvements over time. Major foreseen improvement are presented here.

- *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 under KP-LULUCF, a thorough update of the forest calculations, along with an analysis on how to proceed with irregular data in time is needed.

- Based on studies by Hanegraaf *et al.* (2009) and Reijneveld *et al.* (2009) showing that the mineral soils in the Netherlands are a sink of unknown magnitude, the Netherlands decided to report emissions from all mineral soils conservatively as zero, and therefore notation key NO was used, see also NIR section 7.2. Because of the many comments during previous reviews, methodological improvements are currently being carried out following the same procedure as used for KP-LULUCF. This means that for all land use (change) categories a soil carbon pool will be reported. These improvements are expected to be included for the first time in the NIR 2014.

13.2 Kyoto

The filling of the Kyoto tables has been improved between 2009 and 2012. Still, two areas for future improvement are foreseen.

- *Separate uncertainty estimates for Kyoto values*. Under the KP, there should be separate annual uncertainty estimates for each LULUCF activity, reported carbon pool and geographical location. Currently, uncertainties are based on Tier 1 methods and linkages between KP and Convention categories. It is aimed to have separate uncertainties calculated using a Tier 2 method for the 2014 or 2015 submissions.

- *Improved calculation of emissions in case of multiple consecutive land use changes to one unit of land*. With the implementation of the 2009 land use map, several units of land have been subject to land use change twice. In the future, implementation of the 2012 land use map will increase this to three possible land use changes within one unit of land. In the current submission, the effect of multiple land use changes is taken into account completely for some pools (e.g. soil C emissions from mineral soils for deforestation) but has been based on assumptions of equilibrium where it is known there was none (e.g. in case of reforestation of grassland between 2004 and 2009, of land that changed from cropland to grassland between 1990 and 2004) or on extrapolations of emission factors calculated for the areas becoming ARD land between 1990 and 2004 (e.g. soil C emissions from organic soils, N_2O emissions from disturbance associated with conversion to cropland). Similarly, liming is calculated based on all areas deforested to cropland and grassland, not taking into account any subsequent land use changes to and from the land use categories. Together with the implementation of the 2012 LU map this will be improved.

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Annex 1 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

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

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})
$\bar{V}_{i(t+1)}$ 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

$$\Delta C_{FF_G} = \sum_{1}^{n}\left(A_i \bullet G_{TOTALi}\right) \bullet CF$$
$$G_{TOTALi} = \left(\overline{B_{i\,t+1}} - \overline{B_{i\,t}}\right) \cdot nt_{it}$$

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 below)

10. Carbon stock change on dead wood

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

$$B_{DW\,\mathrm{int}\,o_i} = B_{it} \bullet f_{mort}$$

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

$\Delta C_{FF_{DW}}$ Total net carbon emission due to change in dead wood for Forest land remaining Forest land - FAD in the Netherlands

$B_{DW\,\mathrm{int}\,o_i}$ 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 Section 5.3.1) (Gg C ha^{-1})

A_{LF_t} Area of land converted to forest of age *t* (ha)

2. Deforestation

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

$\Delta C_{FL_{Loss}}$ 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 biomass of living trees of NFI plot *i* at time *t* (kg DW)

Annex 2 Biomass expansion equations

The selection of biomass expansion equations used for the calculations of aboveground biomass (Table A.2.1) and belowground biomass (Table A.2.2), for more information see Appendix I in Nabuurs *et al.*, 2005.

Table A.2.1. 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 A.2.2. 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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Annex 3 Filling of Table NIR-2

Here the rules followed to fill the table NIR-2 are described. For The Netherlands, which has not elected 3.4 activities, the submission under the KP distinguishes three types of land: AR land, D land and other land. For any land under AR or D, carbon stock changes and greenhouse gas emissions need to be reported. Other land is land that is not under the KP and thus no emissions are to be reported. The sum of all land, i.e. AR, D and other, is the total area of the country (reported in the lower left cell) and remains constant over time.

The area of land that is newly re/afforested or deforested between the beginning and the end of the inventory year shows up in the 3rd row (see Table A.3.1). It changes from 'Other' (row heading) to either AR (1st column heading) or D (2nd column heading). The cumulative area of land that has been re/afforested in previous years is shown in the upper left cell, (AR-AR) and the cumulative area of land that has been deforested in previous years is shown in the cell in the same diagonal right of and below this one , i.e. the Def-Def cell. Previously re/afforested land can be deforested again, and is reported then as deforested land. The area AR land that moves to D during the current inventory year is reported in the upper row, 2nd cell from left (row heading = AR, column heading = Def). Once land is reported under D, it remains in this category, even when it is reforested again. Thus, the area of land in Def-Def can only increase, whereas the area of land under Other-Other can only decrease.

Table A.3.1: Calculations of the area change of re/afforestation (ARF) and deforestation (Def) in the period 1990-2009. The red arrows indicate the possible pathways of land reported for the LULUCF sector under the KP submission.

	AR	**Def**	**Other**	**Total area at the beginning of the current inventory year**
AR	Cum AR 1990-2008 (=Annual rate ARF x 19)	0 (until new matrix)		Sum of cells left = total area under AR in previous year
Def		Cum Def 1990-2008 (= Annual rate Def x 19)		Sum of cells left = total area under D in previous year
Other	Annual rate AR 2009	Annual rate Def 2009	Area NL – area in the rest of the matrix	Sum of cells left = total area not under KP in previous year
Total area at the beginning of the current inventory year	Sum of cells above = total area reported under AR	Sum of cells above = total area reported under D	Sum of cells above = total area not under KP	Total area in country

Annex 4 KP - Carbon stock change in living biomass FAD

Aboveground and belowground biomass

For cropland, grassland, wetland, settlement and other land, conversion to Forest according the Definition (FAD) involves creating a growing carbon stock in living tree biomass. This carbon sink in biomass in re/afforested areas is calculated using the same assumptions and emission factors as for land converted to FAD under the Convention (see Chapter 5). The method and its justification for use under KP reporting are summarized below.

1. *It is assumed that the volume growth of recently established forest areas will be similar to the growth of young forests in the national inventories.*
   This is a conservative assumption, as forests historically were most prominent on the poorer soils of The Netherlands, while new forests are being created both on poor and richer soils. Figure A.4.1 shows the change of (averaged) increment with plot age in the HOSP and MFV forest inventories. Plots of 20 to 25 years old have the highest mean NAI increasing up to 15 m^3 ha^{-1} $year^{-1}$, both in the HOSP and in the MFV inventory.

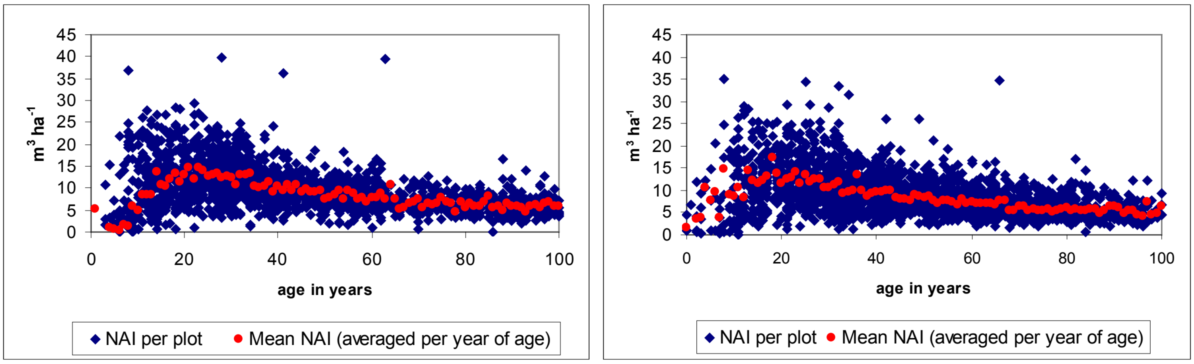

Figure A.4.1. Net annual increment (NAI) over age for the HOSP (1988-1992) (left) and the MFV (2001-2005) (right) forest inventory

2. *It is assumed that for very young plots (i.e. up to 20 years), the use of IPCC default conversion factors is more robust than allometric relations. Carbon sink rates are calculated from increment rates using IPCC default conversion factors.*
   Most of the allometric relations are not developed for very young trees with low diameters. Therefore, carbon sink rates are calculated from increment data using IPCC default conversion factors.

3. *It is assumed that at time of regeneration, growth is close to zero*
   This assumption is quite general and Figure A.4.1 shows that it is consistent with both HOSP and MFV data.

4. *Between forest regeneration and 20 years old forest, the specific growth curve is unknown and is approximated by the simplest function, being a linear curve*
   Figure 5.1 shows the carbon sink rate over age for both the HOSP and MFV inventories. For the HOSP inventory, the linear curve is a good approximation, for the MFV inventory, the linear curve underestimates the carbon sink for plots younger than 10 years. As such, the linear curve is a conservative approximation of the relation between carbon sink and age.

5. *The exact height of this linear curve is best approximated by a linear regression of mean carbon sink rate on age. One mean carbon sink rate value is taken for each age, to avoid confounding effects of the age distribution on the NFI plots (not all of which were really afforested)*
The regression lines are drawn in Figure 5.1. The high increments are translated in carbon sinks increasing up to 5 (HOSP) and 6 (MFV) Mg C ha^{-1} year^{-1} for 20 year old forest, i.e. which is in its most productive phase.

6. *Consistent with the way data are used for the calculation of carbon sink rates in forests, HOSP data are used between 1990 and 2000 and MFV data from 2001 onwards.*

7. *The effect of age structure is retained when calculating the annual net emissions, i.e. as plots grow older, their carbon sink will increase according to the previous regression on age.*
This mean that with a constant rate of re/afforestation, the IEF will increase monotonically from very low values for 1 year old forest plots to slightly over 3 Mg C ha^{-1} year^{-1} when plots of all ages are equally represented after 20 years. As Figure A.4.2 shows, this is in the higher range of the IPCC default values. This can be understood from the high occurrence of young plots on former agricultural, productive soils, and also related to the history of high nitrogen deposition and nutrient enrichment on generally poorer forest soils in The Netherlands.

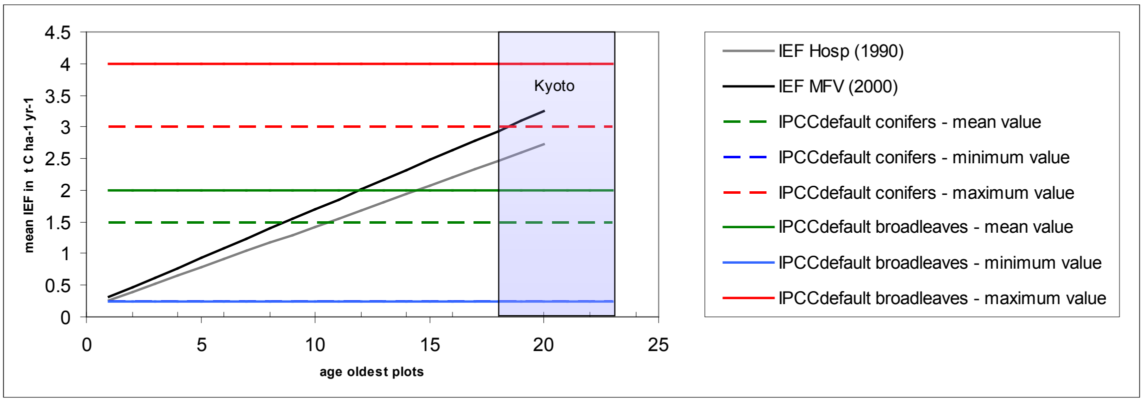

Figure A.4.2. Mean IEF at national scale for cumulative AR-activities with constant rate of land use change.

8. *Above- and below ground growth carbon sinks are distinguished based on the mean ratio in the plots (based on IPCC defaults) used as basis for the regression of the carbon sink on age.*
This resulted in 69% of the carbon sink in the aboveground biomass and 31% in the below ground biomass. This ratio was applied consistently over all AR-forests.

9. *It is assumed that for forests younger than 25 years old, the occurrence of harvest and thinning is negligible. Thus, biomass loss is reported as (NO, 0)*
No data are available to distinguish the origin of harvested wood.

The method as described above was developed to calculate the carbon sink associated with the conversion of land to Forest Land under the Convention. In the Dutch submission, land converted to Forest Land remains in a separate category (5.A.2) for 20 years, after which it is included in Forest land remaining Forest Land. Based on a linear regression, it is not correct to extrapolate beyond these 20 years of age. Therefore, plots over 20 years of age were reported using the emission factor for forests remaining forests (Chapter 5), thus ensuring full consistency between the Convention and KP reporting.

Annex 5 Carbon stock change in mineral and organic soils for KP reporting

1 Introduction

Under the Convention, The Netherlands reports that as a whole, including all land uses and land use changes but leaving out the cultivation of organic soils for agricultural use, the soil of The Netherlands is most probably a sink of a highly uncertain magnitude. As such, no soil emissions are reported for mineral soils (Van den Wyngaert *et al.*, 2009). However, for reporting under the Kyoto Protocol (KP) the carbon stock changes need to be reported separately per pool and per activity (i.e. deforestation and re/afforestation). Therefore, another methodology is needed to report correctly under the Kyoto Protocol, for which carbon pools are spatial allocated and linked to the areas of deforestation and re/afforestation.

For organic soils, the emissions from cultivation of organic soils are reported under the Convention as a total for the Netherlands, without allocating the emissions to a certain area or land use. All emissions from organic soils are for the Convention reported separately under grassland. The procedure is based on an overlay of a map with water level regimes and the soil map indicating the area with peat soils, combined with assumptions typically valid for agricultural peat soils in The Netherlands. However, to report the emissions correctly under the Kyoto Protocol for the areas of deforestation and re/afforestation a spatially distributed methodology is needed.

For both the mineral and organic soil carbon pool an updated methodology was developed to address the need for spatially distributed emissions and removals for KP reporting. In this note a brief description of the updated methodology for both mineral and organic soils is given and the new results for reporting under the Kyoto Protocol are presented.

2 Methodology

2.1 Mineral soils

The updated methodology for carbon stock changes in mineral soils is based on the previous methodology as described in De Groot *et al.* (2005). In this study a soil carbon stock map was made for the Netherlands based on data derived from the LSK, a national sample survey of soil map units (Finke *et al.*, 2001). The LSK database contains quantified soil properties, including soil organic matter, for about 1400 locations at five different depths. Based on these samples soil carbon stocks for the upper 30 cm were determined (De Groot *et al.*, 2005). The LSK was stratified to groundwater classes and soil type. However, land use was not included as separate variable. Therefore it was not possible to quantify carbon stock changes related to the Kyoto activities deforestation and re/afforestation.

In a study by Lesschen *et al.* (2012) the same base data from the LSK survey were used, but classified differently into new soil – land use combinations. For each of the sample locations the land use at the time of sampling was known. The soil types for each of the sample points were reclassified to 11 main soil types (Figure A.5.1 and Table A.5.1), which represent the main variation in carbon stocks within the Netherlands. The number of observations for each soil type is still sufficient to calculate representative average soil carbon stocks for the main land uses. In Figure A.5.2 the calculated average carbon stocks for grassland, cropland and forest are shown.

Table A.5.1. Main soil types in the Netherlands and number of observations in the LSK database

Soil Type	Soil type Dutch name	Area (km^2)	Nr. Observation
Brick soil	Brikgrond	272	32
Earth soil	Eerdgrond	2084	58
Old clay soil	Oude kleigrond	387	19
Loamy soil	Leemgrond	258	26
Sandy soil without lime	Kalkloze zandgrond	3793	249
Peaty soil	Moerige grond	1914	61
Podzol soil	Podzol grond	7393	246
River clay soil	Rivierklei grond	2652	111
Peat soil	Veengrond	3369	208
Marine clay soil	Zeekleigrond	7751	299
Sandy soil with lime	Kalkhoudende zandgrond	958	75

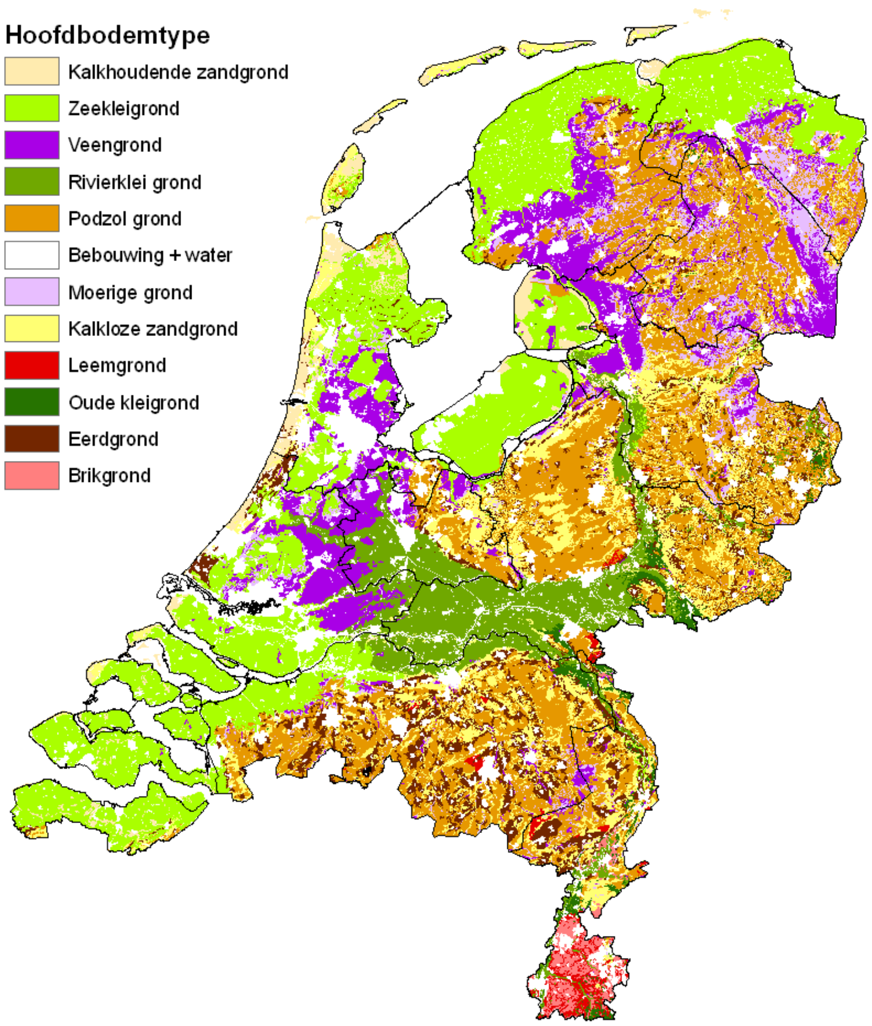

Figure A.5.1. Distribution of the main soil types in the Netherlands

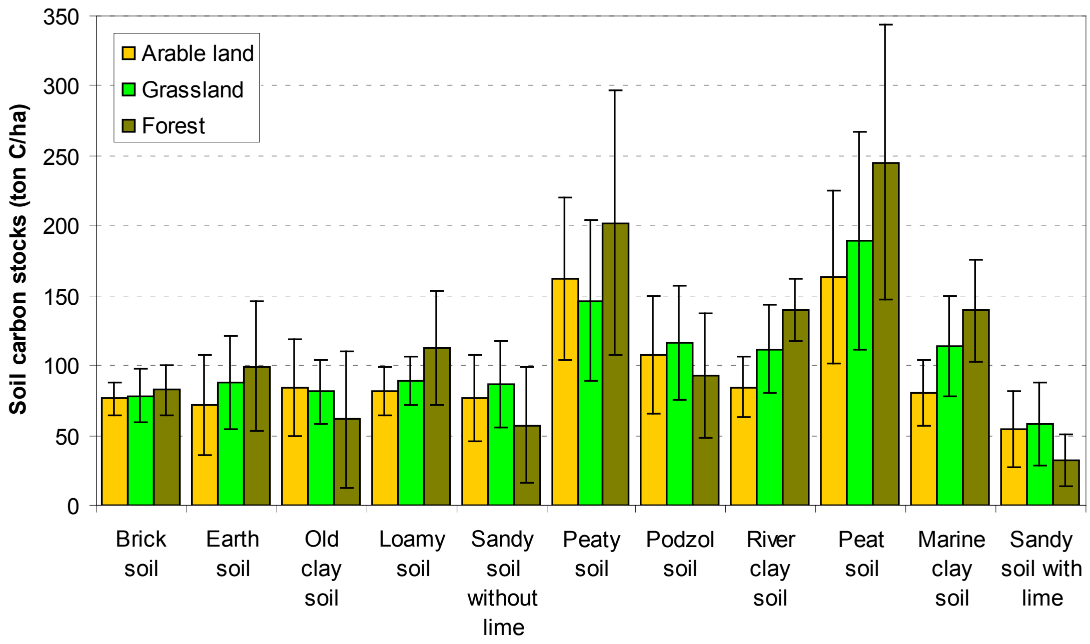

Figure A.5.2. Average soil carbon stocks per land use soil type combination. The error bars indicate the standard deviation.

The LSK data set only contains data on soil carbon stocks for the land uses grassland, cropland and forest. For the remaining land uses no data about soil carbon is available in the LSK database or other studies. Therefore, estimates had to be made, especially for settlements it is important to estimate carbon stocks, since about 25% of the deforestation is conversion to settlements. In the IPCC 2006 guidelines some guidance is provided for soil carbon stocks for land converted to settlement, see the text box below. Considering the high resolution of the land use change maps in the Netherlands (25x25 m grid cells) it can be assumed that in reality a large portion of that grid cell is indeed paved. Using the following assumptions an average soil carbon stock under settlement that is 0.9 times the carbon stock of the previous land use is assumed:

1. 50% of the area classified as settlement is paved and has a soil carbon stock of 0.8 times the corresponding carbon stock of the previous land use
2. The remainder 50% consists mainly of grassland and wooded land for which the reference soil carbon stock is assumed.

For wetlands and trees outside forest (TOF) no change in carbon stocks in mineral soils is assumed upon conversion to or from forest. For other land a carbon stock of zero is assumed. This is a conservative estimated, but in some cases indeed a reality, e.g. forest is removed to create drifting sands areas for nature purposes, in that case the complete topsoil is removed.

The IPCC 2006 guidelines state the following for land converted to settlement for the soil carbon pool:

Default stock change factors for land use after conversion (Settlements) are not needed for the Tier 1 method for *Settlements Remaining Settlements* because the default assumption is that inputs equal outputs and therefore no net change in soil carbon stocks occur once the settlement is established. Conversions, however, may entail net changes and it is *good practice* to use the following assumptions:

1. for the proportion of the settlement area that is paved over, assume product of F_{LU}, F_{MG} and F_I is 0.8 times the corresponding product for the previous land use (i.e., 20% of the soil carbon relative to the previous land use will be lost as a result of disturbance, removal or relocation);
2. for the proportion of the settlement area that is turfgrass, use the appropriate values for improved grassland from Table 6.2, Chapter 6;
3. for the proportion of the settlement area that is cultivated soil (e.g., used for horticulture) use the no-till F_{MG} values from Table 5.5 (Chapter 5) with F_I equal to 1; and
4. for the proportion of the settlement area that is wooded assume all stock change factors equal 1.

The difference between land use classes, divided by 20 years (IPCC default) is the estimated annual C flux associated with re/afforestation or deforestation. Thus, re/afforestation of cropland to forest for example has the same annual C flux per hectare as deforestation from forest to cropland, but with an opposite sign:

$$E_{\min} = \frac{C_{t=20} - C_{t=0}}{t} * A_{\min\_x,t=20}$$

in which:

$C_{t=20}$	the final carbon stock after 20 years
$C_{t=0}$	the initial carbon stock 20 years ago
t =	20 years
$A_{min\_x\_t=20}$	the area of mineral soil with land use x after 20 years

2.2 Organic soils

The area of organic soils under forests is small compared to the total forest area in The Netherlands and amounts 11539 ha (3.5%), based on the land use map of 2004. The area of re/afforested land on organic soils is 2912 ha (8%) and of deforested land 1536 ha (5%), based on the land use change between 1990 and 2004 (Kramer *et al.*, 2009). The majority of this is involved in a conversion between Kyoto forest and agricultural land (cropland or grassland). Drainage of organic soils to sustain forestry is not part of the management and not actively done, however, indirectly also organic soils under forest are affected by drainage from the nearby agricultural land.

Kuikman *et al.* (2005) established a relation between subsidence and either ditch water level or mean lowest groundwater based on many series of long-term measurements. The average ground surface lowering can be described as a function of the soil type of the upper soil layer and the drainage class. The following soil types were distinguished: peat, clay, sand and humus rich sand ('veenkoloniaal dek'). For peat the ground surface lowering is higher than for the other soil types. Three drainage classes are distinguished based on the GLG (average lowest groundwater level): bad drainage (GLG < 80 cm); moderate drainage (GLG 80-120 cm) and good drainage (GLG > 120 cm). In Kuikman *et al.* (2005) the groundwater information from the soil map was used, which was mainly collected during the sixties and seventies. Since this information is outdated, since more land is now drained compared to the sixties, they assumed that 50% of the peat area in a certain groundwater class would now one class higher. In the updated calculation we used the updated groundwater data (GxG files), see Gruijter *et al.* (2004) and van Kekem *et al.* (2005). This map was made based on geostatistics, groundwater level databases and some additional new measurements of groundwater levels. The resulting ground surface lowering for all peat soils in The Netherlands is shown in Figure A.5.3. The total area of peat soils under agricultural land use is 223 thousand ha in The Netherlands.

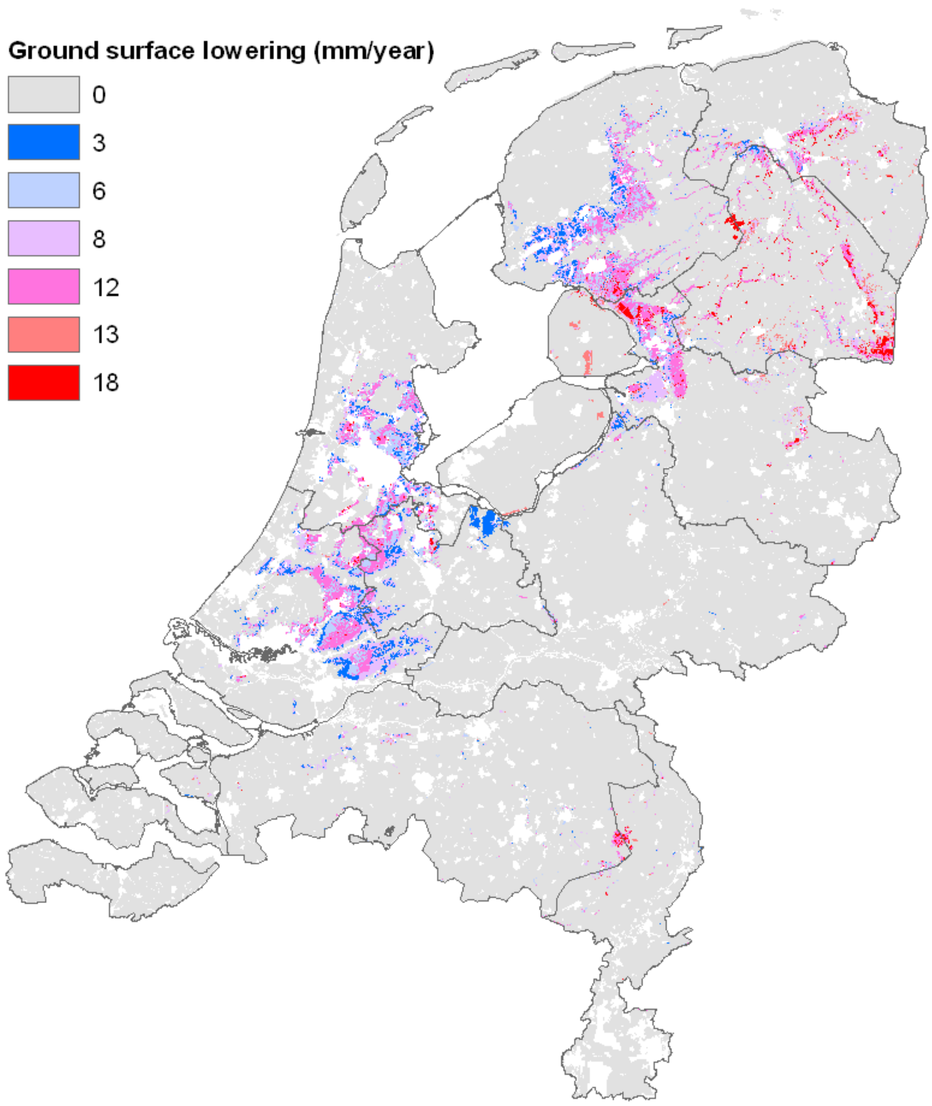

Figure A.5.3. Location of the organic soils and their average ground surface lowering

Based on the land use maps of 1990 and 2004 the locations of deforestation and re/afforestation were determined and overlaid with the ground surface lowering map (Figure A.5.3). The emissions from organic soils can now be calculated using the ground surface lowering rate, the bulk density of the peat, the organic matter fraction and the carbon fraction in organic matter (see Kuikman *et al.*, 2005). For organic soils under deforestation the assumption that emissions are equal to the emissions of cultivated organic soils seems valid. However, for re/afforestation this assumption rather conservative, since active drainage in forests is not common practice. However, since no data is available about emissions from peat soils under forest or about the water management of forests, we assume that emissions remain equal to the emissions on cultivated organic soils before re/afforestation.

3 Results

3.1 Mineral soils

Figure A.5.4 shows the land use conversions for deforestation and re/afforestation based on the land use change matrix of 1990-2004. Deforestation is mainly due to conversions of forest to grassland and settlement, whereas re/afforestation is mainly due to conversions of grassland and cropland to forest. The distribution of these land use changes over the main soil types is shown in Figure A.5.5. The average carbon stock changes per soil type for the land use conversion related to deforestation and re/afforestation are presented in Table A.5.2.

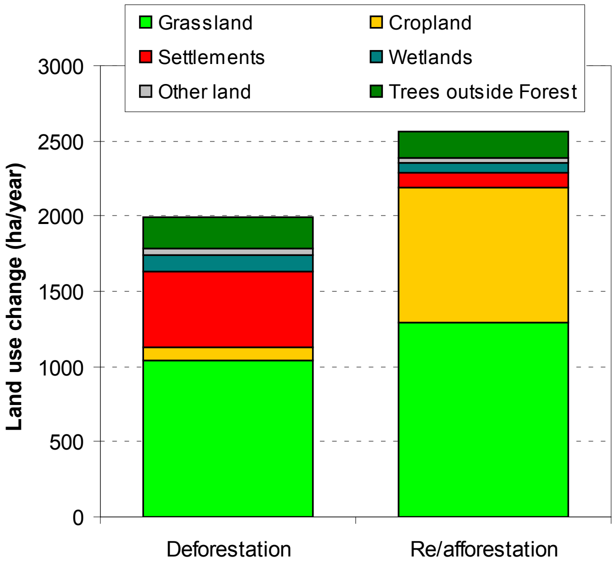

Figure A.5.4. Land use changes for deforestation and re/afforestation

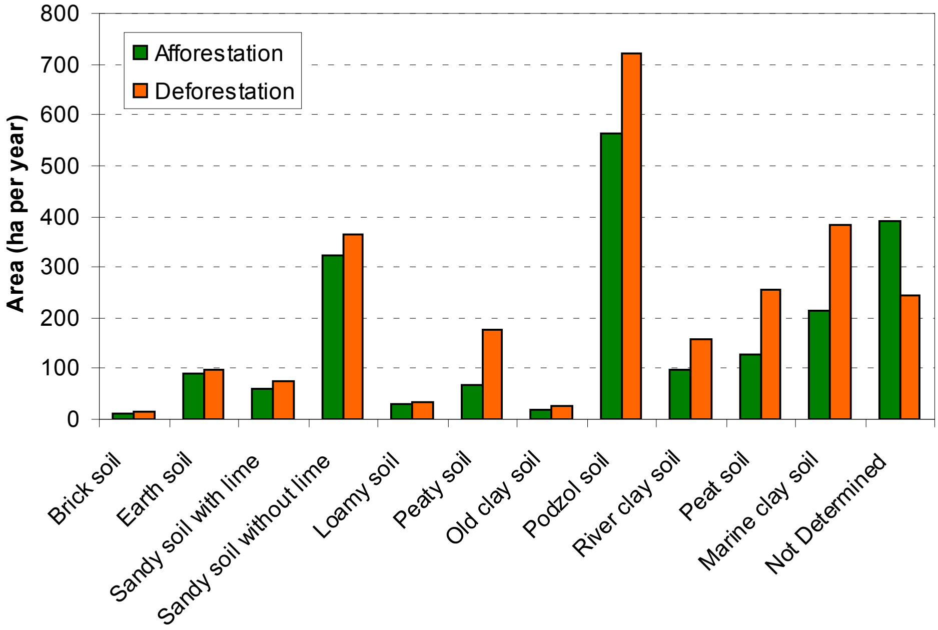

Figure A.5.5. Areas of re/afforestation and deforestation in relation to soil type

Table A.5.2. Average carbon stock changes per soil type for land use conversions (ton C/ha/year)

Soil type	**Grassland to forest**	**Cropland to forest**	**Settlements to forest**	**Wetlands to forest**	**Other land to forest**	**TOF to forest**	**Forest to grassland**	**Forest to cropland**	**Forest to settlements**	**Forest to wetlands**	**Forest to other land**	**TOF outside forest**
Brick soil	0.2	0.3	0.4	0.0	4.1	0.0	-0.2	-0.3	-0.4	0.0	-4.1	0.0
Earth soil	0.6	1.4	0.5	0.0	5.0	0.0	-0.6	-1.4	-0.5	0.0	-5.0	0.0
Sandy soil with lime	-1.3	-1.1	0.2	0.0	1.6	0.0	1.3	1.1	-0.2	0.0	-1.6	0.0
Sandy soil without lime	-1.5	-1.0	0.3	0.0	2.9	0.0	1.5	1.0	-0.3	0.0	-2.9	0.0
Loamy soil	1.2	1.5	0.6	0.0	5.6	0.0	-1.2	-1.5	-0.6	0.0	-5.6	0.0
Old clay soil	-1.0	-1.1	0.3	0.0	3.1	0.0	1.0	1.1	-0.3	0.0	-3.1	0.0
Podzol soil	-1.2	-0.8	0.5	0.0	4.6	0.0	1.2	0.8	-0.5	0.0	-4.6	0.0
River clay soil	1.4	2.8	0.7	0.0	7.0	0.0	-1.4	-2.8	-0.7	0.0	-7.0	0.0
Marine clay soil	1.3	2.9	0.7	0.0	7.0	0.0	-1.3	-2.9	-0.7	0.0	-7.0	0.0
Not determined	-0.9	0.3	0.4	0.0	4.4	0.0	0.9	-0.3	-0.4	0.0	-4.4	0.0

Combining the carbon stock changes per soil type with the related areas of deforestation and re/afforestation results in a net sink of 4.4 kton CO_2 per year for deforestation and a net sink of 32.7 kton CO_2 per year for re/afforestation in 2008. The reason for the net sink of deforestation is that a large part of the forest is converted to grassland and on sandy soils, where a large part of the forest is located, this results in an increase of the soil carbon pool. This offsets the negative carbon stock changes due to deforestation on other soil types.

3.2 Organic soils

In Table A.5.3 the result of the overlay of the ground surface lowering map of peat soils with the locations of re/afforestation and deforestation is shown. The average CO_2 emission from organic soils under re/afforestation is 23.7 ton CO_2 per year and under deforestation 23.9 ton CO_2 per year. This is slightly higher compared to the average of all cultivated land in the Netherlands. The total calculated CO_2 emission from organic soils for 2008 (19 years) is 93.6 kton CO_2 for re/afforestation and 49.9 kton CO_2 for deforestation. In addition to CO_2 also N_2O is emitted from the organic soils, however, this is reported under agriculture and not included in this note.

Table A.5.3. CO_2 emissions from organic soils under deforestation and re/afforestation

Ground surface	**Emission**	**Area**		**Total emission**	
lowering class		Re/afforestation	Deforestation	Re/afforestation	Deforestation
mm	kg C ha/year	ha/year	ha/year	kton CO_2/year	kton CO_2/year
3	1,848	12.1	6.5	0.08	0.04
6	3,696	31.6	21.2	0.43	0.29
8	4,928	47.5	16.4	0.86	0.30
12	7,392	69.1	44.8	1.87	1.21
13	8,008	22.4	5.7	0.66	0.17
18	11,088	25.3	15.2	1.03	0.62
Total		208.0	109.7	4.9	2.6

4 Discussion and conclusion

The new approaches for the calculation of the changes in carbon pools for both mineral and organic soils for reporting under the Kyoto Protocol have been described in this note. The approaches can be considered as updates of previous approaches used for reporting to the UNFCCC. The carbon stock changes for these two pools for 2008 are summarized in Table A.5.4.

Table A.5.4. Summary of carbon stock changes for re/afforestation and deforestation for 2008 (kton CO_2)

	Re/Afforestation	**Deforestation**
Mineral soils	32.7	4.4
Organic soils	-93.6	-49.9

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