Greenhouse gas reporting for the LULUCF sector in the Netherlands

Methodological background, update 2020

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Abstract

Arets, E.J.M.M., J.W.H van der Kolk, G.M. Hengeveld, J.P. Lesschen, H. Kramer, P.J. Kuikman & M.J. Schelhaas (2020). *Greenhouse gas reporting of the LULUCF sector in the Netherlands. Methodological background, update 2020*. Statutory Research Tasks Unit for Nature & the Environment (WOT Natuur & Milieu), Wageningen. WOt-technical report 168. 127 p; 21 Figures; 51 Tables; 69 References; 6 Annexes.

This report provides a complete methodological description and background information of the Dutch National System for Greenhouse gas reporting of the LULUCF sector. It provides detailed description of the methodologies, activity data and emission factors that were used. Each of the reporting categories Forest Land, Cropland, Grassland, Wetlands, Settlements, Other land and Harvested Wood Products are described in a separate chapter. Additionally it gives a table-by-table elaboration of the choices and motivations for filling the CRF tables for KP-LULUCF.

Keywords: Greenhouse Gas Reporting, Kyoto Protocol, Land Use, Land use Change, Forestry, LULUCF, National Inventory report, National system greenhouse gases, the Netherlands, UNFCCC, Emissions and Removals of greenhouse gases

Referaat

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Dit rapport geeft de methodologische achtergrondinformatie die gebruikt wordt binnen het nationale systeem om de broeikasgasemissies voor de LULUCF (landgebruik en bosbouw) sector te berekenen zoals die aan de VN Klimaatconventie (UNFCCC) en het Kyoto Protocol (KP) worden gerapporteerd. Het rapport geeft gedetailleerde beschrijvingen van de gehanteerde methodologie, gebruikte activiteitendata en emissie-factoren. De te rapporteren categorieën Bos (Forest land), Bouwland (Cropland), Grasland (Grassland), Wetlands, Bebouwd gebied (Settlements), Ander land, en geoogste houtproducten worden per hoofdstuk beschreven. Daarnaast worden in een apart hoofdstuk de gebruikte aggregatiestappen gegeven om tot de berekeningen voor het Kyoto Protocol te komen en worden voor iedere KP-LULUCF-CRF-tabel de gemaakte keuzes om de tabel te vullen, beschreven en gemotiveerd.

Trefwoorden: Broeikasgasrapportage, VN Klimaatconventie, Kyoto Protocol, LULUCF, Nationaal Inventarisatie Rapport, Nationaal Systeem Broeikasgassen, Nederland, emissies en verwijderingen van broeikasgassen.

Preface

This report provides a complete methodological 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 (KP-LULUCF) for its submissions from 2020 onwards.

The contents are largely the same as in the previous methodological background report (Arets et al. 2019) that was prepared with the NIR 2019. For the 2020 inventory submission five methodological changes have been implemented.

First, the trend in area of organic soils is extrapolated from 2014 onwards, in line with the gradually decreasing area of organic soils in the Netherlands between 1977 and 2014. In the NIR 2019 the area was kept constant after 2014. This change has an effect on areas of, and emissions from, organic soils in both the "land converted to" and "remaining" land use categories and also in the KP LULUCF activities Af/Reforestaion (AR), Deforestation (D) and Forest Management (FM). The updated methodology is described in Chapter 3.5.

Second, also the emission factors for drainage of organic (peat and peaty) soils have been improved to reflect the changed extent of organic soils that is the result of the use of the 2014 soil map. The emission factor for peat soils has decreased from an average of 19.0 ton CO_2 per ha of drained peat soil in 2004 (the date of the map, on which the original emissions factors are based) to 17.7 ton CO_2 per ha in 2014 (based on the 2014 soil map). The emission factor for peaty soils decreased from 13 ton CO_2 per ha in 2004 to 12 ton CO_2 per ha in 2014. Between 2004 and 2014 the trends in decreasing emission factors for peat and peaty soils are interpolated and after 2014 the trends are extrapolated. The emission factor before 2004 is set to that of 2004. Analyses are underway to also characterise the emission factor based on the 1977 soil map. This will be included in future submissions. This will then result in updated emission factors for the period 1990-2004.
Peat areas with deepest draining contribute relatively strongly to the emission factor for peat (see Chapter 11.2.1), while at the same time in these areas the peat layer is lost quickest, with in some cases total loss of the peat layer. As a result over time these areas do not longer contribute to the emissions from peat, resulting in the decreasing emission factors. This change has an effect on emissions from organic soils in both the "land converted to" and "remaining" land use categories and also in the KP LULUCF activities Af/Reforestaion (AR), Deforestation (D) and Forest Management (FM).

Third, N_2O emissions from drainage of organic soils under forest land are included. In the NIR2019 only the CO_2 emissions were reported. The updated methodology is described in Chapter 11.3.1.

Fourth, the total roundwood harvest is now completely allocated to forest land remaining forest land (Chapters 4.2.1 and 10 and Annex 1) to be more consistent with the used data for assessing roundwood harvests. This is an addition to the approach introduced in the NIR 2019 for assessing wood harvests from forests.

Fifth, the total area included in the reporting increased from 4,151.5 kha to 4,153 kha. Between 2008 and 2013 about 2000 ha of land was reclaimed from the sea as an extension of the harbour in Rotterdam (Maasvlakte 2). Until the NIR2019 the land area of the 1990 land-use map was used as the basis for all overlays. On this map the area of open water that includes the later harbour extension was only partly included.

The background report reflects as much as possible the structure for national inventory reports as laid out in the appendix to Decision 24/CP.19 and follows the guidance in Decision 6/CMP.9 and Annex II of Decision 2/CMP.8 for reporting activities under Article 3.3 and 3.4 of the Kyoto Protocol. Moreover the methodology follows the IPCC 2006 guidelines for Agriculture, Forestry and Other Land uses

(AFOLU) (IPCC 2006b) and the 2013 revised supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014).

Previous background documents to the submissions under the UNFCCC and Kyoto Protocol, dealing with similar topics, were published as *WOt-Technical Report 1, 26, 52, 89, 95 and 113* (Arets *et al*. 2013; 2014; 2015; 2017a; 2017b; 2018) and 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. (2006; 2008; 2009; 2011a; 2011b; 2012).

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Contents

1 Overview of the LULUCF sector

1.1 Introduction

The Netherlands is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and has also ratified the Kyoto Protocol, committing 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. Some important differences exist between the 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 of managed land, under KP activity based reporting needs to be applied. As of the second commitment period reporting of three types of activities are mandatory. These are the activities under Article 3.3 of the Kyoto Protocol, i.e. Afforestation/Reforestation and Deforestation, and Forest Management which is listed under Article 3.4 of the Kyoto Protocol. Other activities under Article 3.4 can be elected but the Netherlands has chosen not to do so. Due to the difference in emissions to be reported and accounted for under the Convention and KP, these also require different reporting practices. As a result the LULUCF sector 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 (CRF sector 4) and one for KP-LULUCF and is also reported in two different chapters in the NIR.

For GHG reporting of the Land Use, Land Use Change and Forests (LULUCF) sector (CRF Sector 4), the Netherlands has developed and improved an overall approach within the National System since 2003. Detailed background information on methods and assumptions have been documented in several publications, i.e. Nabuurs *et al.* (2003, 2005), De Groot *et al.* (2005), Kuikman *et al.* (2003, 2005) Van den Wyngaert *et al.* (2006, 2008, 2009, 2011a, 2011b and 2012), and Arets *et al.* (2013, 2014, 2015, 2017a, 2017b, 2018 and 2019).

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 methodological background report describes the methodological choices and assumptions as applied for the NIR 2020 onwards.

The applied methodologies meet the '*2006 IPCC Guidelines for National Greenhouse Gas Inventories*' (IPCC 2006b, hereafter referred to as *2006 IPCC Guidelines*) as implemented by Decision 24/CP.19. Additionally this methodological report provides the more detailed methodological background for the reported emissions under the KP in the second commitment period (NIR 2016 onwards) that should follow the 2006 IPCC guidelines and the '*2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*' (IPCC 2014, hereafter referred to as *2013 IPCC KP Guidance*) as implemented by Decisions 2/CMP.8 and 6/CMP.9.

Since there is a lot of overlap between the calculations of GHG emissions and reporting, this report combines the descriptions for LULUCF under the Convention and the Kyoto Protocol as much as possible. Where relevant for future reporting of KP-LULUCF already reference to KP-LULUCF is included.

An overview of the LULUCF sector is provided further in this Chapter 1. The definitions of land use categories are explained in Chapter 2. Information on approaches used for representing land areas, including land use change matrices is provided in Chapter 3. The calculation methods for emissions and removals from living biomass and dead organic matter for the different CRF categories are elaborated in Chapters 4-10.

Methods for emissions from soils are similar among the different categories. Therefore the methodology for soil emissions is separately presented in more detail in Chapter 11. Category specific issues are presented in the category chapters. In Chapter 12 the methodology to estimate GHG emissions from biomass burning is provided.

Chapter 13 provides detailed information on methods to generate the information related to Article 3.3 and Article 3.4 Forest Management of Kyoto Protocol. It presents the underlying sources of data and gives the methodologies used for estimating greenhouse gas emissions.

The uncertainty of the reported emissions was assessed using a Monte-Carlo approach as described in Chapter 14.

1.2 National circumstances relevant for the LULUCF sector

Here we provide a summary of the National circumstances, focussing on issues that are most relevant to understand the LULUCF sector and the assumptions and decisions taken in this report. For a more comprehensive overview of national circumstances covering all emission sectors, we refer to the relevant chapters in the National Communications of the Netherlands to the UNFCCC.

The Netherlands is a densely populated country. In 2017, the population amounted to 17.2 million people, with approximately 507 persons per km^2. A further important demographic factor influencing the pressure on the environment is a decrease in the number of persons per household to 2.16 in 2017 (Source: CBS Statline).

The Netherlands is a low-lying country situated in the delta of the rivers Rhine, IJssel and Meuse, with around 24% of the land below sea level. The highest point is 321 metres above sea level, at the border with Belgium and Germany, and the lowest point is 7 metres below sea level. The total land area is 4,151.5 kha, of which about 60% is used as agricultural land. While the use of land for agriculture is decreasing, land use for settlements and infrastructure is increasing.

The Netherlands is located in the 'temperate climate zone'. The 30-year annual average temperature in the centre of the country is about 10°C, while the mean annual average at 52°N is close to 4°C. An increase of around one degree has been measured in the Netherlands over the last 100 years, with the three warmest years of the last 300 years in 2006, 2014 and 2018.
Agriculture in the Netherlands focuses on dairy farming, crop production and horticulture; of which greenhouse horticulture is the most important subsector. The amount of horticulture in total agricultural production is increasing over time.

Cultivated organic soils are an important source of GHG emissions in the Netherlands. About 274,000 ha (or 6% of the total land area) of the Netherlands are covered by peat soils (excluding peaty soils, see Chapter 3.5). About 207,000 ha of this total peat area are under agricultural land use, mainly as permanent pastures for dairy farming, which is an economically important sector in the Netherlands. The strong modernisation and mechanisation of dairy farming about 40 years ago, required improved drainage and bearing capacity of the pastures on peat soils. To allow for this, in large areas ditch water levels are lowered, causing subsidence of the peat soils and associated emissions of greenhouse gases.

The forested area in the Netherlands by the end of 2016 was 365.58 kha, 8.8% of the total land area. Originally the largest part of the forested area in the Netherlands was planted using regular spacing and just one or two species in even-aged stands, with wood production being the main purpose. A change towards multi-purpose forests (e.g. nature, recreation), which was first started in the 1970s, has had an impact on the management of these even aged stands.

Most of the forested areas in the Netherlands are currently managed according to Sustainable Forest Management principles (see Annex 5 for more information on Dutch forests and their management). Newly established forests are also planted according to these principles. The results of this management style are clearly shown in the 6th National Forest Inventory (Schelhaas *et al.* 2014). Unmixed coniferous stands decreased in favour of mixed stands. Natural regeneration plays an important role in the transformation process from the even-aged, pure stands into those with more species and more age classes.

1.3 National system of GHG reporting for the LULUCF sector

As required by Decision 24/CP.19 The Netherlands follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006b; further referred to as 2006 IPCC Guidelines) for reporting under the UNFCCC. Category 4 'Land Use, Land use Change and Forestry' (LULUCF) consists of six land use categories:

4A Forest Land (FL)
4B Cropland (CL)
4C Grassland (GL)
4D Wetlands (WL)
4E Settlements (Sett)
4F Other Land (OL)

and the additional pool:

4G Harvested Wood Products (HWP)

This methodological background report concerns emissions and removals in the aforementioned six land use groups subdivided in the following two categories:

4.A.1 - 4.F.1: Land use remaining as such (e.g. 4.A.1 – Forest Land remaining Forest Land)
4.A.2 - 4.F.2: Land converted to another specific land use under 4A to 4F (e.g. 4.A.2 Land converted to Forest Land).

The Dutch methodology includes and reports on the entire terrestrial surface area of the Netherlands in a so-called wall-to-wall approach. The national system is based on activity data from land use and land use change matrices for the period 1990-2004, 2004-2009, 2009-2013 and 2013-2017. These matrices are based on topographic maps (see De Groot *et al.* (2005) for a motivation of using topographic maps as basis for our land use calculations). The maps dated at 1 January 1990, 2004, 2009, 2013 and 2017 are gridded in a harmonised way and an overlay produced all land use transitions within these periods (Kramer et al. 2009; van den Wyngaert et al. 2012). An overlay between the five land use maps with the two organic soil maps (Chapter 3.5) allowed estimating the areas of organic soils for reporting categories Forest Land [4A], Cropland [4B] and Grassland [4C]. New land use maps will be compiled on a regular basis (e.g. every 4 years) and then will be used to derive new land use matrices.

This report contains the definitions of land use categories and the allocation of land areas to land use categories (and changes between land use categories) based on the land use database for 1990, 2004, 2009, 2013 and 2017. This report also contains information for estimating data for CRF Tables 4(I)-4(V).

The carbon balance for living and dead biomass in **Forest Land remaining Forest Land** is based on National Forest Inventory (NFI) data and calculated using a bookkeeping model (Nabuurs *et al.*, 2005). NFI plot data are available from three inventories: the HOSP dataset (1988-1992, 3448 plots; Schoonderwoerd and Daamen 1999) the fifth National Forest Inventory dataset (NFI-5; 2001-2005; 3622 plots; Dirkse *et al*. 2007) and the sixth National Forest Inventory (NFI-6; 2012-2013; 3190 plots; Schelhaas *et al.* 2014). The accumulation of carbon in dead wood is based on measured values

in all three inventories, combined with some general parameters. Carbon stored in litter is estimated from a combination of national data sets (see Chapter 4).

The carbon balance for areas changing from **Forest Land to other land use categories** is based on the mean national stocks in biomass and dead organic matter as calculated from the NFI data for biomass and combined data sets for forest litter. On Forest land converted to Trees Outside Forest (TOF) it is assumed that the woody cover is continued, but do involve a loss of dead wood and litter (Chapter 6).

Cropland in the Netherlands mainly consists of annual crops. Therefore, consistent with the IPCC 2006 guidelines, no net accumulation of carbon in living biomass is estimated for **Cropland remaining Cropland**.

For carbon stock changes in living biomass in **Grassland remaining Grassland** that is outside the TOF category, the Netherlands applies the Tier 1 method assuming there is no change in carbon stocks (IPCC 2006b). However, changes in the relative contribution of Orchards to the Grassland area will change average carbon stocks on Grasslands outside TOF. Carbon stock changes in living biomass for the TOF category under Grassland will be the same as for Forests.

The carbon stock changes from changes in living biomass from **Land changing to and from Croplands and Grasslands** are based on Tier 1 methodology (see also Chapters 5 and 6), except for changes to and from 'Trees outside Forest' (Chapter 6).

This report provides the methods for calculating carbon stock levels in soils for the various types of land use (Chapter 11). In principle, the CO_2 emissions are calculated on the basis of changes in C stocks over specific time periods for specific types of land and could cover both losses (CO_2 emissions or sources) or gains (CO_2 sinks) for each land use category.

For mineral soils the CO_2 emissions have been calculated for all land use categories based on a Tier 2 approach. Lesschen *et al*. (2012) used the soil data from the national LSK soil survey, which were 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, which represent the main variation in carbon stocks within the Netherlands. The carbon stock changes are calculated following the land use changes and the 2006 IPCC Guidelines' transition period of 20 years in which the carbon stock changes take place. The carbon emission from cultivation of organic soils was estimated for organic soils (peat and peaty soils) under agriculture and settlements based on ground surface lowering and the characteristics of the peat layers (Kuikman *et al.*, 2005, de Vries et al. unpublished). Ground surface lowering was estimated from either ditch water level or mean lowest groundwater level (Kuikman *et al.*, 2005, de Vries et al. unpublished).

Emissions of N_2O and CH_4 as a result of fertilisation in forests (to be reported in CRF Table 4(I) and 4(II)) are reported 'not occurring' (NO) as these practices do not occur in Dutch forest ecosystems.

N_2O emissions from soil disturbance associated with land use conversions are estimated and are reported in Table 4(III) for the whole time series (from 1990).

Because it is not possible to separate the N inputs applied to land use categories, the direct nitrous oxide (N_2O) emissions from nitrogen (N) inputs to managed soils are reported in the agriculture sector.

Although forest fires seldomly occur in the Netherlands, CO_2, N_2O and CH_4 emissions resulting from forest fires are reported in Table 4(V) for the whole time series (from 1990). Also emissions from other wildfires (i.e. outside forests) are estimated. These emissions are calculated using Tier 1 methods in combination with historic information on annual areas burnt by wildfires in the Netherlands, average carbon stocks in forests for the particular calculation year and Tier 1 combustion and efficiency factors.

CO_2 emissions from drainage of organic soils is reported in CRF Tables 4.A to 4.F. Associated emissions of N_2O are reported in CRF Table 4(II). CH_4 emissions from wetlands are not estimated due to the lack of data.

The following emissions and removals are reported (Table 1.1). Details on the methodology per land use category can be found in Chapters 4-9. The methodology for assessing removals and emissions from harvested wood products is provided in Chapter 10 and those for soils are given in Chapter 11.

Table 1.1 *Carbon stock changes reported per land use (conversion) category.*

From→ To↓	FL	CL	GL (non TOF)	GL (TOF)	WL	Sett	OL
FL	BG, BL, DW, FF	BG, BL, MS, OS	BG, BL, MS, OS	BG, BL, MS, OS	BG, MS	BG, MS, OS	BG, MS
CL	BG, BL, DW, Litt, MS, OS	OS	BG, BL, MS, OS	BG, BL, MS, OS	BG, MS, OS	BG, MS, OS	BG, MS, OS
GL (non TOF)	BG, BL, DW, Litt, MS, OS	BG, BL, MS, OS	BG, BL, WF, OS	BG, BL, MS, OS	BG, MS, OS	BG, MS, OS	BG, MS, OS
GL (TOF)	BG, BL, DW, Litt, MS	BG, BL, MS, OS	BG, BL, MS, OS	BG	BG, MS	BG, MS, OS	BG, MS
WL	BL, DW, Litt, MS	BL, ML, OS	BL, MS, OS	BL, MS, OS		MS, OS	MS
Sett	BL, DW, Litt, MS	BL, ML, OS	BL, MS, OS	BL, MS, OS	MS, OS	OS	MS, OS
OL	BL, DW, Litt, MS	BL, MS, OS	BL, MS, OS	BL, MS	MS	MS, OS	n.a.

Carbon stock changes included are: BG: Biomass Gain; BL: Biomass Loss; DW: Dead Wood; FF: Forest fires; WF: other wildfires; Litt: Litter; MS: Mineral Soils; OS: Organic Soils. Land use types are: FL: Forest Land; CL: Cropland; GL: Grassland; TOF: Trees outside Forest; WL: Wetland; Sett: Settlement; OL: Other Land.

1.4 Workflow

The calculations of areas of land use change, carbon stock changes in biomass and soil and for harvested wood products is the result of combining a large number of databases and maps as input and intermediary calculations. Figure 1.1 gives the work flow of how the different input sources and intermediary calculations are combined to get to the required output data. The basis of this work flow is the same for each CRF table. The results are calculated for all relevant land use change trajectories (Section 3.6) that can be aggregated differently in such way that the aggregation becomes relevant for the UNFCCC CRF classes or KP classification in Afforestation, Reforestation, Deforestation or Forest Management. An overview of input data sources used is provided in Annex 1.
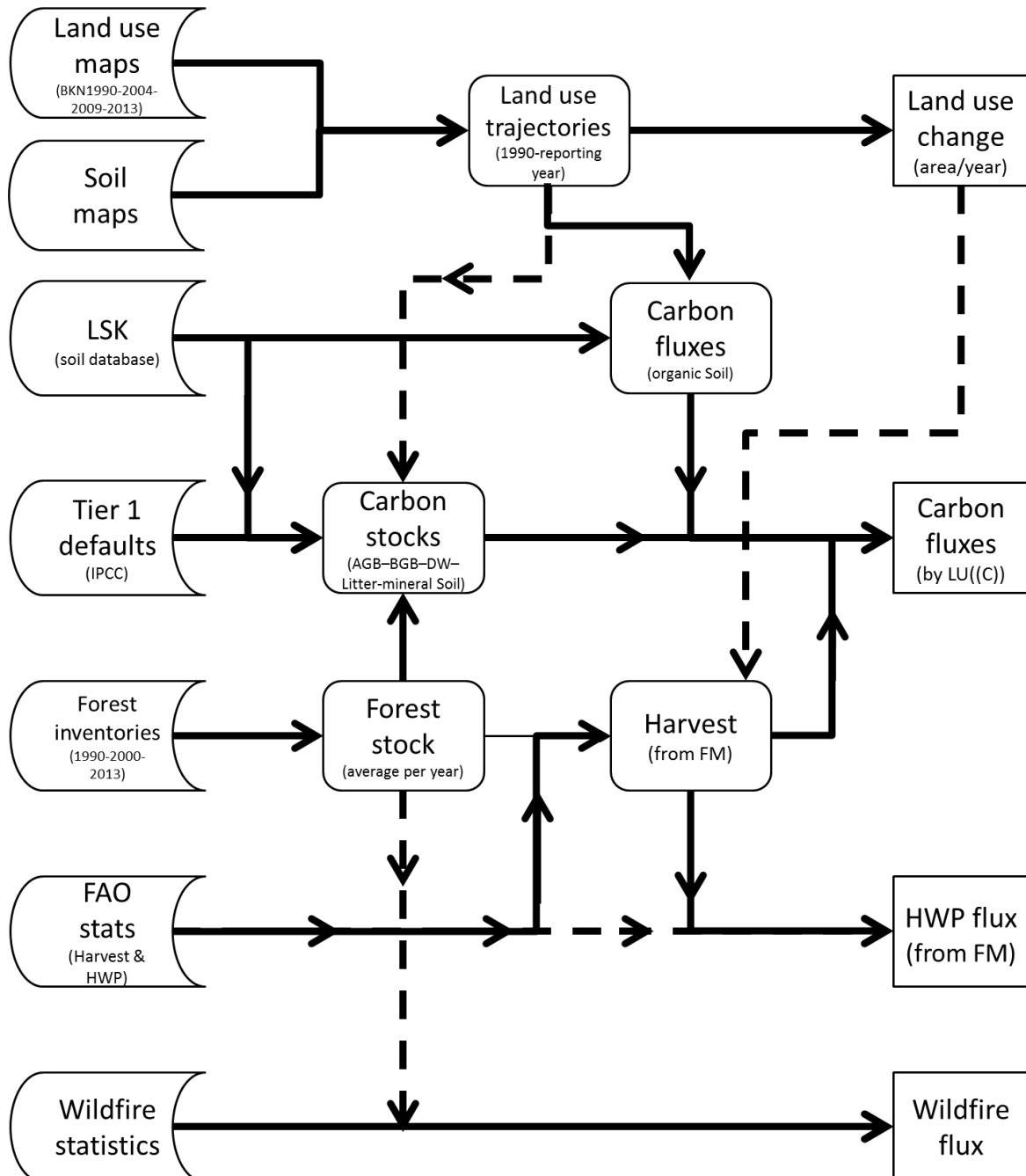
Figure 1.1 *High level overview of the work flow and aggregation of information for calculating the greenhouse gas emissions and removals from the input sources (left), intermediary calculations (middle, rounded squares) and the resulting outputs (right, squares).*

1.5 Kyoto Protocol

Annex II to decision 2/CMP.8 (28 February 2013) includes guidelines on the submission of information on anthropogenic greenhouse gas emissions by sources and removals by sinks from LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol in annual greenhouse gas inventories for its second commitment period. Parties are required to report information on the mandatory Article 3.3 activities (Afforestation, Reforestation and Deforestation) and the Article 3.4 activity Forest Management, which is also mandatory during the second commitment period. Elected activities under Article 3.4 should be the same as during the first commitment period. Additional guidance for reporting information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol and the relevant common reporting format tables are included in Decision 6/CMP.9.

Similar to the first commitment period, the Netherlands has not elected any of the voluntary activities listed under Article 3.4 of the Kyoto Protocol and therefore will only report on emissions related to the compulsory activities; Afforestation (A), Reforestation (R), Deforestation (D), and Forest Management (FM), including Harvested Wood Products (HWP).

The Netherlands prepares its inventories for LULUCF in accordance with relevant decisions of the COP/MOP on land use, land use change and forestry. For providing information on anthropogenic greenhouse gas emissions from LULUCF the Netherlands will apply the 2006 IPCC guidelines (IPCC, 2006) and the "*2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*" (IPCC 2014).

Emissions and removals related to Article 3.3 and 3.4 activities are not included in the national emissions reported under the Convention. The net emissions/removals from these activities are counted as additions or subtractions to the assigned amount (instead of being added to Annex A emissions).

Chapter 13 provides detailed information on the Kyoto tables and how it is based on background information. It presents the underlying sources of data and gives the methodologies used for estimating greenhouse gas emissions from LULUCF. Special issues arising from the methodology used are further elaborated.

This report provides the definition of Forest (Section 2.2) as well as information on the definition of Afforestation and Reforestation (AR), Deforestation (D) as well as to Forest Management (FM) (Section 13.2) and the allocation of land areas to these activities based on the available land use databases (Section 13.3.2). Information on NIR-1 to NIR-3 is provided in Section 13.3. Information on the aggregation of carbon stock changes under AR, D, FM and HWP as reported in the CRF Tables 4(KP), 4(KP-I)A.1, 4(KP-I)A.2, 4(KP-I)B.1, and 4(KP-I)C is provided in Sections 13.4 to 13.6.

Information on the CRF 4(KP-II) tables on other greenhouse gases is provided in Section 13.7. This includes direct N_2O emissions from nitrogen fertilisation (4(KP-II)1, Section 13.7.1), CH_4 and N_2O emissions from drained and rewetted organic soils (4(KP-II)2, Section 13.7.2), N_2O emissions from disturbance associated with land use conversion and management in mineral soils (4(KP-II)3, Section 13.7.3) and Greenhouse gas emissions from biomass burning (4(KP-II)4, Section 13.7.4).

2 Definition of land use categories

2.1 Background

The 2006 IPCC guidance (IPCC 2006b) 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 Grasslands remaining Grasslands (grassland vegetation, nature area, fruit orchards and trees outside forests) and Wetlands (reed swamps and open water).

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 the 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 2006 IPCC guidelines' definition of wetlands. This includes open water bodies, which are typically not defined as wetlands in the scientific literature. 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.

2.2 Forest Land (4.A)

The land use category **'Forest Land'** all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently fall below, but in situ could potentially reach the threshold values used by a country to define the Forest Land category (Chapter 3.2 in IPCC 2006b).

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 areas). This is further defined as:
- forests are patches of land exceeding 0.5 ha with a minimum width of 30 m;
- with tree crown cover of at least 20% and;
- tree height at least 5 metres, or, if this is not the case, these thresholds are likely to be achieved at the particular site.

This definition conforms to the FAO reporting and was chosen within the ranges set by the Kyoto protocol.

Forest may consist of either closed forest formations, where trees of various heights and undergrowth cover a high proportion of the ground, or open forest formations with a continuous vegetation cover in which tree crown cover exceeds 20%. Young natural stands and all forest plantations that have yet to reach a crown density of 20% or tree height of 5 metres are included under the term 'forest', as are areas normally forming part of the forest area, which are temporally unstocked as a result of human intervention or natural causes, but which are expected to revert to forest land.

Forest land also includes:

- Forest nurseries and seed orchards, only in case these constitute an integral part of the forest.
- Forest roads, cleared tracts, firebreaks and other small open areas, which are smaller than 6 metres within the forest.
- Forest in national parks, nature reserves and other protected areas, such as those of special environmental, scientific, historical, cultural or spiritual interest, covering an area of over 0.5 ha and a width of over 30 metres.
- Windbreaks and shelterbelts of trees.

This excludes tree stands in agricultural production systems, for example in fruit plantations and agro-forestry systems. Units of land with trees that does otherwise meet the Forest definition except for the minimum area of 0.5 ha are not reported as Forest land but as Trees outside Forest (TOF) as a subcategory under Grassland.

The topographic map classes (Chapter 3) that are reported under Forest land are deciduous forest, coniferous forest, mixed forest, poplar plantations and willow coppice. 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. A patch of a certain forest class is allocated to Forest land if it exceeds the minimum area requirements, i.e. larger than 0.5 ha and more than 30 m width, and to Trees outside Forest otherwise.

In the Netherlands, all forest land is considered to be managed. Consequently all emissions and removals are reported under managed land, and no further sub-division is used between managed and unmanaged forest land.

Due to the resolution of the land use maps, small changes at the border of forest between the different land use maps may show up as forest no longer connected to the larger forest area, while in the next land use maps this connecting is 'restored'. Also forest area could be separated by small areas of settlements (e.g. the construction of a road).

2.3 Cropland (4.B)

The land use category '**Cropland**' includes arable and tillable land, rice fields, and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category, and is not expected to exceed those thresholds at a later time (Section 3.2 in IPCC 2006b).

The Netherlands has chosen to define croplands as arable lands and nurseries (including tree nurseries). For part of the agricultural land, rotation between arable land and grassland is frequent, but data on where exactly this is occurring are 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 are reported (Chapter 3). 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.

2.4 Grassland (4.C)

The land use category '**Grassland**' includes different types of vegetation. At the level of the reporting two main sub-categories are identified: 1) Grassland and 2) 'Trees outside Forest' (TOF) (see Table 2.1). The subcategory Grassland will be identified with 'Grassland (non-TOF)' to prevent confusion with the main category Grassland.

The conversions of land use from and to Grassland (non-TOF) and Trees outside Forest are separately monitored and subsequent calculations of carbon stock changes differ (see Chapter 6)

Table 2.1 *Division of the main category Grassland in sub-categories that are reported in the NIR and CRF tables and the underlying subcategories for Grassland (non-TOF).*

Main category	Reported sub-categories	Underlying sub-categories
Grassland (4.C)	Grassland (non-TOF)	Grassland vegetation
		Nature
		Orchards
	Trees Outside Forest	-

Grassland (non-TOF)

The Grassland (non-TOF) category covers land that is dominated by a grassland vegetation, including rangelands and pasture land that are not considered Cropland. It covers all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, consistent with national definitions (Section 3.2 in IPCC 2006b). It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category.

This sub-category is further stratified in (also see Table 2.1):
- 'Grassland vegetation', i.e. all areas predominantly covered by grass vegetation (whether natural, recreational or cultivated).
- 'Nature', i.e. all natural areas not covered under the grassland vegetation. It mainly consists of heathland, peat moors and other nature areas. Many nature areas have the occasional tree as part of the typical vegetation structure.
- Orchards, i.e. areas with standard fruit trees, dwarf varieties or shrubs. They do not conform to the forest definition, and while agro-forestry systems are mentioned in the definition of Croplands, in the Netherlands the main undergrowth of orchards is grass. Therefore, these orchards are reported under grasslands.

The topographic map (Chapter 3) class heathland and peat moors, as stratified to 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 landscape and the high biodiversity values associated with it.

In background calculations of the land use matrix, this 'nature' category is seen as a separate (spatially explicit) land use class, and all land use transitions to and from this class are treated in the same way as transitions to and from other classes. However, in the reporting 'nature' is seen as a subcategory of grasslands and transitions between 'nature' and grassland vegetation are therefore treated as Grassland (non-TOF) remaining Grassland (non-TOF). When land use on a unit of land changes, the soil carbon stock will gradually change from the current value to the new equilibrium value, assuming a transition period of 20 years. If land use on the same unit of land again changes before the 20 years transition is finished, a new 20 year transition period is started, using the same calculation method. Land is always reported under its last known transition. A piece of land that is converted from cropland to 'nature' and subsequently to grassland vegetation will therefore be reported first under Cropland converted to Grassland (non-TOF) until its conversion to grassland vegetation, and as Grassland (non-TOF) remaining Grassland (non-TOF) thereafter.

In the calculations orchards are not spatially explicitly included. Instead statistics on areas of fruit orchards as reported by Statistics Netherlands[1] are used. It includes the cultivation areas for apples, pears, stone fruits (plum, cherry), nuts and small fruit (blueberry, blackberry, raspberry, red currant, wine grape, black currant). The area of small fruit is excluded in the used area for orchards. Data are available from 1992 and are updated annually with provisional figures for the previous year being published in April. Areas for 1990 and 1991 are estimated based on extrapolation of the trend 1992-1993.

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[1] https://opendata.cbs.nl/statline/#/CBS/en/dataset/70671ENG/table?ts=1517913547111

Trees outside Forest

'Trees outside Forest' are wooded areas that comply with the forest definition (see Section 2.2) except for their surface, i.e. they are smaller than 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.

On the topographic map classes (Chapter 3) groups of trees are mapped as forest if they have a minimum surface of 50 m^2, or of 1000 m^2 in built-up areas or parks. If such patches of trees subsequently also meet the Forest definition minimum area requirement (>0.5 ha) these units of land are allocated to Forest land, but if the patch remains smaller than 0.5 ha it will be allocated to Trees outside Forest.

2.4.1   Wetland (4.D)

The land use category '**Wetland**' includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions (Section 3.2 in IPCC 2006b).

The Netherlands is characterised by many wet areas, but because many of these areas are covered by a grassy vegetation 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 included in Forest Land.

In the Netherlands, only reed marshes and open water bodies are included in the Wetlands 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 on the topographic maps. Because it is not included in any of the previous categories its was translated to separate areas in the extracted land use maps (Kramer *et al.*, 2007, Chapter 3). In the Netherlands there is currently no peat extraction.

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.

2.5   Settlements (4.E)

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 (Section 3.2 in IPCC 2006b).

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 classes are actually covered by grass, the distinction cannot be made based on maps.

2.6   Other Land (4.F)

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 (Section 3.2 in IPCC 2006b).

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 Representation of land and land use change matrix

3.1 Introduction

The Netherlands has a full and spatially explicit land use mapping that allows for geographical stratification at 25 m x 25 m (0.0625 ha) pixel resolution (Kramer *et al*. 2009; *van den Wyngaert et al.* 2012). This corresponds with the wall-to-wall approach used for reporting under the Convention (approach 3 in Chapter 3 of IPCC 2006b) and is described as reporting method 2 in the *2013 IPCC KP Guidance* (Section 2.2.2 of IPCC 2014).

This approach was chosen 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 five maps representing the land use on 1 January 1990 (Kramer and van Dorland 2009), 2004 (Kramer *et al.* 2007), 2009 (Kramer and Clement 2016), 2013 (Kramer and Clement 2015) and 2017 (Kramer 2019, and see further in Chapter 3.2). These maps thus represent land use changes from 1 January 1990 until 1 January 2017.

In Kramer *et al.* (2009, 2015) all steps involved in the calculation of the land use and land use change matrix used are described in detail. In this chapter a short summary of the methodology is given and the resulting land use change matrices derived from map overlays are given. In addition, a number of corrections to afforestation and deforestation that were necessary in the 2017 map are described in Chapter 3.2, below.

3.2 Source maps

The land use maps are based on the Nature Base maps that were originally used for monitoring nature development in the Netherlands; in Dutch 'Basiskaart Natuur' (BN). After 2009 these maps were not used anymore for monitoring nature development, but in order to guarantee consistency in the land-use change matrix for LULUCF reporting they are still developed on request as a basis for the LULUCF land-use change monitoring.

These maps are based on different topographic maps of the Dutch Kadaster (Land Registry Office). The source material for BN1990 (Kramer and van Dorland 2009) consists of the topographic map 1:25,000 (Top25) and digital topographic map 1:10,000 (Top10Vector, see Table 3.1 for more details). The paper TOP25 maps were converted to a digital high resolution raster map. The source material for BN2004 (Kramer *et al.* 2007) consists of the digital topographic map 1:10,000 (Top10Vector).

The source materials for BN2009 (Kramer and Clement 2016),BN2013 (Kramer and Clement 2015) and BN2017 (Kramer 2019) are based on the Top10NL digital topographic maps 1:10,000, which is the successor of the Top10Vector map. The Top10NL maps differ in some aspects from the Top10Vector maps. 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. On the 2013 map the representations of these elements were similar to the 2009 map as both are based on the TOP10NL source.

For all years the most recent version of the topographic map on 1 January of that year was used (i.e. based in the most recent aerial source photographs at that time, see Table 3.1). The BN 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 (see Annex 2 for the land use statistics and land use maps for the different years). The latest BN maps, therefore, paid attention to the requirements for UNFCCC reporting.

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 3.1   *Characteristics of the maps BN1990, BN2004, BN2009 BN2013 and BN2017.*

Characteristics	BN1990	BN2004	BN2009	BN 2013	BN 2017
Name	Historical Land use Netherlands 1990	Base map Nature 2004	Base map Nature 2009	Base map Nature 2013	Base map Nature 2017
Aim	Historical land use map for 1990	Base map for monitoring nature development		Consistent monitoring of land use and land-use change for LULUCF	
Resolution	25 m				
Coverage	The Netherlands				
Base year source data	1986-1994	1999-2003	2004-2008	2009-2012	2015
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			
Number of classes	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			

Correction of forest area on the 2017 land-use map
A comparison of the 2013 and 2017 map showed a net loss of forest area. Further investigation revealed the following causes for this reduction:
1. Deforestation continued in more or less the same pace as before, mainly due to conversion of forest to settlements, for nature development and because temporary poplar forests that were planted 25-30 years ago under a set aside regulation for agricultural land, were harvested and converted back to agriculture in line with the conditions in the regulation.
2. Afforestation declined considerably. While in principle deforestation needs to be compensated with afforestation of an equal area elsewhere, exception to these rules is when conversion to priority nature takes place on the basis of ecological arguments, like on the basis of Natura 2000 management plans. In such cases forest conversion can take place without compensation..
3. Some areas were mapped in greater detail than before, particularly build-up areas with a lot of trees. Part of these areas were earlier incorrectly classified as forest and now on the 2017 map corrected to settlement.

4. In recent years several forest owners increased their harvest activity in the forest, with in many cases an explicit orientation to facilitate regeneration or to introduce different species. These practices need larger clear cut areas. Subsequently these areas on the 2017 map were often incorrectly classified as heathland or grassland, while in fact these areas are only temporary unstocked and therefore according to the forest definition should have been classified as forest land.

Points 1 and 2 above, are considered valid explanations of the observed development. Point 3, however, leads to a (small) overestimation of the forest area on earlier maps which is now corrected. Because correcting and reclassifying earlier maps was considered to be an excessive effort, this "deforestation" was accepted as a conservative estimate.

The misclassifications as indicated under point 4 above, were corrected using the following procedure.
- All polygons that were classified as deforestation of 1 ha and larger were checked visually using aerial images.
- Each polygon was assigned a code: accept deforestation, reject deforestation or uncertain. In most cases, the difference between a nature development project or a regeneration felling was clearly visible. Nature development projects were often irregular in shape, connected open areas in the landscape and/or were adjacent to existing open areas. Regeneration areas were usually of a more regular size, not too large, well within the forest boundaries and often already showed signs of a new regeneration of trees. In a few cases no decision could be made and the polygon was classified as uncertain.
- In order to decrease future uncertainty around afforestation and deforestation, we also checked all polygons equal to or larger than 1 ha that were converted to forest.
- These were also classified as accept, reject or uncertain based on the visual interpretation of the aerial images.
- These maps were combined into a BN2017 correction layer which was used to create a corrected BN2017 map.
   - For all pixels located in polygons classified as "accept" the land use in 2017 was accepted.
   - For all pixels located in polygons classified as "reject", the land use from the 2013 map was restored.
   - The same procedure was applied to pixels located in a polygon classified as "uncertain". In this way, these pixels will not be deforested now and afforested again in the next map if incorrectly classified, and will still be classified as deforested if the next map and aerial pictures provide evidence of deforestation. The same applies to the pixels labelled as uncertain afforestation.

Table 3.2   *Result of the check of deforestation and afforestation polygons derived from the BN2013 and 2017 maps. All deforestation and afforestation polygons ≥ 1 ha were checked.*

Result	Afforestation (ha)	Deforestation (ha)
accept	2319.0	5233.6
reject	135.7	688.9
in doubt (reject)	300.1	431.9
not checked (< 1 ha)	6627.1	13878.0
total	9381.9	20232.4

The same procedures will be applied to forthcoming land use maps. The correction was limited to polygons of 1 ha and more because of the huge number of separate polygons classified as afforestation or deforestation, and because the misclassifications due to regeneration areas are most likely to be in this size category. Out of the more than 144 thousand polygons classified as deforested, the majority (~75%) was of the size of a single pixel (25 m x 25 m). For deforestation, 2046 polygons were checked, equal to 6354 ha out of the total 20,232 ha classified as deforestation (Table 3.2). For afforestation, 1134 polygons were checked, equal to 2754.8 ha out of the 9381.9 ha classified as afforestation (Table 3.2).

3.3 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 (Section 3.2), 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 would be 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, 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 3.3.

Table 3.3 *Overview of allocation of topographic classes to IPCC land use (sub)categories (based on Kramer et al. 2007).*

Topographic class	Dutch name	IPCC 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
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

3.4 Land use change matrix

The land use change matrices are the result of overlays between land use maps of 1990 and 2004, of 2004 and 2009, of 2009 and 2013 and of 2013 and 2017, using 25 m × 25 m grid cells. Until the NIR 2019 the 1990 map was used as a mask for the overlay of all maps, resulting in a constant total land area. However, from the NIR 2020 onwards the 2017 land-use map was used as the basis for all overlays to be able to include the total area of the of land that was reclaimed from the sea as an extension of the harbour in Rotterdam (Maasvlakte 2), which is ongoing since 2008 (see the 2017 map, Figure A2.5, Annex5). The total extent of this area is about 2000 ha. About 0.5 kha of this area was already included as sea (open water) in the 1990 map. As a result of this change there are differences in the total land area and land-use changes compared to the previous versions. The total area included in the reporting increased by 1.5 kha from 4,151.5 kha to 4,153 kha. By 1-1-2017 (i.e. the date of the 2017 map), the outer contour with seawall and part of the reclamation was completed, resulting in increased changes in land use from Wetland to Settlement and Other land between 2013

and 2017 compared with the old situation. Note that part (0.5 kha) of the changes that were within the mask of the 1990 map were already included in the old situation.

The overlay of the land use maps of 1990 and 2004 resulted in a land use and land use change matrix over fourteen years (1-1-1990 to 1-1-2004; Table 3.4). The overlay of the land use maps of 2004 and 2009 results in a land use change matrix over five years (1-1-2004 to 1-1-2009; Table 3.5), while the overlays of the 2009, 2013 and 2017 maps results in a land use change matrices over 4 years (1-1-2009 to 1-1-2013; Table 3.6, and 1-1-2013 to 1-1- 2017; Table 3.7).

These matrices show 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 3.4, to 3.7, and annual changes in Tables 3.8 to 3.11). The definitions of the UNFCCC land use categories are given in Chapter 2.

Table 3.4   *Land Use and Land Use Change Matrix for 1990-2004 aggregated to the six UNFCCC land-use categories (in ha) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

| BN 1990 | BN 2004 | | | | | | | |
	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	Total
Forest land	334,211	1,218	14,586	2,852	1,503	7,031	699	*362,100*
Cropland	12,520	739,190	176,797	2,039	6,821	81,782	201	*1,019,352*
Grassland (non-TOF)	18,066	196,595	1,190,740	4,474	18,641	78,259	907	*1,507,682*
Trees outside forest	2,352	386	3,316	11,336	319	2,988	110	*20,806*
Wetland	888	596	9,092	328	777,519	2,836	2,791	*794,051*
Settlement	1,452	1,623	10,987	1,078	1,390	392,804	122	*409,457*
Other land	552	8	2,547	98	2,583	629	33,143	*39,562*
Total	*370,041*	*939,617*	*1,408,064*	*22,207*	*808,777*	*566,330*	*37,973*	*4,153,009*

Table 3.5   *Land Use and Land Use Change Matrix for 2004-2009 aggregated to the six UNFCCC land-use categories (in ha) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

| BN 2004 | BN 2009 | | | | | | | |
	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	Total
Forest land	357,474	350	5,219	1,516	703	4,571	208	*370,041*
Cropland	2,007	813,282	108,480	297	1,794	13,729	27	*939,617*
Grassland (non-TOF)	7,119	106,547	1,243,329	1,708	10,610	37,705	1,047	*1,408,064*
Trees outside forest	1,701	137	1,198	16,893	126	2,122	30	*22,207*
Wetland	374	177	9,633	92	796,297	1,441	762	*808,777*
Settlement	4,597	4,367	23,123	1,558	3,033	529,415	237	*566,330*
Other land	209	2	506	29	890	137	36,200	*37,973*
Total	*373,480*	*924,863*	*1,391,488*	*22,092*	*813,453*	*589,121*	*38,512*	*4,153,009*

Table 3.6 *Land Use and Land Use Change Matrix for 2009-2013 aggregated to the six UNFCCC land-use categories (in ha) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

| BN 2009 | BN 2013 | | | | | | | |
	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	Total
Forest land	360,211	1,315	6,245	1,483	699	3,324	204	*373,480*
Cropland	2,480	793,892	116,002	311	1,410	10,740	28	*924,863*
Grassland (non-TOF)	8,081	145,410	1,194,126	1,591	10,849	30,915	516	*1,391,488*
Trees outside forest	1,347	220	1,534	17,215	164	1,582	31	*22,092*
Wetland	651	304	6,179	112	803,050	1,311	1,846	*813,453*
Settlement	2,530	3,198	20,653	815	4,477	557,312	135	*589,121*
Other land	444	1	970	49	1,825	328	34,896	*38,512*
Total	*375,743*	*944,340*	*1,345,709*	*21,575*	*822,474*	*605,512*	*37,656*	*4,153,009*

Table 3.7 *Land Use and Land Use Change Matrix for 2013-2017 aggregated to the six UNFCCC land-use categories (in ha) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

	BN 2017							
BN 2013	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	*Total*
Forest land	356,631	1,662	9,345	2,012	804	4,886	404	*375,743*
Cropland	901	762,447	170,184	244	1,674	8,865	24	*944,340*
Grassland (non-TOF)	4,816	103,116	1,197,036	1,500	9,185	28,661	1,394	*1,345,709*
Trees outside forest	1,143	205	1,658	16,549	146	1,834	41	*21,575*
Wetland	837	291	6,717	191	807,284	4,417	2,736	*822,474*
Settlement	1,034	2,582	21,372	710	1,559	578,065	191	*605,512*
Other land	215	7	735	34	1,399	429	34,838	*37,656*
Total	*365,577*	*870,310*	*1,407,046*	*21,240*	*822,052*	*627,156*	*39,628*	*4,153,009*

The total area of land use change in the period 1990 to 2004 was about 6,741 km², which is around 16% of the total area, in the period 2004 to 2009 3,601 km² (8.7%), in the period 2009-2013 3,923 km² (9.4%), and in the period 2013-2017 4,002 km² (9.6%) changed. Note, however, that the time intervals differ among these periods, which results in accelerating dynamics of land use change from 481 km² yr⁻¹ over 1990-2004, 720 km² yr⁻¹ over 2004-2009, 981 km² yr⁻¹ over 2009-2013 to 1,000 km² yr⁻¹ over 2013-2017. The largest changes in land use are seen in the conversion of cropland to grassland and vice versa. Other important land use changes are the conversions of Cropland and Grassland to Settlements (urbanisation).

Table 3.8 *Annual changes in land us for the period 1990-2004 aggregated to the six UNFCCC land use categories (in ha yr⁻¹) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

	To:							
From:	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	Total
Forest land		87	1,042	204	107	502	50	*1,992*
Cropland	894		12,628	146	487	5,842	14	*20,012*
Grassland (non-TOF)	1,290	14,042		320	1,332	5,590	65	*22,639*
Trees outside forest	168	28	237		23	213	8	*676*
Wetland	63	43	649	23		203	199	*1,181*
Settlement	104	116	785	77	99		9	*1,189*
Other land	39	1	182	7	184	45		*458*
Total	*2,559*	*14,316*	*15,523*	*777*	*2,233*	*12,395*	*345*	*48,147*

Table 3.9 *Annual changes in land us for the period 2004-2009 aggregated to the six UNFCCC land use categories (in ha yr⁻¹) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

	To:							
From:	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	Total
Forest land		70	1,044	303	141	914	42	*2,513*
Cropland	401		21,696	59	359	2,746	5	*25,267*
Grassland (non-TOF)	1,424	21,309		342	2,122	7,541	209	*32,947*
Trees outside forest	340	27	240		25	424	6	*1,063*
Wetland	75	35	1,927	18		288	152	*2,496*
Settlement	919	873	4,625	312	607		47	*7,383*
Other land	42	0	101	6	178	27		*355*
Total	*3,201*	*22,316*	*29,632*	*1,040*	*3,431*	*11,941*	*462*	*72,024*

Table 3.10 *Annual changes in land us for the period 2009-2013 aggregated to the six UNFCCC land use categories (in ha yr^{-1}) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

From:	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	Total
Forest land		329	1,561	371	175	831	51	*3,317*
Cropland	620		29,000	78	352	2,685	7	*32,743*
Grassland (non-TOF)	2,020	36,352		398	2,712	7,729	129	*49,340*
Trees outside forest	337	55	383		41	396	8	*1,219*
Wetland	163	76	1,545	28		328	461	*2,601*
Settlement	633	799	5,163	204	1,119		34	*7,952*
Other land	111	0	242	12	456	82		*904*
Total	*3,883*	*37,612*	*37,896*	*1,090*	*4,856*	*12,050*	*690*	*98,077*

Table 3.11 *Annual changes in land us for the period 2013-2017 aggregated to the six UNFCCC land use categories (in ha yr^{-1}) with Grassland (GL) divided in GL non-TOF and Trees outside Forest (TOF).*

From:	FL	CL	GL (non-TOF)	TOF	WL	Sett	OL	*Total*
Forest land		415	2,336	503	201	1,221	101	*4,778*
Cropland	225		42,546	61	419	2,216	6	*45,473*
Grassland (non-TOF)	1,204	25,779		375	2,296	7,165	349	*37,168*
Trees outside forest	286	51	415		37	458	10	*1,257*
Wetland	209	73	1,679	48		1,104	684	*3,797*
Settlement	258	645	5,343	177	390		48	*6,862*
Other land	54	2	184	8	350	107		*705*
Total	*2,236*	*26,966*	*52,503*	*1,173*	*3,692*	*12,273*	*1,198*	*100,040*

From 1 January 2017 onwards the annual changes as presented in Table 3.11 are used to extrapolate the land use changes. These values will be used until the new land use map is available.

3.5   Organic and mineral soils

The areas of organic and mineral soils have to be reported separately. Spatial distribution of mineral and organic soil types is taken from two different versions of the digital soil map of the Netherlands. The original version is based on soil mapping that was carried out over the period 1960-1995 (de Vries et al. 2003) and on average is dated on 1977. De Vries et al. (2010) showed that the areas of organic soils (peat and peaty soils) are decreasing as a result of the oxidation the organic soils, particularly in the drained agricultural areas on organic soils, . In order to quantify these changes, between 2012 and 2014 the geographic extent of peat and peaty soils was updated (de Vries et al. 2014). This resulted in an 2014 update of the soil map on which spatial extent and information of organic soils was updated. Where organic soils changed to mineral soil, the information on the mineral soil was included.

Mineral soils
For reporting of mineral soils 9 specific main soil types were distinguished (see Chapter 11.2). Since there is no reason to assume changes in main soil type within the mineral soil area the spatial classification of the specific mineral soil types was based on the 2014 update of the soil map. Nonetheless, as a result of oxidation some of the organic soils will change to mineral soils over time, resulting in increasing areas of mineral soils Changes after 2014 are extrapolated from the trend between 1977 and 2014. The resulting mineral soils are classified following the spatial distribution of mineral soil types from the 2014 updated soil map.

Organic soils

Two types of organic soils are recognised; peat soils and peaty soils ('*moerige gronden*' in Dutch). These differ in the depth of the peat layer (see Chapter 11.2.1 for details). To assess changes in areas of peat soils and peaty soils the original digital soil map of 1977 and the 2014 updated soil map were combined. Between the original and 2014 updated version of the soil map 56.8 kha (out of the original 337.5 kha) of peat soil were converted to peaty soils while 6.2 kha were converted to mineral soils. At the same time 85.8 kha of peaty soil were converted to mineral soil. After 2014 the rate of loss of organic soils is extrapolated.

The loss of peat and peaty soil over the past decades is the result of oxidation in drained agricultural areas on organic soils and drainage for infrastructure and settlements. Commercial extraction of peat does not occur anymore since 1992[2], but at that time the last company had been phasing out the activities already for quite some time. While the quantity of peat extraction in 1990 and 1991 is unknown, it is believed that the affected area and resulting emissions are negligible. Until the 1950's peat was an important energy source in the Netherlands, but after that time other fossil fuels like coal and gas were more important energy sources. After that at a much smaller scale peat was extracted for application in potting soil. This extraction, however, largely ended by the early 1980's with the latest company stopping in 1992. Most of the peat for potting soils nowadays is imported from Germany and the Baltic states.

Peat and peaty soils have their specific emission factor (see Chapter 11.2.1), but emissions are eventually lumped into one category of organic soils.

Organic and mineral soil area for Forest land, Cropland, Grassland, and other land uses is presented in Table 3.12. This shows that 21% of the Grasslands, 10% of the Croplands, 6% of Forests and 5% of the other land uses are on organic soils, with a 11% total area on organic soils. More information about the emission from organic soils can be found in Chapter 11.

Table 3.12 *Land use on organic and mineral soils on 1 January 1990, 2004, 2009, 2013 and 2017.*

Land use	Soil	1990	2004	2009	2013	2017
Forest land	organic soils area (ha)	20,482	21,990	21,885	21,453	20,396
	mineral soils area (ha)	341,619	348,052	351,595	354,291	345,183
	% organic	6%	6%	6%	6%	6%
Cropland	organic soils area (ha)	108,979	85,117	80,816	75,967	66,842
	mineral soils area (ha)	910,373	854,500	844,046	868,373	803,468
	% organic	11%	9%	9%	8%	8%
Grasslands (non-TOF)	organic soils area (ha)	322,053	292,709	282,252	276,031	278,616
	mineral soils area (ha)	1,185,629	1,115,356	1,109,236	1,069,678	1,128,425
	% organic	21%	21%	20%	21%	20%
Trees outside forest	organic soils area (ha)	2,216	2,237	2,221	2,132	2,120
	mineral soils area (ha)	18,590	19,970	19,872	19,443	19,120
	% organic	11%	10%	10%	10%	10%
Other land uses	organic soils area (ha)	45,142	61,999	64,440	66,082	68,718
	mineral soils area (ha)	1,196,416	1,349,571	1,375,136	1,398,050	1,418,613
	% organic	4%	4%	4%	5%	5%
Total	organic soils area (ha)	498,873	464,051	451,615	441,666	436,691
	mineral soils area (ha)	3,652,627	3,687,449	3,699,885	3,709,834	3,714,809
	% organic	12%	11%	11%	11%	11%

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[2] https://www.nrc.nl/nieuws/1992/06/26/het-veen-is-op-nederlands-laatste-turfwinning-stopt-7147920-a517002

3.6 From land use change matrix to activity data

From overlays of the successive land use and soil maps, the unique land use-soil sequences are derived. These sequences only provide information on the land use in the years for which maps are available. For each sequence, all intermediate land use trajectories are calculated through linear interpolation. It is assumed that only a single land use change has occurred between map-dates. Each trajectory is then assigned an equal proportion of the area on which the corresponding sequence occurs.

Fluxes are calculated for each trajectory separately. Land use change related biomass fluxes are calculated as the instantaneous flux of the difference between the biomass stocks of the two land use categories. Land use change related soil carbon fluxes are assumed to be released over a 20 years interval (for details see Chapter 11). With successive land use changes, yearly soil carbon flux is calculated as $1/20^{th}$ of the difference between the accumulated soil carbon stock and the soil carbon stock of the new land use. This flux is then attributed to the last land use change that has occurred. For reporting under the Kyoto Protocol these land use changes are aggregated for Afforestation, Reforestation, Deforestation and Forest Management.

When calculating beyond the last land use map, the general relative trends in land use change between the last two maps are extrapolated towards the desired end-year. The newly calculated endpoint is added to the sequences and intermediate trajectories are calculated. As a result, the calculation will be less focussed on rare and frequently changing land use sequences.

3.7 Land related information for KP reporting

The spatially explicit, wall-to-wall land use mapping allows for application of "Reporting Method 2", that is based on the spatially-explicit and complete geographical identification of all land units subject to Article 3.3 and Article 3.4 activities as described in Section 2.2.2 of the 2013 IPCC KP Guidance (IPCC 2014). As a result A/R, D and FM activities are recorded on a pixel basis. For each individual pixel it is known whether it is part of a patch that complies with the forest definition or not.

Any pixel changing from non-compliance to compliance to the forest definition is treated as AR. Similarly, any pixel changing from compliance with the Kyoto forest definition to non-compliance is treated as Deforestation. Areas of land that comply with the forest definition in 1990 are reported as FM as long as they remain doing so.

4   Forest Land [4.A]

4.1   Description

The definition for the land use category Forest land is provided in Section 2.2. This category includes emissions and sinks of CO_2 caused by changes in forests. All forests in the Netherlands are classified as temperate, 30 per cent of which are coniferous, 38 per cent broadleaved and the remaining area a mixture of the two. The share of mixed and broadleaved forests has grown in recent decades (Schelhaas *et al.*, 2014[3]).

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 (see Section 2.2 for the definition). In the Netherlands, with its very high population density and strong pressure on land, all forests are managed. Consequently no further sub-division is used between managed and unmanaged forest land. Where such sub-divisions are asked for in the CRF, the notation key 'NO' will be used in the tables for unmanaged forests.

Within the category 4A, Forest Land, two subcategories are distinguished:

1. *4.A1 Forest Land remaining Forest Land (FF)*
   Areas of land that have been Forest land for at least 20 years. 'The greenhouse gas inventory for the land use category "Forest land remaining Forest land (FF)" involves estimating the changes in carbon stock from five carbon pools (i.e. above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter), as well as emissions of non-CO_2 gases.' (see Page 4.11 in IPCC 2006b).

2. *4.A2 Land converted to Forest Land (LF)*
   This concerns changes in the carbon stocks for areas that have been forested for less than 20 years, and are the result of conversion from other land use categories. 'Managed land is converted to forest land by Afforestation and Reforestation, either by natural or artificial regeneration (including plantations)'. These activities are covered under categories 4.A2.1 through 4.A2.5 of the *2006 IPCC Guidelines*. The conversion involves a change in land use.' (see Page 4.29 in IPCC 2006b).

   Land that is converted to forest land should, in theory, remain in this category for 20 years. After this it is reported under the category 'Forest land remaining Forest land'. However, due to the lack of historical material (prior to 1990) and the working methods for conducting forest inventories and map analysis for land use change, a more practical solution has been found (see Section 4.2).

Besides the Forest Land category, information on carbon stocks in Forest Land is needed for the following categories:

3. *4.B2 - 4.F2: Forest Land converted to another land use category*, i.e. Deforestation. This concerns changes in the carbon stocks for areas that were forest land and are converted to any other land use category.

Expanding forest lands retain carbon. This retention can change as a result of changes in three components (carbon pools), i.e. (see Page in 1.9 in IPCC 2006b):

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[3] Report on the 6th Forest Inventory with results only in Dutch. For English summary of the results and an English summary flyer "State of the Forests in The Netherlands", see: http://www.wageningenur.nl/en/Expertise-Services/Research-Institutes/alterra/Projects/Dutch-Forest-Inventory/Results.htm

1. Living biomass, further specified in:
    ▪ above-ground biomass; trunk and branches;
    ▪ below-ground biomass; roots.
2. Dead organic matter (DOM), further specified in:
    ▪ dead wood;
    ▪ litter.
3. Soil organic matter (SOM).

Emissions are reported for variables from Forest Land and for land use change to other categories as shown in Table 1.1 in Chapter 1.

4.2   Methodological issues

4.2.1   Forest Land remaining Forest Land (4.A1)

The basic approach to assess carbon emissions and removals from forest biomass follows the 2006 IPCC Guidelines where a stock-difference approach is suggested. The net change in carbon stocks for Forest Land remaining Forest Land is calculated as the difference in carbon contained in the forest between two points in time. Our approach combines activity data from land use maps (see Chapter 3) and emission factors from National Forest Inventories (Figure 4.1). Carbon in the forest is derived from the growing stock volume, making use of other forest traits routinely determined in forest inventories. For the period of interest, i.e. 1990 and onwards, data from three National Forest Inventories were available for the Netherlands: the so called HOSP data (1988-1992), the NFI-5 data (2001-2005) and the NFI-6 data (2012-2013). With these three repeated inventories, changes in biomass and carbon stocks were assessed for the periods 1990-2003 and 2003-2012. The annual changes for the years between 1990-2003 and 2003-2012 are determined using linear interpolation. Information between 2013 and 2020 was based on projections using the EFISCEN model. This information for the period 2013-2020 will be updated when the information from the 7th National Forest Inventory (NBI7) will become available by 2020.

National Forest Inventories
The HOSP (Hout Oogst Statistiek en Prognose oogstbaar hout) inventory was designed in 1984 and conducted between 1988 and 1992 and 1992-1997 (Schoonderwoerd and Daamen 1999). For the LULUCF calculations only the data from the time period 1988-1992 were used, as these best represent the situation in the base year 1990. The HOSP was not a full inventory and its methodology was also different from earlier and later forest inventories. It was primarily designed to get insight in the amount of harvestable wood, but it still provides valuable information on standing stocks and increment of forest biomass. 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 310,736.3 ha, the estimated surface of forest where harvesting was relevant in 1988.

The fifth National Forest Inventory (NFI-5; also referred to as Meetnet Functie Vervulling Bos, MFV) 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).

The sixth National Forest Inventory (NFI-6; Zesde Nederlandse Bosinventarisatie, NBI6) was conducted between September 2012 and September 2013 (Schelhaas *et al.* 2014). To facilitate the direct calculation of carbon stock changes between the NFI-5 and NFI-6, the methodology of the NFI-6 closely followed the methodology of the NFI-5 (see Schelhaas *et al.* 2014). Measurements were done on 3190 sample plots, of which 1235 were re-measurements of NFI-5 sample plots.
By 2020 a new NFI (NBI7) is planned. The data from that NFI will be used similarly as the NFI-6 to assess actual carbon stock changes over the period 2013-2020. In the meantime the EFISCEN model is applied to project future carbon stocks for the year 2023. These projected carbon stocks in living

biomass then subsequently are used to calculate carbon stock changes between the most recent NFI-6 and the projected carbon stocks (see Table 4.2). The year 2023 is used because the model calculates changes in time steps of 5 years, with 2013 as the starting point (i.e. 2 time steps were used).
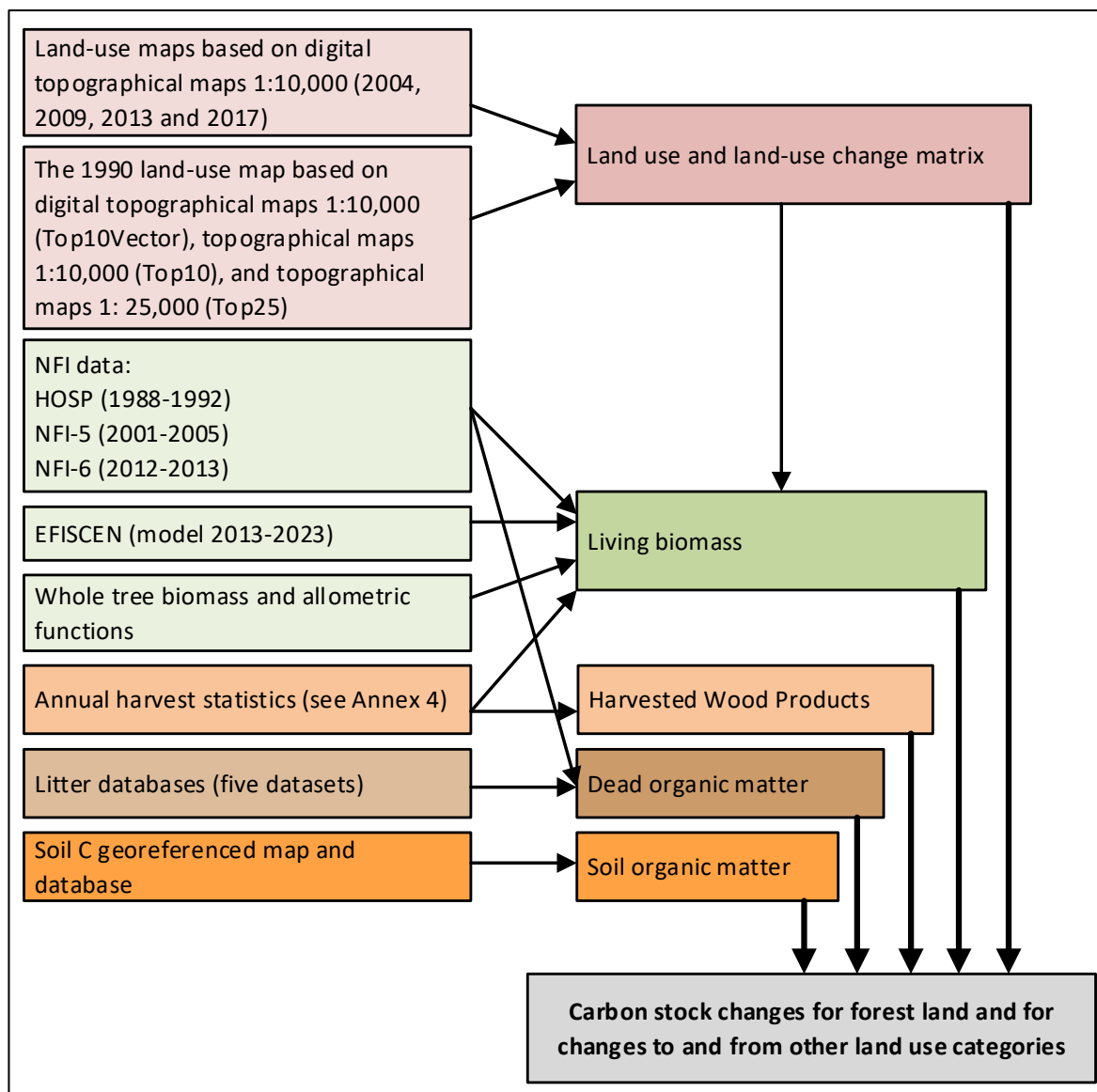
Figure 4.1 Sources for the allocation of Forest Land and the calculations of carbon stock changes from Forest Land.

EFISCEN extrapolation of forest information for 2013-2023

EFISCEN is a large-scale forest scenario model that assesses the availability of wood and projects forest resource development on regional to European scales (Sallnäs 1990; Nabuurs *et al.* 2007; Eggers *et al.* 2008). EFISCEN is an area-based matrix model that is especially suitable for projections on a regional or country level. The model simulates the development of forest resources in terms of increment, growing stock, area, tree species and age class distribution, in time steps of five years, for periods of usually 50 to 60 years. A detailed model description is given by Schelhaas *et al.* (2007).

In EFISCEN, the state of the forest is described as an area distribution over age and volume classes in matrices, based on forest inventory data on the forest area available for wood supply. Area transitions between matrix cells during simulation represent different natural processes and are influenced by management regimes and changes in forest area. Growth dynamics are simulated by shifting area proportions between matrix cells. In each 5-year time step, the area in each matrix cell moves up one age class to simulate ageing. Part of the area of a cell also moves to a higher volume class, thereby simulating volume increment. Growth dynamics are estimated by the model's growth functions whose coefficients are based on inventory data or yield tables.

The version of the model that was applied is EFISCEN V4.1, release 11 April 2014. Input data and parameterisation and calibration of the model were done based on data from the NFI-6. Detailed information on the set-up and calibration of the EFISCEN model used is provided in Annex 6.

Carbon stock changes in living biomass
For each plot that is measured during the forest inventories, information is available on the presence of the dominant tree species, standing stock (stem volumes) and the forest area it represents. Based on this information the following calculation steps are implemented:

1. Based on the growing stock information and biomass expansion factors for each plot in the NFIs total tree biomass per hectare is calculated. Tree biomass is calculated on the basis of growing stock information from the three forest inventories. For a sub-sample of trees in the NFI-5 (n=7544) and NFI-6 (n=7365) both diameter and height was measured. Using the allometric equations from Annex 3 (Table A.3.2 and A.3.3) for this subsample of trees biomass conversion and expansion factors (BCEF) were calculated by tree species group (Table 4.1). Subsequently for all plots in the NFI datasets, biomass is calculated using the dominant tree species group's specific BCEF.

2. Weighted for the representative area of each of the NFI plots for each of the inventories the average growing stocks (m^3 ha^{-1}), average biomass conversion and expansion factors (BCEF) (tonnes biomass m^{-3}) and average root-to-shoot ratios are calculated (Table 4.2). These inventory specific BCEFs reflect the shifts in species composition seen over the years.

3. Based on the distribution of total biomass per hectare over coniferous and broadleaved plots (determined on the basis of the dominant tree species), the relative share of coniferous and broadleaved forest is determined (Table 4.2).

4. The average growing stock, average BCEF's, average root-to-shoot ratios and shares of coniferous and broadleaved forests are linearly interpolated between the NFI's to estimate those parameters for the intermediate years.

5. Combining for each year average growing stock, the average BCEF and root-to-shoot ratios the average aboveground and belowground biomasses (tonnes dry matter ha^{-1}) are estimated for each year.

6. Using the relative share of coniferous and broadleaved forests and the differentiated carbon fractions (Table 4.3 of IPCC 2006b) of 0.51 tonnes C per tonne dry matter for conifers and 0.48 tonnes C per tonne dry matter for broad-leaved species, above- and belowground biomass were converted to carbon.

7. Losses from wood harvesting are already included in the differences in carbons stocks between the three forest inventories, HOSP, NFI-5 and NFI-6 (see below on approach to determine carbon stock losses and gains using harvest data.

Table 4.1 *Biomass conversion and expansion factors per species group in tonnes biomass per m^3 stemwood*

Species group	BCEF	Species group	BCEF
Acer spp.	0.80	*Picea* spp.	0.53
Alnus spp.	0.74	*Pinus* other	0.46
Betula spp.	0.68	*Pinus sylvestris*	0.48
Broadleaved other	0.73	*Populus* spp.	0.53
Coniferous other	0.55	*Pseudotsuga menziesii*	0.65
Fagus sylvatica	1.18	*Quercus* spp.	1.28
Fraxinus excelsior	1.06	*Robinia pseudoacacia*	1.25
Larix spp.	0.53	*Tilia* spp.	1.30

Table 4.2 *Per NFI inventory, its reference year, average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes ha^{-1}), BCEF (tonne d.m. per m^3 stemwood volume), net annual increment (NAI; m^3 ha^{-1} yr^{-1}), belowground biomass (AGB; tonnes ha^{-1}), root to shoot ratio (R), share of conifer biomass in the total forest biomass, mass (tonnes ha^{-1}) of standing deadwood (DWs) and lying deadwood (DWl). The EFISCEN data are based on a model projection (paragraph on EFISCEN projections 2013-2023 below), except DW biomass which are based on extrapolation from the period before.*

NFI	Year	GS	AGB	BCEF	BGB	R	Share Conifers	DW Biomass DWs	DWl
HOSP	1990	158	112.8	0.714	20.6	0.18	0.44	0.84	0
NFI-5	2003	195	143.2	0.736	25.8	0.18	0.42	1.33	1.53
NFI-6	2012	222	165.5	0.744	29.9	0.18	0.40	1.97	2.03
EFISCEN	2023	241	182.9	0.758	33.7	0.18	0.39	2.61	2.52

Effects of wood harvests on biomass gains and losses

Information on annual volume of roundwood harvesting is only available at the national level and is based on a combination of information from the forest inventories and FAO harvest statistics (see Annex 4). Wood production is given as production roundwood in m^3 under bark. The total annual volume removed from the forest includes bark as well as losses that occur during harvesting. This volume removed is calculated from roundwood under bark harvest statistics as follows:

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

With:

H_{NL} — Annually extracted total volume over bark from forests in NL (m^3 $year^{-1}$)

H_{NLub} — Annually extracted volume roundwood under bark from forests in NL (m^3 $year^{-1}$)

$f_{\frac{ob}{ub}}$ — Conversion from under bark to over bark (1.136 m^3 over bark / m^3 under bark)

$f_{\frac{tw}{rw}}$ — Conversion from roundwood to total wood (1.06 m^3 wood / m^3 roundwood $year^{-1}$)

For each year, the total volume of roundwood harvests is considered to be taken from Forest land remaining Forest land. This assumption is consistent with the way the total roundwood harvest is calculated, i.e. based on information on harvesting from permanent sample plots in the NFI's. The fraction of harvest from Forest Management from the total harvest is later used in the calculations for the harvested wood products (see Section 10.2).

The differences in carbon stocks of the remaining forest biomass between the different NFIs (Figure 4.2) already includes the effect of wood harvesting. As a result the calculated carbon stock differences between the NFI's will provide the net carbon stock changes in living biomass. However the CRF also asks for the underlying gains and losses in carbon stocks in living biomass. Gains in carbon stocks are the result of the annual increment in biomass, while losses are the result of wood harvesting. Therefore for the calculation of carbon stock gains in living biomass in a given year the carbon in the biomass of the harvested wood in that year (Figure 4.3) was added to the carbon stock changes in living biomass in that year as derived from the NFI's (Figure 4.4). At the same time this amount of harvested carbon was reported under carbon stock losses from living biomass. As a consequence, the net stock change is gradual (i.e. based on the carbon stock difference between NFI's), but the gains and losses are more erratic (i.e. annual harvest statistics).
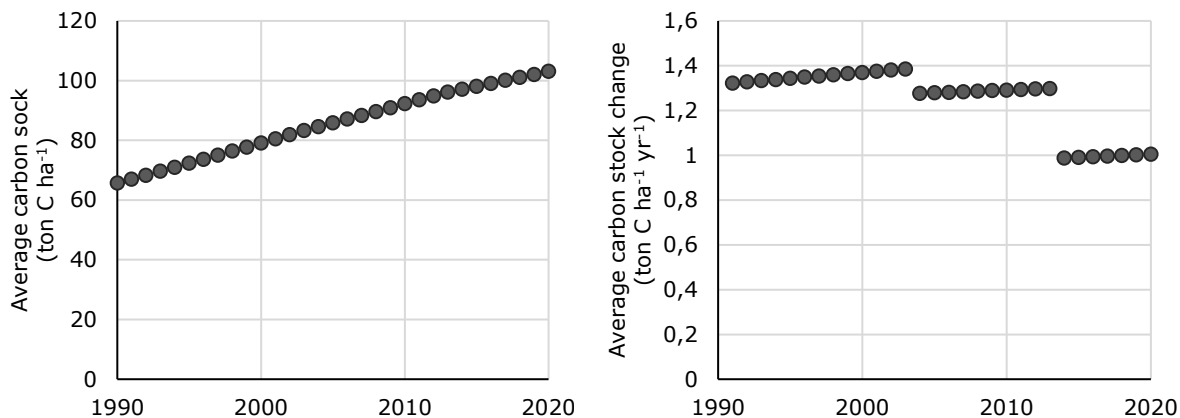
Figure 4.2. *Average carbon stocks and net carbon stock changes in biomass in forest land remaining forest land based on the stock differences in the NFI data.*
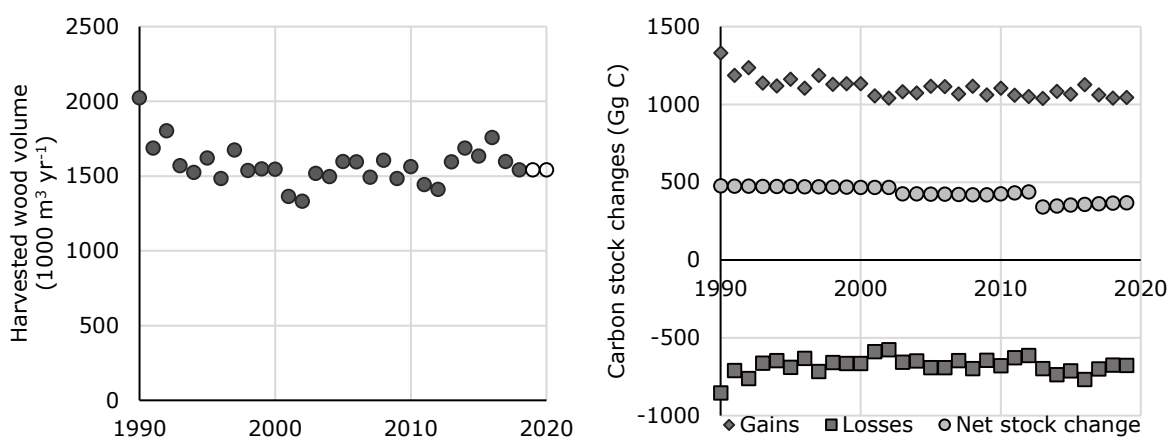
Figure 4.3. *Harvested roundwood volume (1000 m³ yr-1) since 1990. Projected years will be updated once new harvest statistics become available.*

Figure 4.4. *Carbon stock gains and losses combining net carbon stock changes from the NFI data with the (stock change, cf. Figure 4.2) with the harvest statistics (Figure 4.3).*

Growth rates versus increase in growing stock

In several review reports the ERT referred to the apparent high growth rates of biomass in Dutch forests, indicating that it is among the highest in Annex I countries. This is considered a misinterpretation of the results. Although the increase in growing stock in Dutch forests indeed appears to be higher than in other countries, the volume growth rates are not. It is due to the overall very low harvest intensities in the Netherlands, with only about 55% of the increment being harvested (see Schelhaas et al. 2018), that the growing stock strongly increases over time.

Since the 1970's the purpose of forest management has changed from forests with a predominant wood production function to multifunctional forests that serve multiple purposes (e.g. nature conservation, recreation and wood production) (see Annex 5 for more details on Dutch forests and forest management). Moreover, forest policy in the Netherlands has been integrated into the nature policy over the past decades, which reflects the change towards multi-purpose forests in which more functions are combined. Nature subsidies (SNL) are an important source of income for forest owners. Forest owners covering in total 80% of the Dutch forest area receive a SNL subsidy. Of this subsidised forest area, 60% falls under the scheme for forests with production function, i.e. forest with explicitly integrated nature conservation and timber production objectives. Harvesting in these forests therefore is usually limited to thinnings and small group fellings (<0.5 ha).

In the other 40%, that is subsidised as natural forests, harvests are limited to 20% of the increment. These harvests are generally aimed at removing exotic species or improving forest structure. Forests with a production function usually integrate wood production with other functions like nature conservation and recreation.

In multifunctional forest, harvesting rates are on average 5.7 m³ per ha per year, while in natural forests on average 2.9 m³ is harvested per hectare per year (Schelhaas et al. 2018). The growing stocks on average increase annually by 2.0 m³ per hectare in multifunctional forests to 2.9 m³ per hectare for natural forests (Schelhaas et al. 2018).

Harvested Wood Products
The carbon stocks present in the wood from the harvest from Forest Land remaining Forest land enter the Harvested Wood Products (HWP) carbon pool, which is a separate Category [4.G] and is further explained in more detail in Chapter 10.

Carbon stock changes in dead wood
Dead wood volume was available from the three forest inventory datasets. The calculation of changes carbon stock changes in dead organic matter in forests follows the approach for calculation of carbon emissions from living biomass and is done for lying and standing dead wood (Table 4.2, above). Carbon stocks and their changes in dead wood in forest from 2013 until data from a new Forest inventory are available is done on the basis of extrapolation of the trend from the past two forest inventories. Once a new forest inventory is available the carbon stocks and carbon stock changes for dead wood will be updated.

Carbon stock changes in litter
The carbon stock change from changes in the litter layer was estimated using a stock difference method at national level. Data for litter layer thickness and carbon in litter were available from five different datasets (van den Burg 1999; de Vries and Leeters 2001, Schulp 2009 and unpublished data from Schulp and co-workers; Forest Classification database; NFI-5 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 (Schulp 2009). They based their selection of species and soils on the NFI-5 forest inventory. During the last two years of the NFI-5 sampling (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 NFI-5 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 NFI-5 (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 NFI-5 in the years 2004 and 2005), regressions for rich and poor sands based on data from (Schulp 2009) 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 NFI-5 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 NFI-5 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 specific 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.
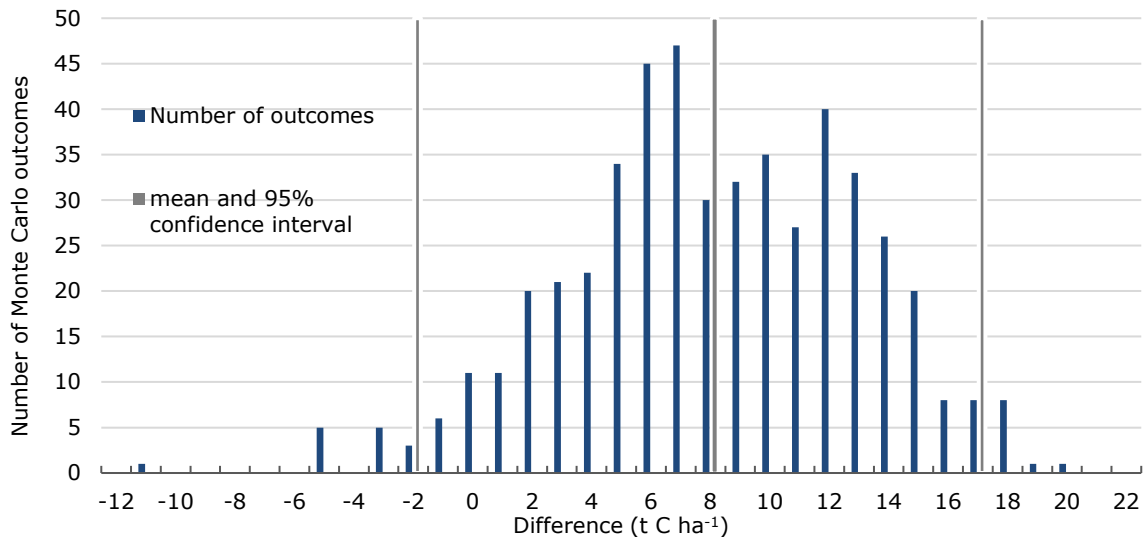
Figure 4.5. *Distribution of differences in carbon stock between HOSP and NFI-5 datasets based on a Monte Carlo analysis (positive values indicate a sink).*

The difference between 2004 (NFI-5 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. To calculate the difference in carbon stocks between the two NFI's, a Monte Carlo uncertainty analysis was carried out with random litter carbon stocks taken from the distribution of stocks in plots measured in the HOSP and NFI-5, rather than comparing the mean values. The results of the Monte Carlo analysis consistently showed a carbon sink in litter; however the magnitude was very uncertain (Figure 4.5). Therefore, the more conservative estimate was used to set the accumulation of carbon in litter in Forest Land remaining Forest Land 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. Consequently under the KP accounting the litter carbon pool under Forest Management is considered to be not a source.

Carbon stock changes in soils
See Chapter 11 for the calculation methods for carbon stock changes in soils for the different soil types.

4.2.2 Land converted to Forest Land (4.A2)

Carbon stock gains in living biomass
Previously carbon stock gains resulting from forest growth on newly established units of forest land (i.e. land converted to forest land after 1990) were derived from the net change in growing stock volume based on data from young forest plots in the national forest inventory. A major issue with that approach was that after the applied default 20 years transition period, while being transferred to the category forest land remaining forest land, forest biomass and carbon stocks were not yet at the same level as the average forest under forest land remaining forest land. As a result in this approach the reported carbon stocks on these areas of newly established forests after 20 years instantly went from the level of a young forest at age 20, to the carbon stock associated with the average forest in the Netherlands. As a result the carbon stocks on part of the forest area were overestimated. Particularly this affected the removals reported in the afforestation/reforestation (AR) activity under the Kyoto Protocol from 2010 onwards.

Additional piecewise regression analyses of the information on young forests from the National Forest Inventories show that it takes approximately 30 years before the forest biomass is similar to the biomass in the average forest reported as Forest Land remaining Forest Land in the Netherlands. Based on this insight, a new approach was implemented in which below and above ground biomass in newly established forest areas are assumed to grow from zero just after establishment to the biomass in average forests after 30 years (Figure 4.6). After 20 years these newly established units of forest land will be reported under forest land remaining forest land, but carbon stock changes in biomass follow those of newly established forests until 30 years after conversion to forest land.

Conversions from the Grassland subcategory Trees outside Forest to Forest land may occur if surrounding area is converted to forest, resulting in the areas previously reported under Trees outside Forest also meeting the minimum area requirement for Forest land, i.e. more than 0.5 ha and more than 30 m width. Hence the change in category (from TOF to FL) on these units of land is not the result of changes on these units of land, but is the result of changes in surrounding units of land. In such cases the growth of the biomass is assumed to continue from the previous years.

Carbon stock losses
Carbon stock losses resulting from converting cropland or grassland to forest land are calculated as the complete loss of carbon stock in biomass associated with those land use categories (see Chapters 5 and 6). Exception on this is the conversion from Trees outside Forest under Grassland. For such conversion no changes in carbon stock in biomass are assumed. In subsequent years the biomass in Trees outside Forest is assumed to follow the growth of biomass of Forest land.

Carbon stock changes in dead wood and litter
Conversions of land towards Forest Land should yield an increase in both dead wood and litter, as no other land categories are assumed to have significant amounts of those carbon stocks. 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.
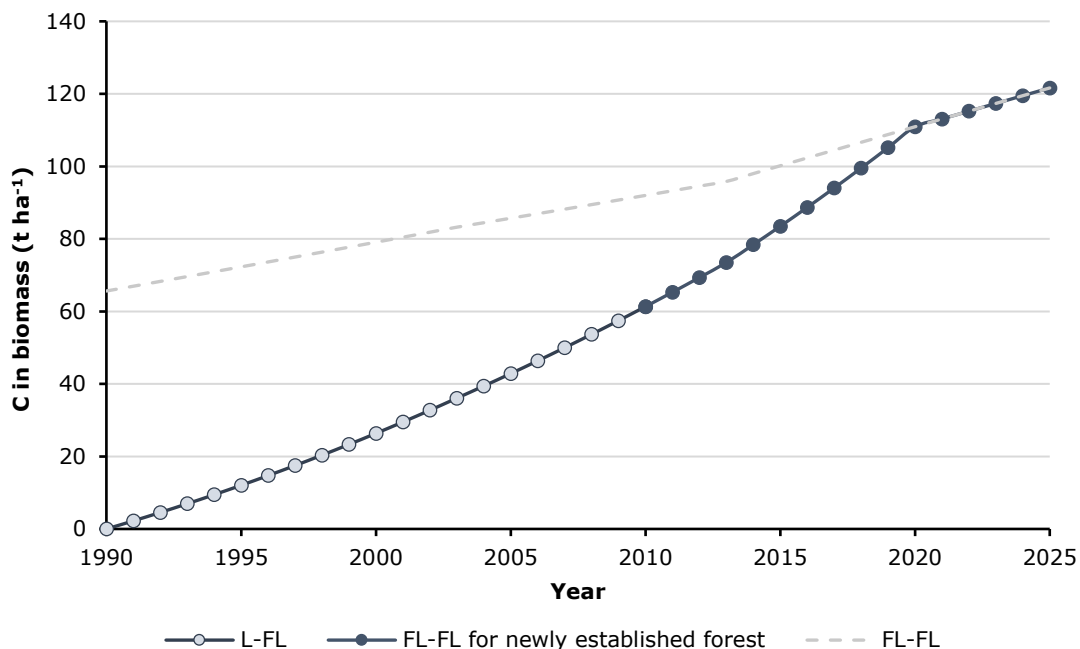
Figure 4.6. *Example of the development of carbon stocks (t ha⁻¹) on units of forest land newly established in 1990 (important: the graph follows the same 1 ha over time from 1990 to 2025). Within 30 years the carbon stock grows from 0 at the time of establishment (1990 in this example) to the average carbon stock of forest land remaining forest land (FL-FL). For the first 20 years after establishment these units of land are reported under land converted to forested land (L-FL). After 20 years these units of land are reported under forest land remaining forest land (line FL-FL for newly established forest).*

4.2.3 Forest Land converted to other land use classes

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. National averages are used as there is no record of the spatial occurrence of specific forest types. An exception is conversion from Forest to Trees outside Forest under Grassland. Conversion from Forest to TOF may occur if connected surrounding units of Forest land are converted to other land uses and the remaining area does not comply any longer to the forest definition. Such units of land are considered to remain with tree cover but losses of carbon in dead wood and litter will occur (see also Chapter 6).

Carbon stock changes in living biomass
The average carbon stock in living biomass follows the average interpolated above- and belowground biomass from the NFIs for the period 2000-2012 (see Section 4.2.1). These average stocks of carbon increase every year structurally, reflecting the fact that annual increment exceeds annual harvests in the Netherlands The resulting emission factors (in Mg C ha⁻¹) for Deforestation are year dependent and will therefore be yearly added to the table with emission factors for Deforestation in the NIR chapter on LULUCF.

Carbon stock changes in dead wood and litter
When Forest Land is converted to other land use categories it is assumed that dead wood and litter are removed within one year of conversion. The average carbon stock in dead organic matter is the sum of two pools: dead wood and the litter layer (L+F+H).
- The average carbon in dead wood follows the average interpolated standing dead wood and lying dead wood as calculated in Section 4.2.1.

- The average carbon in litter is based on a national estimate using best available data for the Netherlands as described in Section 4.2.1. Emission factors for litter between 1990 and 2013 are based on the calculated litter values based on the HOSP (1990) NFI-5 (2003) and NFI-6 (2013) using the approach described in Section 4.2.1. From 2013 onwards, the changes in carbon stocks from litter are linearly extrapolated from the changes in the years before.

The assessment of the carbon stocks and changes thereof in litter in Dutch forests have been based on extensive datasets on litter thickness and carbon content in litter (Section 4.2.1).Carbon stock changes per area of litter pool of the area of deforestation is much higher than those reported by other Parties. As a result of characteristic combination of geomorphological and climate conditions, a large share of the forest area in the Netherlands is on poor Pleistocene soils that are characterised by a relatively thick litter layer, which may explain the differences with other countries. Additional information on geomorphological aspects is provided in de Waal et al. (2012) and Schulp *et al.* (2008).

Carbon stock changes in soils
See Chapter 11 for the calculation methods for carbon stock changes in soils for the different soil types.

4.3　Category specific QA/QC and verification

Verification of the EFISCEN initialisation procedure
Table 4.3 shows area, average volume and average increment per species in the NFI-6 database and according to EFISCEN after initialisation. Area and average volume are a direct result of the initialisation procedure and show small differences due to rounding in the procedures. Increment is the result of different processes in the model and often shows larger deviations from the measured values. By adjusting certain parameters in the model, it is possible to influence the increment level to have a more accurate simulation of the increment. These parameters are allowed to vary in a certain range, based on the experience of the user. Generally, a deviation of 0.5 m^3 ha^{-1} yr^{-1} is considered as acceptable.

Table 4.3. Area (ha), average volume (m^3 ha^{-1}), and average increment (m^3 ha^{-1} yr^{-1}) per species in the NFI-6 database, according to EFISCEN after initialisation, and the difference between these two.

Species	NFI-6 data			EFISCEN initial situation			Difference		
	Area ha	Vol. m^3 ha^{-1}	Incr. m^3 ha^{-1} yr^{-1}	area ha	Vol. m^3 ha^{-1}	Incr. m^3 ha^{-1} yr^{-1}	area ha	Vol. m^3 ha^{-1}	Incr. m^3 ha^{-1} yr^{-1}
AE	9381	209.5	7.75	9378	210.1	7.81	-3	0.6	0.06
BE	26729	123.7	4.55	26723	123.9	4.56	-6	0.2	0.02
BU	16632	287.9	7.08	16629	288.7	7.20	-3	0.8	0.12
ZE	9634	169.1	6.65	9631	169.3	6.67	-3	0.2	0.02
ES	14184	219.9	9.87	14185	220.2	9.55	1	0.3	-0.32
EI	69460	225.3	6.11	69457	226.4	6.11	-3	1.0	0.00
OL	14145	168.6	6.84	14142	168.8	6.49	-3	0.2	-0.35
PO	13331	202.4	7.56	13327	202.6	7.72	-4	0.1	0.17
WI	6798	161.9	7.65	6794	166.5	7.45	-4	4.5	-0.20
DG	20471	309.3	13.70	20467	310.1	13.98	-4	0.8	0.27
GD	120574	203.3	6.09	120579	204.1	6.06	5	0.8	-0.03
ON	18688	275.9	9.74	18681	276.2	9.86	-7	0.4	0.11
JL	19649	223.6	8.77	19647	223.7	9.16	-2	0.1	0.39
FS	13803	277.5	12.02	13793	277.1	12.21	-10	-0.4	0.19
Total	373480	216.5	7.30	373433	217.2	7.32	-47	0.7	0.02

5 Cropland [4.B]

5.1 Description

The definition for the land use category Cropland is provided in Section 2.3. Within the category 4B, Cropland, two subcategories are distinguished:

1. *4.B1 Cropland remaining Cropland*
    In *annual* cropland over time no net accumulation of biomass carbon stocks will occur. In a single year the increase in biomass stocks is assumed to be equal to the biomass losses from harvest and mortality in the same year (IPCC 2006b). The IPCC 2006 guidelines therefore indicate that change in biomass is only estimated for woody perennial crops. Because cropland in the Netherlands mainly consists of annual cropland, carbon stock changes in living biomass are not estimated for Cropland remaining Cropland. Like for living biomass, also no carbon stock changes in mineral soils are expected. Therefore for Cropland remaining Cropland also no net carbon stock changes in mineral soils are calculated.

    Emissions from lowering the groundwater table in organic soils under Cropland, however, are explicitly calculated for areas of Cropland remaining Cropland using the Tier 2 approach provided in Section 11.2.1.

2. *4.B2 Land converted to Cropland*
    Emissions of CO_2 from carbon stock changes in living biomass for Land converted to Cropland is calculated using a Tier 1 approach (see Section 5.2 below). This value is also used for determining emissions for Cropland converted to other land use categories (4.A2, 4.C2-4.F2). Net carbon stock changes in both mineral and organic soils for land use changes involving Cropland are calculated based on the Tier 2 approaches provided in Chapter 11.

5.2 Methodological issues

Carbon stock changes in biomass
Carbon stock changes due to changes in biomass in land use conversions to and from Croplands were calculated based on Tier 1 default carbon stocks (Table 5.1) for total biomass. For the root-to-shoot ratio, no T1 value is available in the 2006 IPCC guidelines. For cropland we assumed this ratio to be 1. Annual land use change rates were multiplied with the negative carbon stocks to calculate the loss in case of Croplands 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.

Table 5.1 *Tier 1 carbon stocks for annual croplands used to calculate carbon stock changes due to changes in biomass associated with land use conversions.*

Land use	C stock in biomass	Error	Reference
Croplands	5 tonnes C ha^{-1}	75%	2006 IPCC Guidelines, table 5.9 (IPCC 2006b), value for land converted to annual croplands.

Additional methodology to calculate carbon stock changes in biomass for Forest Land converted to Cropland is provided in Section 4.2.3.

Carbon stock changes in soils
See Chapter 11 for the calculation methods for carbon stock changes in soils for the different soil types.

6   Grassland [4.C]

6.1   Description

The definition for the land use category Grassland is provided in Section 2.4. Within the category 4C, Grassland, two main categories are distinguished, 4.C1 Grassland remaining Grassland and 4.C2 Land converted to Grassland. In each main category Grassland is subdivided in Grasslands (non-TOF) and Trees outside Forest (TOF) (see Section 2.4).

6.1.1   4.C1 Grassland remaining Grassland

Grassland (non-TOF)
This category is further differentiated in (also see Section 2.4):
- 'Grassland vegetation', 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). Depending on the year, nature areas cover about 3-5% of the total Grassland area.
- Orchards of mainly fruit trees, which in the Netherlands predominantly have an undergrowth of grass.

The annual production of biomass in grassland vegetation can be large, but due to rapid turnover changes of standing biomass will be limited in permanent grasslands (IPCC 2006b). For carbon stock changes in living biomass in grassland vegetation and nature remaining in those categories a Tier 1 method is applied, assuming there is no change in carbon stocks (IPCC 2006b). Also for changes between grassland vegetation and nature which is also reported under Grassland (non-TOF) remaining Grassland (non-TOF) (see Section 2.4), no changes in carbon stocks in biomass are considered.

In fruit orchards an increase in carbon stocks can be expected with aging of the trees. However data from Statistics Netherlands indicate that the average age of orchards remains relatively constant over time at approximately 10.5 years. This estimate is based on statistics providing the areas of apple and pear orchards in age classes (0-5, 5-10, 10-15, 15-25 and >25 years) in the Netherlands for 1997, 2002, 2007 and 2012[4]. Average age is based on the area corrected age distribution assuming that age class midpoint is representative for the age class and for >25 years 30 years was used. Therefore it is assumed that at the national scale on average the carbon stocks per area of orchards will not change. Changes in carbon stocks in living biomass from orchards therefore only is the result of changing areas.

Following the Tier 1 IPCC guidelines no carbon stock changes in mineral soils are expected for Grassland (non-TOF) remaining Grassland (non-TOF). However, since transitions between 'nature' and grassland vegetation are treated as Grassland (non-TOF) remaining Grassland (non-TOF) and land is always reported under its last known transition (see Section 2.4), a unit of land that is converted from another land use to 'nature' (or grassland vegetation) and subsequently to grassland vegetation (or nature) will therefore be reported first under land converted to Grassland (non-TOF) until its conversion to grassland vegetation, and as Grassland (non-TOF) remaining Grassland (non-TOF) thereafter. However, the soil carbon stock is still in its transition phase, causing a change in the mineral soil carbon stock in the Grassland (non-TOF) remaining Grassland (non-TOF) category even if soil carbon under grassland is assumed to be stable.

No spatially explicit distinction is made between agricultural intensively and extensively managed Grasslands. Nevertheless, emissions from lowering the groundwater table in organic soils under

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[4] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81735NED/table?ts=1517993072950

Grassland vegetation and orchards are calculated under Grassland (non-TOF) remaining Grassland (non-TOF) (see Section 11.2.1). In the organic soil area under nature lowering of the groundwater table is not common and therefore such emissions from organic soils are considered negligible.

Trees outside Forest
For Trees outside Forest, no specific data on growth or increment are available. It is assumed that Trees outside Forest grow with the same growth rate as Forests. 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 land.

Conversions between Grassland (non-TOF) and Trees outside Forest
Whereas conversions between Grassland (non-TOF) and Trees outside Forest are reported under Grassland remaining Grassland, the two subcategories in the calculations are considered as separate categories.

Conversions from Grassland (non-TOF) to TOF will result in the loss of the Grassland (non-TOF) biomass in the year of conversion and subsequent growth of biomass in TOF. The conversion from TOF to Grassland (non-TOF) will involve the loss of the carbon stocks in biomass from TOF and increase in carbon stocks from Grassland (non-TOF), similar to conversions from other land use categories (see Section 6.1.2 below).

6.1.2   4.C2 Land converted to Grassland

Grassland (non-TOF)
Emissions of CO_2 from carbon stock changes in living biomass for Land converted to Grassland is calculated using a Tier 1 approach (see Section 6.2 below). Carbon stocks in Grassland (non-TOF) depend on carbon stocks per unit of area of grassland vegetation, nature and orchards and the relative contribution of these categories to the Grassland (non-TOF) area. This value is also used for determining emissions for Grassland converted to other land use categories (4.A2, 4.B2, 4.D2-4.F2). Net carbon stock changes in both mineral and organic soils for land use changes involving Grassland (non TOF) are calculated based on the methodology provided in Chapter 11.

Trees outside Forest
For land use conversion to Trees outside Forest the same biomass increase and associated changes in carbon stocks is assumed as for land converted to Forest land. Similarly to Forest land, no dead wood nor litter layer built up is assumed (see Section 4.2.2). Conversion from Forest to TOF may occur if connected surrounding units of Forest land are converted to other land uses and the remaining area does not comply any longer to the forest definition. Such units of land are considered to remain with tree cover but losses of carbon in dead wood and litter will occur. Net carbon stock changes in both mineral and organic soils for land use changes involving Trees outside Forest are calculated based on the methodology provided in Chapter 11 for which Trees outside Forest are treated similar as Forest land.

6.2   Methodological issues

Carbon stock changes in biomass for Grassland (non-TOF)
Carbon stock change due to changes in biomass in land use conversions to and from Grasslands (non-TOF) are calculated based on Tier 1 default carbon stocks. For the whole Grasslands (non-TOF), including grassland vegetation, nature and orchards an average carbon stock per unit of land is assessed based on the carbon stocks per unit area (see below) for grassland vegetation, nature and orchards weighted for their relative area contribution to the Grassland (non-TOF) category. As a result the average carbon stocks for Grassland (non-TOF) will vary over time as a result of varying relative

contributions of the different vegetation types to the total Grassland (non-TOF) area. Below the average carbon stocks per Grassland (non-TOF) vegetation type are provided. The yearly updated areas for the different types and resulting average carbon stocks for Grassland (non-TOF) are provided in the NIR.

To assess the carbon stock changes resulting from conversions to and from Grassland (non-TOF), the annual land use change rates are multiplied with the negative carbon stocks to calculate the loss in case of Grasslands (non-TOF) 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 Grasslands (non-TOF).

Grassland vegetation and nature
For grassland vegetation and nature the same Tier 1 default carbon stocks (Table 6.1) for total biomass are applied. These are combined with default root-to-shoot ratios (Table 6.2) to allocate total carbon stock to above- and belowground compartments.

Table 6.1   *Tier 1 carbon stocks for Grassland used to calculate carbon stock changes due to changes in biomass associated with land use conversions.*

Land use	C stock in biomass	Error	Reference
Grassland	13.6 tonnes dry matter ha^{-1} (~ 6.4 tonnes C ha^{-1})	75%	2006 IPCC Guidelines Table 6.4 (value for cold temperate-wet) and the generic T1 value for the CF for biomass of 0.47 tonnes C per tonne dry matter

Table 6.2   *Tier 1 Root-to-Shoot values Grassland used to calculate carbon stock changes due to changes in biomass associated with land use conversions.*

Land use	R:S ratio	Error	Reference
Grassland	4.0	150%	2006 IPCC Guidelines Table 6.1 (value for cold temperate – wet grassland)

Orchards
Carbon stocks in biomass in orchards were based on the average age of trees in orchards from Statistics Netherlands (information for 1997, 2002, 2007 and 2012) and a Tier 1 biomass accumulation rate of 2.1 ton C ha^{-1} yr^{-1} (IPCC 2003). The average age of trees in orchards is 10.5 years, which does not appear to change much over time. The average carbon stock in living biomass in orchards then is estimates at 22 tonnes C ha^{-1}.

7 Wetlands [4.D]

7.1 Description

The definition for the land use category Wetlands is provided in Section 2.4.1. Only reed marshes and open water bodies are included in the Wetlands land use category. Other wetland and peatland areas covered by grasses or shrubby vegetation or forested wetlands are reported under the categories Grassland or Forest Land. Within the category 4D, Wetlands, two subcategories are distinguished:

1. *4.D1 Wetlands remaining Wetlands*
   Because the Wetlands category mainly includes open water and flooded land no carbon stock changes in living biomass, dead organic matter and soil are considered for Wetlands remaining Wetlands, which is also in line with the guidance for Flooded land in the 2006 IPCC Guidelines. All Wetlands in the Netherlands are reported under 4.D1.3 Other Wetlands remaining other Wetlands. Within this category a differentiation is made for reed swamps and open water.

2. *4.D2 Land converted to Wetlands*
   Carbons stocks in living biomass and dead organic matter for flooded land and open water are considered to be zero. For conversion from other land uses to Wetlands, the Netherlands applies a stock difference method assuming that all the carbon in biomass and organic matter that existed before conversion is emitted (IPCC 2006b).

7.2 Methodological issues

Carbon stock changes in biomass
Methodology to calculate carbon stock changes in biomass for Forest Land converted to Wetlands is provided in Section 4.2.3. Sections 5.2 (Cropland) and 6.2 (Grassland) provide the methodology to calculate carbon stock changes in biomass for conversions from Cropland and Grassland to Wetlands. Land use conversions from Settlements or Other Land to Wetlands will not result in differences in carbon stocks.

Carbon stock changes in soils
See Chapter 11 for the calculation methods for carbon stock changes in soils for the different soil types for land use conversions to Wetlands.

8 Settlements [4.E]

8.1 Description

The definition for the land use category Settlements is provided in Section 2.5. In the Netherlands Settlements are urban areas and transportation infrastructure, as well as built-up areas. Within the category 4.E, Settlements, two subcategories are distinguished:

1. *4.E1 Settlements remaining Settlements*
   Although Settlements also include areas with grass and trees, biomass gains and losses are expected to be in balance. Moreover, land within urban areas that meets the criteria for Forest Land or Grassland will be reported under those land use categories and is not reported under Settlements. Since no additional data are available on carbon stocks in biomass and dead organic matter in Settlements, the Netherlands applies the Tier 1 method, assuming no change in carbon stocks in biomass in Settlements remaining Settlements. Similarly it is assumed that no carbon stock changes occur in mineral soils under Settlements remaining Settlements.

   Emissions from lowering the groundwater table in organic soils under Settlements are explicitly calculated for areas of Settlements remaining Settlements (see Section 11.2.1).

2. *4.E2 Land converted to Settlements*
   Because no information is available on carbon stocks in biomass in the land use category Settlements, this is conservatively estimated at zero. For conversion from other land uses to Settlements, the Netherlands applies a stock difference method assuming that all the carbon in living biomass and organic matter that existed before conversion is emitted at once.

8.2 Methodological issues

Carbon stock changes in biomass
Methodology to calculate carbon stock changes in biomass for Forest Land converted to Settlements is provided in Section 4.2.3. Sections 5.2 (Cropland) and 6.2 (Grassland) provide the methodology to calculate carbon stock changes in biomass for conversions from Cropland and Grassland to Settlement. Land use conversions from Wetlands or Other Land to Settlements will result in no differences in carbon stocks.

Carbon stock changes in soils
See Chapter 11 for the calculation methods for carbon stock changes in soils for the different soil types for land use conversions to Settlements.

9 Other Land [4.F]

9.1 Description

The definition for the land use category Other land is provided in Section 2.6. Within the category 4.F, Other Land, two subcategories are distinguished:

1. *4.F1 Other Land remaining Settlement*

2. *4.F2 Land converted to 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 areas that do not fall into any of the other five categories. (IPCC 2006b).

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 soils that are not included in any other category.

The land cover category 'Sand' is completely included in this category. It includes all terrains that do not have vegetation growing on them by nature. The last part of the phrase, 'by nature', is used to distinguish this class from Settlements and fallow Croplands. 'Sand' includes e.g. beaches and coastal dunes with little or no vegetation. It also includes inland dunes where the vegetation has been removed to create spaces for early succession species (and which are being kept open by the wind). Bare inland sand dunes were developed in the Netherlands as a result of heavy overgrazing and were combated (for a long time) by planting forests. These areas were, however, the habitat of certain 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.

It does not include bare areas that emerge from shrinking and expanding water surfaces (these 'emerging surfaces' are included in wetlands).

9.2 Methodological issues

See Chapter 11 for the calculation method for the different soil types.

10 Harvested Wood Products [4.G]

10.1 Description

The Netherlands estimates changes in the Harvested Wood Products (HWP) pools based on the methodological guidance as suggested in the 2013 IPCC KP guidance (IPCC 2014). For greater transparency, and following footnote 12 in the Convention CRF Table 4.G s1, both the HWP changes reported to the convention and reported to KP are calculated using the same methodology. Under the convention HWP is reported in the CRF under Approach B.

10.2 Methodological issues

The approach taken to calculate the HWP pools and fluxes follows the guidance in Section 2.8 of the 2013 IPCC KP guidance. As required by the guidelines, carbon from harvests allocated to Deforestation is reported using instantaneous oxidation (Tier 1) as the method for calculations. The fraction of harvest from Deforestation is based on the land use change calculations under Forest Land (Chapter 4). The remainder of the harvests is allocated to Forest Management and subsequently is added to the respective HWP pools. As no country specific methodologies or half-life constants exist, the calculations for the HWP-pools follows the Tier-2 approach outlined in the 2013 IPCC KP guidance by applying equations 2.8.1 to 2.8.6.

Four categories of HWP are taken into account: sawn wood, wood-based panels, other industrial roundwood, and paper and paperboard. Domestically produced fuel wood is accounted using instantaneous oxidation and therefore does not contribute to the carbon stock changes reported in the HWP pool. Emissions from harvested wood products in solid waste deposit sites (SWDS) are not separately accounted.

The distribution of material inflow in the different HWP pools is based on the data reported to FAO-stat as import, production and export for the different wood product categories, including those for industrial roundwood and wood pulp as a whole (equations 2.8.1 – 2.8.4. in the 2013 IPCC KP guidance). Equation 2.8.4 from 2013 IPCC KP guidance is used to obtain the annual fractions of HWP from domestic harvests and to exclude imported HWP.

The statistics on production, import and export of industrial roundwood in 1990 appeared to be not correct in the FAO forestry statistics database. The data for the base year 1990 are adjusted on the basis of the statistics reported by PROBOS, the Dutch national correspondent to the Joint forest sector questionnaire (JFSQ), reporting national forestry statistics to FAO and other international organisations (Table 10.1).

Table 10.1 *Updated quantities of produced, exported and imported industrial roundwood (in m³) in the Netherlands in 1990 for which the FAO stat data are incorrect.*

Industrial roundwood in 1990	Quantity according FAO-stat (m³)	Quantity according PROBOS (m³)
Production	1,275,000	1,115,000
Export	142,377	480,559
Import	119,567	752,972

To assess carbon amounts in the different HWP categories, the default carbon conversion factors for the aggregated HWP categories sawn wood, wood-based panels, and paper and paperboard were used from tables 2.8.1 and 2.8.2 of the 2013 IPCC KP guidance (see Table 10.2). For the category other industrial roundwood, the values for sawn wood were used. This category includes a variety of roundwood use, like the use of whole stems as piles in building fundaments, and in road and waterworks, and their use as fences and poles. These are considered applications with a long to very long life-time for which the 35 years half-life is considered appropriate.

Table 10.2 *Tier 1 default carbon conversion factors and half-lives factors for the HWP categories as provided by the IPCC KP Guidance (IPCC 2014).*

HWP category	C conversion factor (Mg C per m³ air dry volume)	Half-lives (years)
Sawn wood	0.229	35
Wood based panels	0.269	25
Other	0.229	35
Paper and paperboard	0.386	2

The dynamics of the HWP pools is then calculated by applying equations 2.8.5 and 2.8.6 and the half-life constants reported in table 2.8.2 of the 2013 IPCC KP guidance (see Table 10.2).

11 Carbon stock changes in mineral and organic soils

11.1 Introduction

The Netherlands developed a Tier 2 approach for carbon stock changes in mineral soils and for organic soils. For mineral soils the approach is based on the overlay of the land use maps with the Dutch soil map, combined with soil carbon stocks that were quantified for each land use soil type combination. For organic soils the procedure is based on an overlay of a map with water level regimes and the soil map indicating the area with peat and peaty soils, combined with assumptions typically valid for agricultural peat and peaty soils in the Netherlands. To report the emissions correctly under the Kyoto Protocol for the areas of Deforestation and Re/Afforestation a spatially distributed methodology is used.

11.2 Mineral soils

The methodology for carbon stock changes in mineral soils is based on Lesschen *et al.* (2012), who made a new soil carbon stock map for the Netherlands based on data derived from the LSK, a national sample survey of soil map units (Finke et al. 2001; Visschers et al. 2007). 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 de Groot et al. 2005). The LSK was stratified to groundwater classes and soil type. However, land use was not included as separate variable.

Lesschen *et al.* (2012) used the base data from the LSK survey, but classified them differently into new soil – land use combinations. For each of the LSK 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 (Table 11.1 and Figure 11.1), which represent the main variation in soil 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 11.2 the calculated average carbon stocks for Grassland (non-TOF), Cropland and Forest are shown.

Table 11.1 *Main soil types in the Netherlands and number of observations in the LSK database*

Soil Type	Soil type Dutch name	Area (km^2)	No. 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
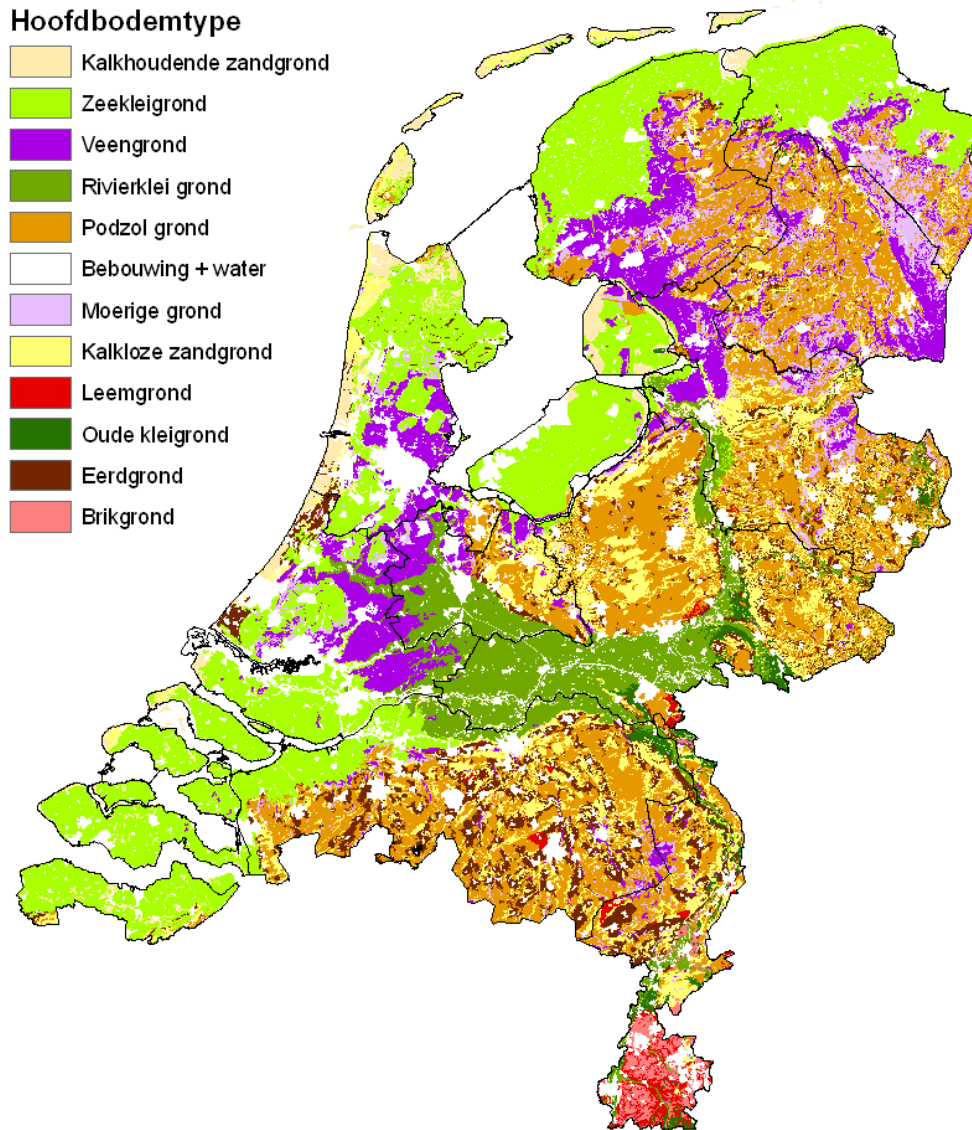
Figure 11.1. *Distribution of the main soil types in the Netherlands (Lesschen et al., 2012). Legend is in Dutch, see Table 11.1 for corresponding English names for the soil types.*
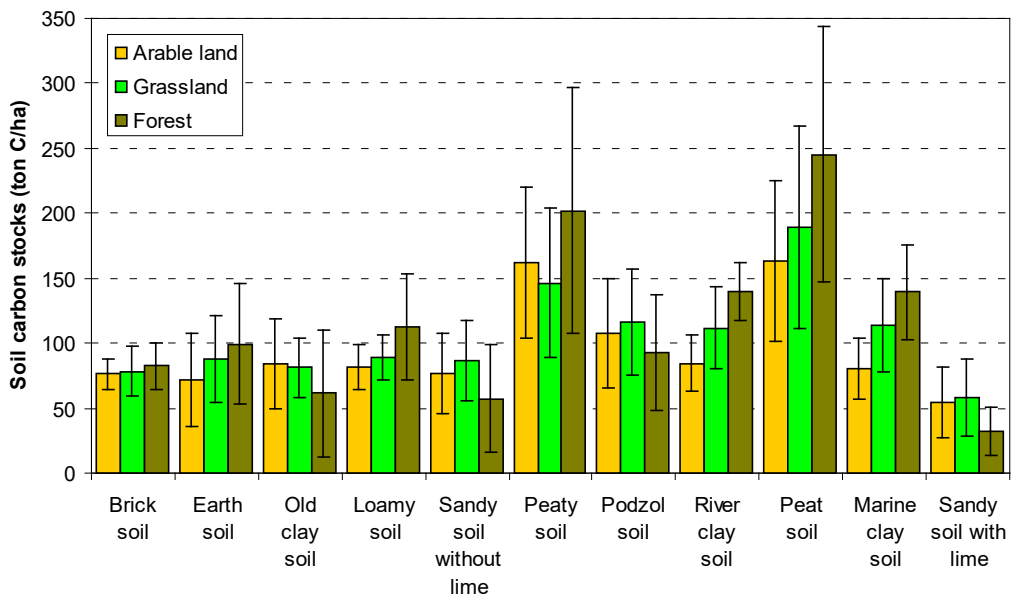
Figure 11.2. *Average soil carbon stocks per land use soil type combination. The error bars indicate the standard deviation (Lesschen et al., 2012). Grassland refers to the Grassland (non-TOF) subcategory. For soil Trees outside Forest are treated similar to Forest.*

The LSK data set only contains data on soil carbon stocks for the land uses Grassland (non-TOF), Cropland and Forest. For the other land use categories (i.e. settlement, wetland and other land) 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 conversion to settlements is one of the main land use changes. 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 (25 x 25 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 Settlements that is 0.9 times the carbon stock of the previous land use is assumed:

- 50% of the area classified as Settlements is paved and has a soil carbon stock of 0.8 times the corresponding carbon stock of the previous land use (IPCC default value)
- The remainder 50% consists mainly of grassland and wooded land for which the reference soil carbon stock is assumed (IPCC default value of 1 for all three stock change factors).

For wetlands the same soil carbon stock as forest land is assumed for the different soil types. For other land a soil carbon stock of zero is assumed for all soil types, as other land comprises dunes and drift sands, which hardly contain any soil carbon

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2006 IPCC guidelines

The 2006 IPCC guidelines (IPCC 2006b) state the following for land converted to Settlements 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 Settlements 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 Settlements area that is turfgrass, use the appropriate values for improved grassland from Table 6.2, Chapter 6;
3. for the proportion of the Settlements area that is cultivated soil (e.g., used for horticulture) use the no-till FMG values from Table 5.5 (Chapter 5) with F_I equal to 1; and
4. for the proportion of the Settlements 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 land use changes. Thus, land use change of cropland to forest for example has the same annual C flux per hectare as land use change from forest to cropland, but with an opposite sign:

$$E_{\min} = \frac{C_{t=20} - C_{t=0}}{t} * A_{\min\_x, t=20} \tag{11.1}$$

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

In Table 11.2 the annual changes for the relevant land use changes to and from forest land are provided. This table shows that the sign of the soil carbon stock changes is depending on the soil type, and not the same for each land use change. For example, conversion of forest to cropland results in an increase in SOC stock, because the sandy soils are improved by high manure inputs from the intensive agriculture in the Netherlands.

Considering a 20 years transition period for carbon stock changes in mineral soils means that land use changes in 1970 will still have a small effect on carbon stock changes in mineral soils in 1990. Here we implemented a transition period starting from 1990 as we do not have sufficient information on land use changes before 1990.

Table 11.2 *Average carbon stock changes per soil type for land use conversions to and from Forest Land (tonnes C ha^{-1} year^{-1}). Grassland refers to the subcategory Grassland (non-TOF). Trees outside Forest are treated similar to Forest.*

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

11.2.1 Nitrous oxide emissions from disturbance associated with land use conversions

Nitrous oxide (N_2O) emissions from soils by disturbance associated with land use conversions are calculated using a Tier 2 methodology, with Equation 11.8 of the 2006 IPCC guidelines for each aggregated soil type (also see emissions from carbon stock change in mineral soils in Section 11.2 of this report). The default EF1 of 0.01 kg N_2O-N/kg N was used. For three aggregated soil types, average C:N ratios, based on measurements, were available and used (17.3 for sandy soils with lime; 23.4 for sandy soils without lime; 25.6 for podzol soils). For all other aggregated soil types, we used the default C:N ratio of 15 (2006 IPCC guidelines p. 11.16). For aggregated soil types where conversion of land use led to a net gain of carbon, the nitrous oxide emission was set to zero.

11.3 Organic soils

As from the NIR 2015 two types of organic soils are identified, peat soils and peaty soils (i.e. shallow peat soils). The definition of organic soils in the 2006 IPCC guidelines is the following:

Organic soils are identified on the basis of criteria 1 and 2, or 1 and 3 listed below (FAO 1998):

1. Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm.
2. Soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter).
3. Soils are subject to water saturation episodes and has either:

- At least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has no clay; or
- At least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has 60% or more clay; or
- An intermediate, proportional amount of organic carbon for intermediate amounts of clay.

Peat soils have a peat layer of at least 40 cm within the first 120 cm, while peaty soils, in Dutch called '*moerige gronden*', have a peat layer of 5-40 cm within the first 80 cm. Based on the available data sets, two different approaches for the emission factors have been developed for peat and peaty soils. For CO_2 emissions from cultivated organic soils[5] the methodology is described in Kuikman *et al.* (2005). This method is based on subsidence as a consequence of oxidation of organic matter. For the peaty soils, another approach was used, based on a large data set of soil profile descriptions over time (de Vries et al. unpublished). From this data set the average loss rate of peat, was derived from the change in thickness of the peat layer over time.

Peat soils

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 used in Kuikman *et al.* 2005 was based on an intermediary organic soils map for 2004 (de Vries et al. 2003; de Vries 2004) with a focus on peat soils. This resulted in 223,147 ha of peat soils under agricultural land use in the Netherlands, which was the best estimate when these calculations were performed.

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

$$C_{em} = R_{GSL} \cdot \rho_{peat} \cdot f_{ox} \cdot [OM] \cdot [C_{OM}] \cdot f_{conv} \qquad (11.2)$$

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 11.2 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 11.2 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 vast majority of the Dutch peat soils are thicker than 80 cm. Besides, the

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[5] N_2O is reported under CRF Sector 3 Agriculture and not further considered here

underestimation of the bulk density will be compensated more or less by the overestimation of the subsidence.

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 de 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 11.3.
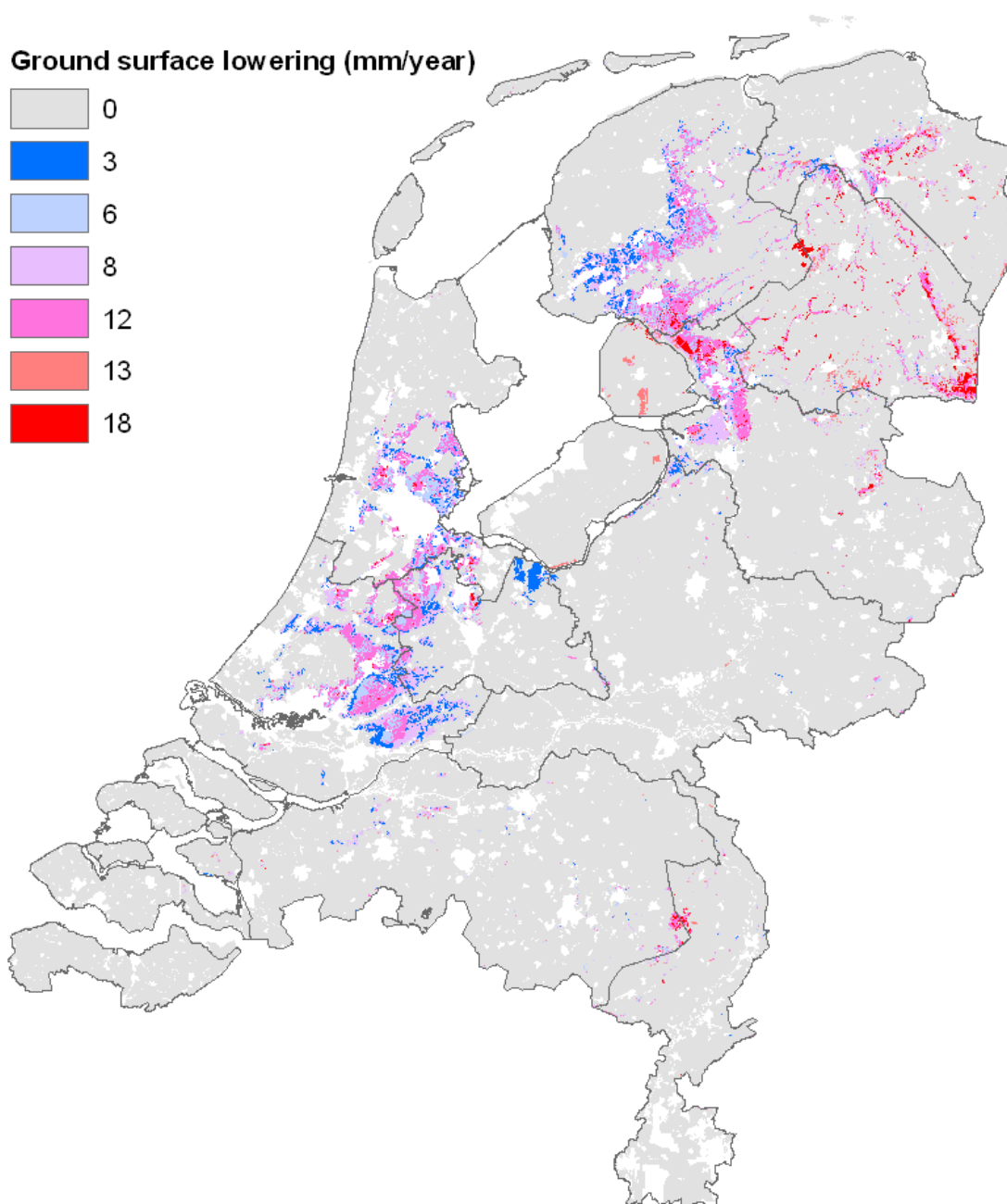
Figure 11.3. *Location of peat soils and their average ground surface lowering*

In Table 11.3 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. In this case, based on the land use map of 2004, the total annual loss of carbon from organic soils under agricultural land use is 1.16 Mtonnes of C, which is an annual emission of 4.25 Mtonnes of CO_2. This has been converted to an annual emission factor of 19.0 tonnes CO_2 ha^{-1}.

Table 11.3 *Carbon emissions as resulting from classification of peat soils in the Netherlands, estimated mean ground surface lowering (gsl) and surface (in ha), based on the 2004 land use map.*

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)	tonnes C yr^{-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**

In 2014 an updated soil map became available for the Netherlands[6]. In part of the Netherlands, especially in the north-eastern part, many of the peat and peaty soils have disappeared over the last decades. Due to its intensive use and drainage the organic soil material has oxidised and these soils now have become mineral soils or peaty soils. The area of organic soils has therefore decreased over the years. On average 1700 ha per year of peat soils (0.5%) have disappeared. This trend, based on the two soils maps, dated 1977 and 2014, has been interpolated between these years, and has also been extrapolated after 2014, following the provisional recommendation L.20 of the ERT in the 2019 review.

Following the new soil map, also the emission factors for organic soils have changed, as especially the deeper drained organic soils, with the highest emissions, have disappeared. Following the same procedure of Kuikman et al. (2005), as described above, a new average emission factor has been calculated for the 2014 soil map. The emission factor for peat soils has decreased from an average of 19.0 ton CO_2 per ha of drained peat soil in 2004 (the date of the organic soil map, on which the original emissions factors are based) to 17.7 ton CO_2 per ha in 2014 (based on the 2014 soil map). Between 2004 and 2014 the trend in decreasing emission factors has been interpolated and after 2014 the trend is extrapolated. The emission factor before 2004 is set to that of 2004. Analyses are underway to also characterise the emission factor based on the 1977 soil map. This will be included in future submissions. This will then result in updated emission factors for the period 1990-2004.

Peaty soils
For peaty soils, soils with a thin (5-40 cm) peat layer, the subsidence approach from Kuikman *et al.* (2005), as used for peat soils, is not applicable. First of all, because the data on which this approach was based, is not available for peaty soils and second, the behaviour of such a thin layer of peat is different. Therefore a new approach was developed, as described in de Vries et al. (unpublished).

Resampling of soil units during the period of 2000-2002 revealed that large areas of peat and peaty soils were converted into other soil types, since (part of) the peat layer was lost due to continuing

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[6] https://www.wur.nl/nl/show/Bodemkaart-1-50-000.htm

oxidation and disturbance. This led to large scale resampling of soil units with shallow peat soils and peaty soils during the period 2005-2013. The results of this Soil Information System (BIS) project lead to a large database with all soil profile descriptions and an updated soil map. This new 2014 soil map is also used since 2019 for the LULUCF reporting. From this database about 6150 soil profile descriptions were available on soil units that were previously classified as thin peat soils or peaty soils. For the new observations the measured thickness of the peat layer, if still present, was available. The historic thickness of the peat layer was not known, but was estimated using the average thickness for a peat layer in a peaty soil, which was still classified as a peaty soil. This average differed slightly among the three drainage classes, but was close to the arithmetic mean value, i.e. 22.5 cm, since a soil is classified as peaty soil if the peat layer is between 5 and 40 cm thick.

Because of the large number of observations, the average difference between the observed and historic thickness could be used to derive an average peat loss rate. This was differentiated for three drainage classes, similar as done for the peat soils. For each drainage class an average loss rate of the peat layer in the peaty soils was determined, which lead to an overall loss rate of 0.32 cm year^{-1}. Based on the bulk density and carbon content of the peaty soil types, an average C loss per cm of lost peat layer was calculated.

Based on the original organic soils map of 2004, this resulted in an average overall emission factor of 13.0 tonnes CO_2 ha^{-1} year^{-1} for the peaty soils under agriculture. For settlements no data were available, but the same overall emission factor has been used.

Also the area of peaty soils has decreased over the years. On average 800 ha per year of peaty soils (0.4%) has disappeared. As for the peat soils, this trend has been interpolated between 1977 and 2014 years, and has been extrapolated after 2014. Based on the same procedure as described above, a new average emission factor for peaty soils has been calculated for the 2014 soil map. The emission factor decreased from an average of 13.0 ton CO_2 per ha of drained peaty soil in 2004 to 12.0 ton CO_2 per ha in 2014. Similarly as for the peat soils, the trend in decreasing emission factor has been interpolated between 2004 and 2014 and extrapolated after 2014. The emission factor before 2004 is set to that of 2004. Analyses are underway to also characterise the emission factor based on the 1977 soil map. This will be included in future submissions. This will then result in updated emission factors for the period 1990-2004.

Emissions from peat and peaty soils are calculated separately, but in the CRF the sum of these emissions is reported in the relevant categories of organic soils.

Emissions from organic soils under forest land
Drainage of organic soils is usually not applied in forestry in the Netherlands. However, since afforestation often occurs on land with previously agricultural land use, it cannot be completely ruled out that the old drainage systems from the agricultural sites are still active. Therefore, to account for possible emissions, the area of forests and trees outside forests that are planted on organic soils that were in agricultural use before and where drainage systems may still be (partially) functioning was estimated, and associated emissions have been calculated using country specific emission factors.

The total area of forest on peat soils in the 2017 map was 11.3 kha. Out of this area, 2.7 kha (24.2% of the forest area on peat soils) was listed as being Cropland, Grassland or Settlement in at least one of the earlier maps. For each year we therefore assume that 24.2% of the forest area on peat soil is potentially drained and has an emission factor equal to that of agriculture on peat soil.

Similarly, the total area of forest on peaty soil in the 2017 map was 9.1 kha. Out of this area, 2 kha (22.0% of the forest area on peaty soils) was listed as being Cropland, Grassland or Settlement in at least one of the earlier land-use maps. For each year we assume that 22.0% of the forest area on peaty soil is potentially drained and has an emission factor equal to that of agriculture on peaty soils.

11.3.1   Nitrous oxide emissions from organic soils

Apart from CO_2 emissions from organic soils, also N_2O emissions occur, due to mineralisation of organic nitrogen. For cropland and grassland these emissions are included under Agriculture (category 3D). However, those emissions under forestland have to be reported under LULUCF. Based on an overlay of the soil map and land use map, the share of nutrient rich (eutrophic organic soils) and nutrient poor (oligotrophic organic soils) was determined for organic soils under forest. On average 79% of the peat soils is nutrient rich and 21% is nutrient poor. All peaty soils have been classified as nutrient rich, as the average CN ratio is 17. The default IPCC tier1 N_2O emission factors (EF_2) of 0.6 kg N_2O-N/ha for nutrient rich and 0.1 N_2O-N/ha for nutrient poor organic soils have been applied.

12 Greenhouse gas emissions from wildfires [4(V)]

12.1 Controlled biomass burning

The areas included under wildfires, partly include the occasional burning that is done under nature management. Controlled burning of harvest residues is not allowed in the Netherlands (article 10.2 of 'Wet Milieubeheer' - the Environment Law in the Netherlands). Therefore controlled biomass burning does not occur in the Netherlands, and therefore is reported as not occurring (NO).

12.2 Wildfires on forest land

In the Netherlands no country specific information on intensity of forest fires and emissions of Greenhouse gases from those fires is available. Therefore emissions of CO_2, CH_4 and N_2O from forest fires are reported using the Tier 1 method as described in Chapter 2 of the 2006 IPCC guidelines. 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 12.1). This was 37.8 ha (or 0.1 ‰ of the total forest land in the Netherlands) and this area was used from 1990 onwards as an estimate of area burnt.

Table 12.1 *Annual area of forest fires and area of other (outside forest) wild fires in the Netherlands (from Wijdeven et al., 2006)*

Year	Area forest fires (ha)	Area other wild fires (ha)
1980	153	303
1981	12	38
1982	40	645
1983	20	379
1984	65	147
1985	14	20
1986	15	265
1987	27	88
1988	26	54
1989	22	77
1990	40	184
1991	33	381
1992	24	153
Average 1980-1992	**37.8 ± 10.3 (s.e.)**	**210 ± 38.7 (s.e.)**

Equation 2.27 of the 2006 IPCC guidelines was used to calculate greenhouse gas emissions from forest fires. The mass of fuel available (tonnes ha^{-1}) for combustion was based on the annual carbon stock in living biomass, litter and dead wood in forests (calculation in Section 4.2), so these values change over time depending on forest growth and harvesting. The default combustion factor (fraction of the biomass combusted) for "all other temperate forests" is used (0.45; 2006 IPCC guidelines Table 2.6). For each of the gases CO_2, CH_4 and N_2O default emissions factors for "Extra tropical forests" from Table 2.5 in the 2006 IPCC guidelines were used.

With the available data it is not possible to distinguish between forest fires in forests remaining forests and land converted to forest land. Therefore, the total emissions from forest fires are reported in CRF Table 4(V) under wild fires for forests remaining forests.

Based on the total extent of forest fires, greenhouse gas emissions from forest fires are also reported for AR and FM land under KP-LULUCF. Burned areas of AR and FM land are estimated based on the relative areas of AR and FM relative to the total forest area. The total area of burned forest (37.8 ha) was multiplied by the fraction of the area of AR or FM land to total area of forest land for a given year.

Other wild fires
Also CO_2, CH_4 and N_2O emissions from 'other' wildfires (mainly on grassland and heathland) are calculated and reported according the Tier 1 method as described in the 2016 IPPC Guidelines (Equation 2.27, Table 6.4, value for 'cold temperate - wet). For all years from 1990 onwards the area of other wildfires from the historic data was the basis for the area burned (Table 12.1). On average this is 210 ha yr^{-1} (Table 12.1).

In the Netherlands these other wildfires are predominantly fires in dunes and heathlands, that both are reported under Grassland (non-TOF). Emissions from these 'other' wild fires therefore are reported in CRF Table 4(V) under Grassland remaining Grassland.

Under KP-LULUCF emissions from wildfires on deforested land are covered by these other wildfires (i.e. wildfires on land that before was converted from forest to another land use). The total area Grassland (non-TOF) that is under D land, however, is only 1.4 to 2% of the total Grassland (non-TOF) area. Similarly to emissions from forest fires the wildfire area reported under KP-LULUCF Deforestation is calculated proportional to the Grassland (non-TOF) area under Deforestation compared to the total Grassland (non-TOF) area.

12.3 Potential improvements

During the UNFCCC review process of the NIR 2019 the reviewer pointed to available geospatial techniques for the identification of forest fires, like the European Forest Fire Information System (EFFIS), as a possible data source to improve fire activity data after 1992.

In 2016, however, we already undertook an attempt to improve wild fire activity data by testing various remote sensing sensors and geospatial techniques (Roerink and Arets 2016). None of these approaches were very effective in detecting the relevant forest and wild fires. The alternative of combining information on wild fires from the media and subsequently analysing areas per vegetation type of wild fire (forest or non-forest) was effective (see Table 12.2 for results). Although this is only for two years, the average extent of forest (32 ha) and other wildfires (215) is similar to the areas in the historic situation (Table 12.1). The cost to for the monitoring and analyses, however, were considered to be disproportionate to the potential quality improvement for the greenhouse gas inventory.

Table 12.2 *Number and areas (ha) of wildfires in 2014 and 2015 (data from Roerink and Arets 2016)*

Year	Number of wildfires	Total area (ha)	Forest fires (ha)	Other wildfires (ha)
2014	5	410	54	357
2015	3	83	10	73

Additionally, we have looked into possible improvements in wild fire statistics in the Netherlands using the EFFIS data that are reported in its annual fire reports[7] since 2000. Until 2017 the Netherlands did not submit a report to EFFIS, but the EFFIS reports also include independent rapid damage assessment that aim to provide reliable and harmonized estimates of the areas affected by forest fires in collaborating countries. Although The Netherlands are included in these assessments, even with the

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[7] https://effis.jrc.ec.europa.eu/reports-and-publications/annual-fire-reports/

recent improvements in the resolution of fire detection from 50 to 30 ha most fires in the Netherlands appear to remain undetected (Table 12.3).

Table 12.3 *Number and areas (ha) of wildfires reported under the rapid assessment chapter in the annual EFFIS reports since 2000.*

Year	Number of fires	Area forest/OWL	Area other natural	Area agriculture	Total area without Agriculture
2018	3	13	170	0	183
2017					0
2016					0
2015	1		23		22
2014	1	4	342	50	346
2013					0
2012					0
2011	1	55	93		147
2010					0
2009					0
2008					0
2007					0
2006	1	?	?		70
2005					0
2004					0
2003					0
2002					0
2001					0
2000					0

Since 2018 the Netherlands also submits a country report to EFFIS, which is included in the 2018 annual EFFIS report (San-Miguel-Ayanz et al. 2019). The Netherlands Fire Service registered a total of 949 wildfires in 2018. These were concentrated in the summer months July and August. Fires mainly occurred on dry sandy soils in the Veluwe region (centre), Noord-Brabant and Limburg (southeast) and in the sand dunes along the coast. The total number of fires in 2018 was roughly triple that of 2017, when 321 wildfires were registered.

The wildfires registered by the Netherlands Fire Service include a large variation of wild fires, including small roadside fires. As a result the total number of fires registered by the Fire Service is very different from the numbers detected with the geospatial analysis in Roerink and Arets (2016) (Table 12.2) and the EFFIS rapid damage assessment (Table 12.3). Unfortunately the information collected by the Fire Service does not include information on the spatial extent of the registered fires. It does, however, include information on locations, estimated duration of the fires and the number of dispatched water tenders.

We will further explore possibilities to get improved wild fire activity data by combining geospatial analyses with the information registered by the Netherlands Fire Service. Given the currently small extent of wild fires in the Netherlands an important prerequisite will be that such approaches should be cost effective and proportionate to the expected emissions from wild fires.

13 Kyoto tables –detailed information

13.1 Introduction

In this chapter more detailed information for filling of the CRF tables for LULUCF under the Kyoto Protocol is provided. Descriptions on the methodologies, activity data and emission factors are mostly provided in the previous chapters. Where needed additional information will be provided in this chapter.

13.2 Scope and definition

13.2.1 Forest definition

The definition of forests matches the definition of Forest Land in the inventory under the UNFCCC that is given in Chapter 2.2. This definition is in line with the FAO reporting since 1984 and was chosen within the ranges set by the Kyoto Protocol.

13.2.2 Definition of Afforestation, Reforestation, Deforestation and Forest Management

Units of land subject to Article 3.3 *Afforestation and Reforestation* are reported jointly and are defined as units of land that did not comply with the forest definition on 1 January 1990 and do so at any moment (that can be measured) before 31 December of the reporting year. Land is classified as re/afforested as long as it complies with the forest definition.

Units of land subject to Article 3.3 *Deforestation* are defined as units of land that did comply with the forest definition at any moment in time on or after 1 January 1990, and ceased to comply with this forest definition at any moment in time (that can be measured) after 1 January 1990. Once land is classified as deforested, it remains in this category, even if it is reforested and thus complies with the forest definition again later in time.

Units of land subject to Article 3.4 *Forest Management* are units of land meeting the definition of forest that is managed for stewardship and use of forest land since 1 January 1990 up until the reporting year. For this the Netherlands applies the broad interpretation of Forest Management. As a result all forest land under the UNFCCC that is not classified as AR or D land will be classified as FM. Further, since all forest land in the Netherlands is considered to be managed land, and conversions from other land uses to forest land are always human induced, such conversions to forest land will always be reported under AR.

13.3 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).

13.3.1 NIR 1 – Summary table

The NIR-1 table (see Table 13.1 and Table 13.2) provides information on activity coverage and other information relating to activities under Article 3.3 and forest management under Article 3.4. The

Netherlands has not elected any other activities under Article 3.4, which is indicated with the notation key NA.

Table 13.1 *NIR 1 table, coverage of change in carbon pools for the activities afforestation/reforestation (AR), Deforestation (D) and Forest Management (FM). R: Reported, NR: Not Reported, IE: Included Elsewhere, IO: Instantaneous Oxidation.*

Activity		Change in carbon pool reported						
		Above-ground biomass	Below-ground biomass	Litter	Dead wood	Mineral soil	Organic soils	HWP
Art. 3.3	AR	R	R	NR	R	R	R	IE
	D	R	R	R	R	R	R	IO
Art. 3.4	FM	R	R	NR	R	R	R	R

The Netherlands reports all changes in carbon stocks in above and below ground biomass, and mineral and organic soils for the three activities AR, D and FM. Changes in the litter carbon pools for AR and FM are conservatively reported as 'not a source' (see Chapter 4) with the notation key NR (Not reported) in the CRF NIR 1 Table and the notation key NE hence in the CRF tables 4(KP-I)A.1 and 4(KP-I)B.1.

Consistent with the underlying harvest data, where total roundwood harvest is estimated using permanent sample plots from the National Forest Inventories all harvesting of wood is allocated to Forest Management. Forest areas under AR are considered too young for harvesting. In cases where still harvests occurred in AR land, these have been considered under FM and therefore the notation key IE is used in the AR tables. HWP from lands reported under deforestation are reported and accounted on the basis of instantaneous oxidation (IO).

Table 13.2 *NIR 1 table, coverage of reported greenhouse gas emissions for the activities Afforestation/Re-forestation (AR), Deforestation (D) and Forest Management (FM). R: Reported, IE: Included Elsewhere, NO: Not Occurring.*

Activity		Greenhouse gas sources reported							
		Fertilization		Drained, rewetted and other soils	Nitrogen minerali-zation in mineral soils	Indirect N$_2$O emissions from managed soil	Biomass burning		
		N$_2$O	CH$_4$	N$_2$O	N$_2$O	N$_2$O	CO$_2$	CH$_4$	N$_2$O
Art. 3.3	AR	NO	NE	R	R	NO	R	R	R
	D	IE	NE	IE	R	IE	R	R	R
Art. 3.4	FM	NO	NE	R	R	NO	R	R	R

In the Netherlands in general no fertiliser is applied in forests. Therefore N$_2$O emissions from fertilization and indirect N$_2$O emissions from managed soil are not occurring under AR and FM. N$_2$O emissions from fertilization and indirect N$_2$O emissions from managed soil in agricultural areas following deforestation are reported in the Agriculture sector and therefore, here are reported as included elsewhere (IE).

Drainage is not a common practice in forests in the Netherlands. However, since afforestation often occurs on land with previously agricultural land use, it cannot be completely ruled out that the old drainage systems from the agricultural sites are still active . Therefore a conservative estimate of potential area and associated CO2 emissions are included and applied to forest land and AR and FM (see Chapter 11.2.1). Also the associated N$_2$O emissions that occur due to mineralisation of organic nitrogen are calculated for AR and FM. However, due to lack of sufficient supporting data for such

drainage, CH_4 emissions from drained organic soils under AR and FM are not estimated. Also CH_4 emissions from cultivated drained organic soils are assumed to be negligible in the Netherlands. Although these might occur from ditches, these areas are not separately mapped. The area of these ditches is included in the agricultural land use (cropland and grassland after deforestation) under organic soils. For these soils the emissions of CO_2 and N_2O are reported for which the emission factors are much higher compared to the CH_4 emission factor for ditches. N_2O emissions in agricultural land use under Deforestation are included in "Cultivation of Organic Soils" in CRF Table 3.D of the Agriculture Sector and therefore these are reported as IE in the CRF NIR 1 table.

A marginally small area of rewetted organic soils exists in the Netherlands, but these are not mapped as such. Therefore these soils are comprised under the organic soils with their related CO_2 and N_2O emissions.

13.3.2   NIR 2 – land transition matrix

The reported land use changes in the Netherlands are based on a map overlay between land use maps (see Chapter 3). The land use matrix on the basis of these maps shows changes aggregated to the 6 IPCC categories for LULUCF (IPCC 2006b): Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land (see Chapter 3). In the Netherlands all land use changes to and from forests are considered human induced. For reporting under the Kyoto Protocol all areas of land that fulfil the criteria for AR, D and FM are included (see Section 13.2.2). Once land is included under D land, it will remain included under D, even if it is reforested again later in time. As a result the land areas reported under UNFCCC category 4.A.2 "Land converted to Forest land" does not necessarily match the areas reported under AR.

The result is a map with national coverage that identifies between 1990, 2004, 2009 and 2013 for each pixel whether it was subject to D or AR or remains under FM and whether it is located on an organic soil or a mineral soil and which mineral soil type.

Consequently between 1990 and 2004, between 2004 and 2009 and between 2009 and 2013 the status as AR, D or FM land is certain for each of the individual locations on the map that were subject to AR, D and FM. However, it is unknown for each individual location when exactly this occurred during the time period between the maps. Therefore, for each period the mean annual rate for the Netherlands as a whole is derived from this by interpolating. For AR and D occurring after 1 January following the year of the latest available land use map until the reporting year, the mean annual rate for the activities is derived by extrapolating the mean annual rates for the last period for which land use change could be determined from the maps. The exact location of AR and D activities after this map is not known. The location will be specified as soon as a new land use map is created. All AR, D and FM will then be recalculated for the years that were previously based on extrapolation.

13.3.3   NIR 2.1 – Land Transition, area of natural forests converted to planted forests

In the Netherlands conversion of natural forests to planted forests is not occurring and therefore the notation key NO is used. Originally wood-production was the main purpose of forests and as a result the majority of the forest area in the Netherlands is planted (see FAO 2014). Since the 1970's forest use has been diversified and has multiple purposes, like nature conservation, recreation, wood production, etc. As a result management of the previously even-aged stands has changed to transform these forests to stands with more age-classes and higher species richness. Natural regeneration plays an important role in this transformation (FAO 2014).

13.3.4   NIR-3 – key source analysis

Key category analysis is performed by comparing matching categories between KP reporting and Convention reporting, as well as by comparing KP reporting categories with the smallest Convention key categories for level (both including and excluding LULUCF).

13.4   4(KP-I)A.1, 4(KP-I)A.2 and 4(KP-I)B.1

13.4.1   Carbon stock changes

All data tables for Carbon Stock Changes under article 3.3: 4(KP-I)A.1 (AR), 4(KP-I)A.2 (D) and 4(KP-I)B.1 (FM) are filled according to the same structure:

- Aboveground biomass
- Belowground biomass
- Litter
- Dead Wood
- Organic soil
- Mineral soil
- HWP

The calculations of gains and losses in carbon stocks and fluxes follow the methodology for the corresponding UNFCCC categories.

This means that under AR (**4(KP-I)A.1**) the calculations are similar to those for 'Land converted to Forest Land' (Section 4.2.2) during the first 20 years after conversion and follow the calculations for 'Forest Land remaining Forest Land' (Section 4.2.1) for the years thereafter. Losses of biomass in Cropland and Grassland associated with the conversion to Forest land, is calculated as an instantaneous loss of the whole biomass present in a grid cell in the year of conversion.

Under D (**4(KP-I)A.2**), the calculations in the year of deforestation are similar to the calculations of Forest Land converted to other land (Section 4.2.3). In consecutive years the reported gains and losses follow the UNFCCC calculations for the relevant land use categories and changes in land use. Calculations for FM (**4(KP-I)B.1**) follow the calculations for 'Forest Land remaining Forest Land' as described in Section 4.2.1.

13.4.2   Natural disturbances

In the Netherlands natural disturbances such as forest fires and storm damage do not occur very often and damage in such events is usually limited. However, if circumstances require during the second commitment period, the Netherlands wants to be able to apply the provisions to exclude emissions from natural disturbances for the accounting for AR under Article 3.3 of the Kyoto Protocol and/or FM under Article 3.4 of the Kyoto Protocol. In order to fulfil the requirements for using the Natural Disturbances provision, the Netherlands has established a background level and margin for natural disturbances.

Despite the fact that the Netherlands has indicated that it wants to be able to make use of the Natural Disturbances provision, it is unlikely that this actually will be needed given the infrequent occurrences and limited extent of disturbances in forests. Moreover currently natural disturbances are not monitored structurally, while spatially explicit information on location and extent is largely missing and hence does not meet the conditions for applying the provision. We are further exploring possibilities to improve monitoring and reporting of natural disturbances like wild fires (see Section 12.3).

Information on efforts to prevent, manage or control wildfires in the Netherlands are provided in detail in The Netherlands' country report to the European Forest Fire Information System (San-Miguel-Ayanz et al. 2019).

Background level and margin
The background level and margin are calculated using the default method as provided in Section 2.3.9.6 of the IPCC 2013 revised supplementary methods for KP (IPCC 2014). In an elaboration of iterative steps all outliers are removed, providing the resulting annual background level plus margin (i.e. twice the standard error).

Types of natural disturbances

Because natural disturbances in forests in the Netherlands are relatively rare, these disturbances are not actively monitored and recorded and therefore only limited data are available. For AR the Netherlands includes wildfires as disturbance type and for FM the Netherlands includes wildfires and wind storms (as an extreme weather event).

Activity data and emission data used for the calibration period

Based on the total extent of forest fires, greenhouse gas emissions from forest fires are calculated for FM and AR land under KP-LULUCF following the methodology in Chapter 12.

Information on wind storms is used from a proprietary database that is maintained at Wageningen Environmental Research in which damage from major storm events is collected. Part of this data is available through Schelhaas *et al.*, (2003). Salvage logging is estimated to remove 60% of the fallen tree volume, which is subtracted from the total volume. The remaining 40% is included under natural disturbance for calibration. Information on wind damage is in volumes lost stem wood. Because wind damage in the Netherlands mainly involves coniferous forests, this volume stem wood is converted to aboveground biomass using the average biomass conversion and expansion factors for coniferous species (see Table 4.1 in Section 4.2.1). Based on this aboveground biomass the belowground biomass involved is calculated using a root to shoot ratio of 0.18. The Tier 1 carbon fraction for coniferous species (0.51) is used to subsequently convert to carbon.

13.5 Data tables for CSC under article 3.4: 4(KP-I)B.2-B.5 - tables

The Netherlands has not elected any voluntary activities under KP article 3.4. These tables therefore are reported using the notation key "NA".

13.6 4(KP-I)C - Carbon stock changes in the harvested wood products (HWP) pool

The methodology and choice of activity data and emission factors is provided in Chapter 10. For HWP from Deforestation the Netherlands applies Tier 1 instantaneous oxidation. As no country specific methodologies or half-life constants exist for the calculations of the HWP-pools from FM, the Netherlands applies The Tier 2 approach and default carbon conversion factors and half-lives as outlined in the 2013 IPCC KP guidance (see Chapter 10).

13.7 Data tables for other gases under article 3.3 and 3.4: 4(KP-II) tables

13.7.1 4(KP-II)1 Direct N_2O emissions from nitrogen fertilisation

Nitrogen fertilization of forests does not occur in the Netherlands. Therefore, NO is reported here for AR and FM. Direct and indirect N_2O emissions from nitrogen fertilization of agricultural land is reported under the Agriculture Sector. Therefore the emissions for D are reported as IE.

13.7.2 4(KP-II)2 CH_4 and N_2O emissions from drained and rewetted organic soils

Drainage is not a common practice in forests in the Netherlands. However, since afforestation often occurs on land with previously agricultural land use, it cannot be completely ruled out that the old drainage systems from the agricultural sites are still active. Therefore a conservative estimate of potential area and associated CO_2 emissions are included and applied to forest land and AR and FM

(see Section 11.2.1). Also the associated N_2O emissions that occur due to mineralisation of organic nitrogen are calculated for AR and FM using the methodology described in Section 11.3.1. However, due to lack of sufficient supporting data for such drainage, CH_4 emissions from drained organic soils under AR and FM are not estimated. Also CH_4 emissions from cultivated drained organic soils are assumed to be negligible in the Netherlands. Although these might occur from ditches, these areas are not separately mapped. The area of these ditches is included in the forest land use (AR and FM) and agricultural land use (cropland and grassland after deforestation) under organic soils. For these soils the emissions of CO_2 and N_2O are reported for which the emission factors are much higher compared to the CH_4 emission factor for ditches. N_2O emissions in agricultural land use under Deforestation are included in 'Cultivation of Organic Soils' in CRF Table 3.D of the Agriculture Sector and therefore these are reported as IE.

A marginally small area of rewetted organic soils exists in the Netherlands, but these are not mapped as such. Therefore these soils are comprised under the organic soils with their related CO_2 and N_2O emissions.

13.7.3   4(KP-II)3 N_2O emissions from disturbance associated with land use conversion and management in mineral soils

The N_2O emissions associated with land use conversions are calculated based on the Tier 2 methodology provided in Section 11.2.1. Under FM such emissions are not occurring. N_2O emissions under AR, are the result of the land use conversion to forest land. Under Deforestation also emissions due to subsequent land use conversions on D land are taken into consideration.

13.7.4   4(KP-II)4 Greenhouse gas emissions from biomass burning

The calculation of GHG emissions from biomass burning is provided in Section 12.2. The area burned and emissions are attributed to AR and FM land proportional to their share in the total forest land. These estimates are reported in Table 4(KP-II)4 under AR and FM.

Where applicable emissions from other wildfires on deforested grassland are estimated using a Tier 1 methodology and are reported under Deforestation in Table 4(KP-II)4.

14 Uncertainty assessment

14.1 Introduction

To assess the uncertainty of the reported emissions from LULUCF an approach was developed and implemented using a Monte-Carlo approach (Approach 2 cf. Section 3.2.3.2 in IPCC 2006a).

Up to the NIR 2017, the uncertainty of LULUCF emissions was based on the old Tier 1 uncertainty assessment as presented in Olivier *et al.* (2009). That uncertainty assessment is, however, based on calculation methodology that is not used in recent submissions. Furthermore, it contained a strongly simplified implementation of the uncertainty in the land use maps and not all parameters currently reported were included.

The documentation below presents
1. The background on the types of uncertainty addressed.
2. A description of the uncertainty range input parameters used.
3. A description of the MC simulation performed.
4. The resulting uncertainty ranges for the reported fluxes.
5. The temporal development of the uncertainty.
6. The attribution of these uncertainty ranges to different groups of input parameters.

Due to the demanding run times of the currently used Monte Carlo approach, it is not feasible to update this uncertainty assessment every year. Therefore, the assessment presented here does not include the most recent methodology changes yet. The information provided in this chapter is based on runs done in 2017 that included time series until 2014. This means that uncertainty of the new land-use map 2017, and the updated soil map have not been included in the results presented in this chapter. It is likely however that uncertainties remain in the same order of magnitude as presented here.

14.2 Types of uncertainty

The IPCC 2006 guidelines identify nine causes of uncertainty (Table 3.1 in IPCC 2006a). Of these nine causes, two are addressed with this uncertainty assessment: a) the statistical random sampling error and b) the random component in the measurement error. These types of uncertainty are readily assessed using appropriate statistical techniques. With this the precision of the calculated GHG emissions and removals is assessed given the bias in measurements, data and models.

Both type of causes of uncertainty addressed relate to uncertainty in the values of the input data of the calculation. Two approaches are suggested for the combination of these uncertainties. Because one source of uncertainty is in the mapping of land use, which is inherently correlated and analytically intractable, approach 2, the Monte Carlo simulation is applied.

In order to identify the main sources of uncertainty in the total emission estimation, partial uncertainties were derived from emission factors related to biomass, emission factors related to soil carbon and the activity data based on the land use map. These partial uncertainties are derived as the uncertainty-range from those iterations in the Monte Carlo simulation that only include the focal source, divided by the uncertainty-range over all iterations.

14.3   Uncertainty ranges in input

Three main groups of input parameters are identified as uncertain and are evaluated;
1) uncertainties from emission factors related to biomass,
2) emission factors related to soil, and
3) activity data based on the land use map

Where default Tier 1 emission factors and activity data are used from the IPCC 2006 guidelines also their Tier 1 uncertainty ranges are used as input to the Monte Carlos assessment. When measurement data were available, emission factor uncertainty was calculated as twice the standard-error of the mean (S.E.M.) calculated from these measurements (see Tables 14.1 to 14.5).

14.3.1   Biomass-related uncertainty

The biomass related uncertainty includes uncertainty in biomass stock (Table 14.1 and Table 14.2), the ratios between aboveground and belowground biomass, deadwood and litter estimates (Table 14.2) and parameters for the calculation of emission from wildfires (Table 14.3).

Table 14.1 *Uncertainty ranges for non-forest biomass*

Land use	Biomass stock (kton ha^{-1})	S.E.M.
Grassland vegetation & nature	0.0068	0.00255
Cropland	0.005	0.001875

Table 14.2 *Uncertainty ranges for forest biomass and dead wood (see Table 4.2)*

Parameter	Year	Units	Value	S.E.M.
Growing stock	1990	m^3/ha	157.98	1.93
Growing stock	2003	m^3/ha	194.61	1.91
Growing stock	2013	m^3/ha	216.52	2.26
BCEF	1990	kg/m^3	714	5.71
BCEF	2003	kg/m^3	736	6.06
BCEF	2013	kg/m^3	764	5.98
R	1990	-	0.18	0.000708
R	2003	-	0.18	0.000625
R	2013	-	0.18	0.000717
Standing dead wood mass	1990	ton/ha	837.05	35.73
Standing dead wood mass	2003	ton/ha	1333.32	53.12
Standing dead wood mass	2013	ton/ha	1883.49	75.87
Lying dead wood mass	2003	ton/ha	1527.01	74.35
Lying dead wood mass	2013	ton/ha	1927.01	84.51

Table 14.3 *Uncertainty ranges for wild fires*

Parameter	Value	S.E.M.	Unit
Forest area burnt	37.77	10.38	Ha
NonForest area burnt	210	38.69	ha
Combustion efficiency Forest	0.45	0.16	-
Combustion efficiency NonForest	0.71	0.6	-
Gef_CO2_Forest	1569	131	g /kg
Gef_CO_Forest	107	37	g /kg
Gef_CH4_Forest	4.7	1	g /kg
Gef_N2O_Forest	0.26	0.07	g /kg
Gef_NOX_Forest	3	1.4	g /kg
Gef_CO2_NonForest	1613	95	g /kg
Gef_CO_NonForest	65	20	g /kg
Gef_CH4_NonForest	2.3	0.9	g /kg
Gef_N2O_NonForest	0.21	0.1	g /kg
Gef_NOX_NonForest	3.9	2.4	g /kg

14.3.2   Soil-related uncertainty

The soil related uncertainties are the uncertainty in land use and soil type specific carbon stock and C-N ratio for mineral soils (Table 14.4), and carbon-fluxes for organic soils (Table 14.5).

Table 14.4 *Uncertainty ranges for soil carbon stock and C-N ratio for mineral soils*

Land use	Soil type	Cstock (tC/ha)	SEM (C-stock)	CN ratio (-)	SEM (CN ratio)
Grassland	Brikgrond	78.3	5.47	15	2.50
Grassland	Eerdgrond	87.84	6.47	15	2.50
Grassland	Kalkhoudende zandgrond	58.55	7.65	17.3	0.21
Grassland	Kalkloze zandgrond	86.56	2.76	23.4	1.34
Grassland	Leemgrond	88.91	5.32	15	2.50
Grassland	Onbepaald	105.64	1.65	15	2.50
Grassland	Oude kleigrond	81.12	6.36	15	2.50
Grassland	Podzol grond	116.07	4.01	25.6	0.31
Grassland	Rivierklei grond	111.32	3.36	15	2.50
Grassland	Zeekleigrond	113.66	2.77	15	2.50
Cropland	Brikgrond	76.37	2.8	15	2.50
Cropland	Eerdgrond	71.27	7.48	15	2.50
Cropland	Kalkhoudende zandgrond	54.11	5.41	17.3	0.21
Cropland	Kalkloze zandgrond	76.46	4.34	23.4	1.34
Cropland	Leemgrond	81.54	6.05	15	2.50
Cropland	Onbepaald	82.47	1.98	15	2.50
Cropland	Oude kleigrond	83.86	19.96	15	2.50
Cropland	Podzol grond	107.56	6.94	25.6	0.31
Cropland	Rivierklei grond	84.57	6.12	15	2.50
Cropland	Zeekleigrond	80.6	2.18	15	2.50
Forest land	Brikgrond	82.47	12.77	15	2.50
Forest land	Eerdgrond	99.53	17.39	15	2.50
Forest land	Kalkhoudende zandgrond	32.16	5.78	17.3	0.21
Forest land	Kalkloze zandgrond	57.39	5.18	23.4	1.34

Land use	Soil type	Cstock (tC/ha)	SEM (C-stock)	CN ratio (-)	SEM (CN ratio)
Forest land	Leemgrond	112.18	15.41	15	2.50
Forest land	Onbepaald	87.68	3.73	15	2.50
Forest land	Oude kleigrond	61.39	34.37	15	2.50
Forest land	Podzol grond	92.23	4.68	25.6	0.31
Forest land	Rivierklei grond	139.95	7.45	15	2.50
Forest land	Zeekleigrond	139.49	10.54	15	2.50
Wetland	Brikgrond	82.47	12.77	15	2.50
Wetland	Eerdgrond	99.53	17.39	15	2.50
Wetland	Kalkhoudende zandgrond	32.16	5.78	17.3	0.21
Wetland	Kalkloze zandgrond	57.39	5.18	23.4	1.34
Wetland	Leemgrond	112.18	15.41	15	2.50
Wetland	Onbepaald	87.68	3.73	15	2.50
Wetland	Oude kleigrond	61.39	34.37	15	2.50
Wetland	Podzol grond	92.23	4.68	25.6	0.31
Wetland	Rivierklei grond	139.95	7.45	15	2.50
Wetland	Zeekleigrond	139.49	10.54	15	2.50
Settlements	Brikgrond	74.22	11.49	15	2.50
Settlements	Eerdgrond	89.57	15.65	15	2.50
Settlements	Kalkhoudende zandgrond	28.94	5.2	17.3	0.21
Settlements	Kalkloze zandgrond	51.65	4.66	23.4	1.34
Settlements	Leemgrond	100.96	13.87	15	2.50
Settlements	Onbepaald	78.91	3.36	15	2.50
Settlements	Oude kleigrond	55.25	30.94	15	2.50
Settlements	Podzol grond	83.01	4.21	25.6	0.31
Settlements	Rivierklei grond	125.96	6.7	15	2.50
Settlements	Zeekleigrond	125.54	9.48	15	2.50
Grassland	Brikgrond	78.3	5.47	15	2.50
Grassland	Eerdgrond	87.84	6.47	15	2.50
Grassland	Kalkhoudende zandgrond	58.55	7.65	17.3	0.21
Grassland	Kalkloze zandgrond	86.56	2.76	23.4	1.34
Grassland	Leemgrond	88.91	5.32	15	2.50
Grassland	Onbepaald	105.64	1.65	15	2.50
Grassland	Oude kleigrond	81.12	6.36	15	2.50
Grassland	Podzol grond	116.07	4.01	25.6	0.31
Grassland	Rivierklei grond	111.32	3.36	15	2.50
Grassland	Zeekleigrond	113.66	2.77	15	2.50
Wetland	Brikgrond	82.47	12.77	15	2.50
Wetland	Eerdgrond	99.53	17.39	15	2.50
Wetland	Kalkhoudende zandgrond	32.16	5.78	17.3	0.21
Wetland	Kalkloze zandgrond	57.39	5.18	23.4	1.34
Wetland	Leemgrond	112.18	15.41	15	2.50
Wetland	Onbepaald	87.68	3.73	15	2.50
Wetland	Oude kleigrond	61.39	34.37	15	2.50
Wetland	Podzol grond	92.23	4.68	25.6	0.31
Wetland	Rivierklei grond	139.95	7.45	15	2.50
Wetland	Zeekleigrond	139.49	10.54	15	2.50

Table 14.5 *Uncertainty ranges for soil carbon fluxes from organic soils*

Land use	Soil type	Soil Flux	S.E.M.
Grassland / Cropland / Settlement	Peat soils	19.03	9.51
Grassland / Cropland / Settlement	Peaty soils	13.02	6.51

14.3.3   Land use related uncertainty

The land use related uncertainty is expressed as a confusion matrix, based on Kramer *et al.* 2015 Kramer and Clement (2015). This matrix provides the pdf of the land use in a pixel, given the classification of the pixel (Table 14.6, from Kramer and Clement 2015, table 2.12). Using these pdfs random alternative maps are generated for each iteration. Although the actual uncertainty in land use mapping will involve both spatial and temporal auto-correlations, these are not taken into account here due to a lack of data. This confusion matrix is biased from settlements and other land to mainly grassland, cropland and forest. Due to this asymmetry in the confusion matrix, the land use related uncertainty is assessed as the range over iterations with only biomass and soil related uncertainty and iterations with biomass, soil and land use related uncertainty.

Table 14.6 *Confusion matrix for the land use map (from Kramer and Clement 2015)*

PDF -> Classification	Other Land	Grassland	Cropland	Forest	Wetland	Settlements	Heath	Reed
Other Land	0.94	0.04	-	0.02	-	-	-	-
Grassland	0.00	0.98	0.02	0.00	-	0.00	-	-
Cropland	-	0.03	0.97	-	-	-	-	-
Forest	-	0.01	-	0.99	-	-	-	-
Wetland	-	-	-	-	1.00	-	-	-
Settlements	-	0.07	0.02	0.01	-	0.90	-	-
Heath	-	-	-	-	-	-	1.00	-
Reed	-	-	0.02	-	0.02	-	0.02	0.94

14.4   Monte Carlo simulation

In total 683 iterations are performed for the Monte Carlo analysis. Of these iterations, 1 was the nominal iteration without permutations in the input parameters. Of these iterations, 104 only addressed soil uncertainty, 103 only addressed biomass uncertainty and 104 addressed both soil and biomass uncertainty, making a total of 312 iterations without land use map uncertainty. An additional 371 runs included land use map uncertainty (with or without biomass and soil uncertainty)

The number of iterations used for the analysis were based on time constraints. No tests for convergence were performed.

14.5   Total uncertainty

The calculation of the GHG fluxes from LULUCF generate many detailed output. Here only the uncertainty ranges for the main categories in CRF Table 4 are presented for emissions in the year 2014 (Table 14.7).

In general we see that the uncertainty for the different categories varies. For some categories a highly asymmetric uncertainty range occurs. In general the uncertainty in the forest land sink is smaller than the uncertainty in the emissions from other land uses.

Zooming in on the details, it needs to be mentioned that the relative uncertainty is a function of the size of the total emissions or removals reported. Therefore, a large relative uncertainty on a small value can have a minor impact on the total uncertainty. When looking at the contribution of the different categories to the total emissions, we see that Grassland remaining Grassland accounts for 68% of the net emissions and cropland as a whole for 42% of the net emissions, while the forest remaining forest accounts for a sink of the size of 35% of the net emissions. The other categories contribute a maximum of 19% (land converted to settlements). The category with the largest uncertainty (land converted to Grassland) only contributes 6% of the total net emissions.

Table 14.7 *Uncertainty range per category for 2014[8]*

Greenhouse gas source and sink categories	Net CO$_2$ emissions/removals (min, max)
4. Total LULUCF	**(-38%, + 64%)**
A. Forest land	**(10%, + -12%)**
1. Forest land remaining forest land	(11%, + -14%)
2. Land converted to forest land	(26%, + -21%)
B. Cropland	**(-39%, + 44%)**
1. Cropland remaining cropland	(-61%, + 60%)
2. Land converted to cropland	(-45%, + 61%)
C. Grassland	**(-62%, + 75%)**
1. Grassland remaining grassland	(-60%, + 68%)
2. Land converted to grassland	(-220%, + 340%)
D. Wetlands	**(-67%, + 76%)**
1. Wetlands remaining wetlands	IE,NO
2. Land converted to wetlands	(-67%, + 76%)
E. Settlements	**(-23%, + 69%)**
1. Settlements remaining settlements	(-64%, + 53%)
2. Land converted to settlements	(-17%, + 90%)
F. Other land [(4)]	**(-3%, + 152%)**
1. Other land remaining other land	NO
2. Land converted to other land	(-3%, + 152%)
G. Harvested wood products	(-8%, + 1%)
H. Other *(please specify)*	IE,NE,NO

14.6   Temporal variability in uncertainty

Table 14.7 gives the uncertainty over the numbers calculated for 2014. These uncertainty ranges are not stable over time, as different sources of data have different temporal resolution (Table 14.8). Here again the large uncertainty, and the volatility of this uncertainty, for land converted to grassland is apparent. Again the main cause for this is that the absolute value is small, and thus that a similar uncertainty in absolute values, results in an extreme relative uncertainty around 2010.

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[8] A negative maximum implies that the category is a sink.

Table 14.8 *Temporal evolution of the uncertainty ranges by category*

Greenhouse gas source and sink categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
4. Total LULUCF	**(-51%, + 68%)**	**(-46%, + 60%)**	**(-46%, + 60%)**	**(-45%, + 59%)**	**(-45%, + 59%)**	**(-45%, + 60%)**	**(-45%, + 61%)**	**(-46%, + 61%)**	**(-46%, + 61%)**	**(-46%, + 62%)**	**(-46%, + 62%)**	**(-45%, + 61%)**	**(-45%, + 61%)**
A. Forest land	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -14%)**	**(15%, + -13%)**	**(15%, + -13%)**	**(15%, + -13%)**	**(14%, + -13%)**
1. Forest land remaining forest land	(15%, + -13%)	(15%, + -13%)	(14%, + -13%)	(14%, + -13%)	(14%, + -14%)	(14%, + -14%)	(14%, + -14%)	(14%, + -14%)	(14%, + -14%)	(14%, + -15%)	(14%, + -15%)	(14%, + -15%)	(14%, + -16%)
2. Land converted to forest land	(-39%, + 63%)	(-45%, + 65%)	(-53%, + 70%)	(-76%, + 92%)	(-137%, + 153%)	(-939%, + 878%)	(213%, + -170%)	(108%, + -71%)	(81%, + -45%)	(69%, + -34%)	(61%, + -28%)	(56%, + -23%)	(54%, + -22%)
B. Cropland	**(-49%, + 58%)**	**(-48%, + 56%)**	**(-47%, + 55%)**	**(-46%, + 54%)**	**(-44%, + 54%)**	**(-43%, + 53%)**	**(-42%, + 53%)**	**(-41%, + 52%)**	**(-40%, + 52%)**	**(-40%, + 51%)**	**(-39%, + 50%)**	**(-38%, + 50%)**	**(-37%, + 49%)**
1. Cropland remaining cropland	(-55%, + 68%)	(-55%, + 67%)	(-55%, + 66%)	(-55%, + 65%)	(-55%, + 65%)	(-56%, + 65%)	(-56%, + 65%)	(-57%, + 64%)	(-57%, + 64%)	(-57%, + 64%)	(-58%, + 64%)	(-58%, + 64%)	(-58%, + 64%)
2. Land converted to cropland	(-152%, + 175%)	(-112%, + 135%)	(-88%, + 107%)	(-73%, + 94%)	(-62%, + 85%)	(-55%, + 77%)	(-49%, + 71%)	(-46%, + 67%)	(-41%, + 63%)	(-37%, + 59%)	(-35%, + 56%)	(-33%, + 54%)	(-32%, + 54%)
C. Grassland	**(-53%, + 69%)**	**(-53%, + 69%)**	**(-54%, + 69%)**	**(-54%, + 70%)**	**(-55%, + 70%)**	**(-55%, + 70%)**	**(-56%, + 70%)**	**(-56%, + 70%)**	**(-56%, + 70%)**	**(-57%, + 70%)**	**(-58%, + 70%)**	**(-58%, + 71%)**	**(-59%, + 71%)**
1. Grassland remaining grassland	(-56%, + 68%)	(-56%, + 67%)	(-56%, + 67%)	(-56%, + 67%)	(-56%, + 67%)	(-56%, + 67%)	(-56%, + 66%)	(-57%, + 66%)	(-57%, + 66%)	(-57%, + 66%)	(-57%, + 67%)	(-57%, + 67%)	(-57%, + 67%)
2. Land converted to grassland	(-111%, + 150%)	(-116%, + 154%)	(-123%, + 161%)	(-134%, + 168%)	(-140%, + 175%)	(-150%, + 184%)	(-162%, + 192%)	(-173%, + 204%)	(-186%, + 213%)	(-206%, + 228%)	(-218%, + 251%)	(-246%, + 277%)	(-266%, + 305%)
D. Wetlands	**(-24%, + 27%)**	**(-25%, + 29%)**	**(-27%, + 31%)**	**(-28%, + 33%)**	**(-30%, + 35%)**	**(-32%, + 37%)**	**(-35%, + 39%)**	**(-38%, + 41%)**	**(-41%, + 45%)**	**(-45%, + 50%)**	**(-52%, + 55%)**	**(-58%, + 64%)**	**(-65%, + 73%)**
1. Wetlands remaining wetlands	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
2. Land converted to wetlands	(-24%, + 27%)	(-25%, + 29%)	(-27%, + 31%)	(-28%, + 33%)	(-30%, + 35%)	(-32%, + 37%)	(-35%, + 39%)	(-38%, + 41%)	(-41%, + 45%)	(-45%, + 50%)	(-52%, + 55%)	(-58%, + 64%)	(-65%, + 73%)
E. Settlements	**(-22%, + 33%)**	**(-22%, + 34%)**	**(-23%, + 34%)**	**(-23%, + 35%)**	**(-23%, + 37%)**	**(-23%, + 38%)**	**(-23%, + 38%)**	**(-23%, + 39%)**	**(-24%, + 39%)**	**(-24%, + 40%)**	**(-24%, + 40%)**	**(-25%, + 41%)**	**(-26%, + 41%)**
1. Settlements remaining settlements	(-59%, + 58%)	(-59%, + 58%)	(-59%, + 58%)	(-59%, + 57%)	(-59%, + 56%)	(-59%, + 55%)	(-59%, + 55%)	(-59%, + 55%)	(-59%, + 55%)	(-59%, + 54%)	(-59%, + 54%)	(-60%, + 54%)	(-60%, + 54%)
2. Land converted to settlements	(-20%, + 41%)	(-19%, + 40%)	(-18%, + 39%)	(-17%, + 39%)	(-18%, + 38%)	(-18%, + 40%)	(-19%, + 40%)	(-19%, + 40%)	(-19%, + 41%)	(-19%, + 43%)	(-18%, + 44%)	(-19%, + 45%)	(-20%, + 46%)
F. Other land	**(-4%, + 119%)**	**(-3%, + 116%)**	**(-3%, + 115%)**	**(-3%, + 113%)**	**(-3%, + 112%)**	**(-3%, + 111%)**	**(-3%, + 111%)**	**(-3%, + 111%)**	**(-3%, + 110%)**	**(-3%, + 110%)**	**(-3%, + 109%)**	**(-3%, + 109%)**	**(-3%, + 109%)**
1. Other land remaining other land	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
2. Land converted to other land	(-4%, + 119%)	(-3%, + 116%)	(-3%, + 115%)	(-3%, + 113%)	(-3%, + 112%)	(-3%, + 111%)	(-3%, + 111%)	(-3%, + 111%)	(-3%, + 110%)	(-3%, + 110%)	(-3%, + 109%)	(-3%, + 109%)	(-3%, + 109%)
G. Harvested wood products	(0%, + -8%)	(-5%, + 0%)	(-10%, + 0%)	(-8%, + 0%)	(-9%, + 0%)	(-7%, + 1%)	(-4%, + 1%)	(-4%, + 1%)	(-7%, + 1%)	(-2%, + 2%)	(-3%, + 20%)	(-7%, + 1%)	(-6%, + 1%)

Greenhouse gas source and sink categories	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4. Total LULUCF	**(-44%, + 59%)**	**(-46%, + 62%)**	**(-47%, + 63%)**	**(-46%, + 63%)**	**(-46%, + 63%)**	**(-47%, + 65%)**	**(-45%, + 61%)**	**(-47%, + 64%)**	**(-46%, + 63%)**	**(-45%, + 61%)**	**(-39%, + 65%)**	**(-38%, + 64%)**
A. Forest land	**(25%, + -20%)**	**(23%, + -21%)**	**(22%, + -20%)**	**(22%, + -20%)**	**(21%, + -21%)**	**(20%, + -20%)**	**(20%, + -20%)**	**(19%, + -18%)**	**(19%, + -18%)**	**(21%, + -19%)**	**(10%, + -12%)**	**(10%, + -12%)**
1. Forest land remaining forest land	(25%, + -25%)	(25%, + -25%)	(25%, + -25%)	(25%, + -25%)	(25%, + -25%)	(25%, + -26%)	(25%, + -26%)	(23%, + -22%)	(23%, + -23%)	(23%, + -23%)	(11%, + -14%)	(11%, + -14%)
2. Land converted to forest land	(51%, + -18%)	(34%, + -17%)	(30%, + -16%)	(25%, + -16%)	(22%, + -17%)	(18%, + -17%)	(19%, + -19%)	(20%, + -19%)	(20%, + -19%)	(22%, + -24%)	(23%, + -23%)	(26%, + -21%)
B. Cropland	**(-36%, + 49%)**	**(-40%, + 49%)**	**(-39%, + 49%)**	**(-39%, + 49%)**	**(-38%, + 49%)**	**(-38%, + 49%)**	**(-43%, + 49%)**	**(-43%, + 49%)**	**(-42%, + 48%)**	**(-42%, + 48%)**	**(-40%, + 45%)**	**(-39%, + 44%)**
1. Cropland remaining cropland	(-59%, + 64%)	(-59%, + 63%)	(-59%, + 62%)	(-60%, + 62%)	(-60%, + 62%)	(-60%, + 62%)	(-60%, + 62%)	(-60%, + 62%)	(-60%, + 61%)	(-60%, + 61%)	(-61%, + 61%)	(-61%, + 60%)
2. Land converted to cropland	(-31%, + 54%)	(-47%, + 68%)	(-45%, + 66%)	(-44%, + 64%)	(-42%, + 63%)	(-41%, + 62%)	(-54%, + 71%)	(-54%, + 69%)	(-52%, + 67%)	(-51%, + 66%)	(-47%, + 63%)	(-45%, + 61%)
C. Grassland	**(-59%, + 71%)**	**(-67%, + 78%)**	**(-68%, + 78%)**	**(-68%, + 79%)**	**(-69%, + 79%)**	**(-69%, + 80%)**	**(-69%, + 77%)**	**(-69%, + 77%)**	**(-68%, + 76%)**	**(-68%, + 76%)**	**(-62%, + 75%)**	**(-62%, + 75%)**
1. Grassland remaining grassland	(-57%, + 67%)	(-58%, + 67%)	(-58%, + 67%)	(-58%, + 67%)	(-58%, + 67%)	(-59%, + 67%)	(-59%, + 67%)	(-59%, + 67%)	(-59%, + 67%)	(-59%, + 67%)	(-60%, + 68%)	(-60%, + 68%)
2. Land converted to grassland	(-288%, + 331%)	(369%, + -320%)	(394%, + -370%)	(424%, + -412%)	(444%, + -469%)	(483%, + -524%)	(1682%, + -1702%)	(-35719%, + 38682%)	(-1358%, + 1499%)	(-700%, + 794%)	(-246%, + 363%)	(-220%, + 340%)
D. Wetlands	**(-74%, + 85%)**	**(-72%, + 76%)**	**(-74%, + 80%)**	**(-76%, + 84%)**	**(-80%, + 86%)**	**(-87%, + 89%)**	**(-76%, + 81%)**	**(-77%, + 82%)**	**(-77%, + 81%)**	**(-78%, + 82%)**	**(-64%, + 73%)**	**(-67%, + 76%)**
1. Wetlands remaining wetlands	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
2. Land converted to wetlands	(-74%, + 85%)	(-72%, + 76%)	(-74%, + 80%)	(-76%, + 84%)	(-80%, + 86%)	(-87%, + 89%)	(-76%, + 81%)	(-77%, + 82%)	(-77%, + 81%)	(-78%, + 82%)	(-64%, + 73%)	(-67%, + 76%)
E. Settlements	**(-26%, + 42%)**	**(-26%, + 45%)**	**(-25%, + 45%)**	**(-25%, + 46%)**	**(-24%, + 46%)**	**(-24%, + 47%)**	**(-25%, + 47%)**	**(-25%, + 47%)**	**(-24%, + 46%)**	**(-24%, + 46%)**	**(-23%, + 69%)**	**(-23%, + 69%)**
1. Settlements remaining settlements	(-60%, + 54%)	(-61%, + 53%)	(-62%, + 53%)	(-62%, + 53%)	(-63%, + 53%)	(-64%, + 53%)	(-64%, + 53%)	(-63%, + 53%)	(-63%, + 53%)	(-63%, + 53%)	(-63%, + 53%)	(-64%, + 53%)
2. Land converted to settlements	(-21%, + 46%)	(-19%, + 52%)	(-20%, + 53%)	(-20%, + 54%)	(-20%, + 55%)	(-21%, + 57%)	(-21%, + 58%)	(-21%, + 58%)	(-20%, + 58%)	(-19%, + 58%)	(-18%, + 89%)	(-17%, + 90%)
F. Other land	**(-3%, + 109%)**	**(-4%, + 125%)**	**(-4%, + 122%)**	**(-4%, + 120%)**	**(-4%, + 118%)**	**(-4%, + 116%)**	**(-3%, + 107%)**	**(-3%, + 106%)**	**(-3%, + 104%)**	**(-3%, + 102%)**	**(-3%, + 151%)**	**(-3%, + 152%)**
1. Other land remaining other land	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
2. Land converted to other land	(-3%, + 109%)	(-4%, + 125%)	(-4%, + 122%)	(-4%, + 120%)	(-4%, + 118%)	(-4%, + 116%)	(-3%, + 107%)	(-3%, + 106%)	(-3%, + 104%)	(-3%, + 102%)	(-3%, + 151%)	(-3%, + 152%)
G. Harvested wood products	**(-8%, + 1%)**	**(-10%, + 1%)**	**(-8%, + 1%)**	**(-10%, + 1%)**	**(-12%, + 0%)**	**(-9%, + 1%)**	**(-5%, + 1%)**	**(-4%, + 1%)**	**(-6%, + 1%)**	**(-6%, + 1%)**	**(-9%, + 1%)**	**(-8%, + 1%)**

14.7   Partial uncertainties

To estimate the relative contribution of the different uncertainty sources to the total uncertainty estimate, calculations were performed with the specified uncertainties blocked. Partial uncertainties are discussed here for 2014 (Table 14.9). To understand the partial uncertainties, it must be said that they are calculated in two different ways. For the biomass and the soil based partial uncertainties, an uncertainty range is determined by a Monte Carlo simulation focussed on these uncertainties. The minimum and maximum values of the 95% interval of the results is then expressed relative to the minim and maximum values of the 95% interval of a Monte Carlo simulation with all uncertainties included. Thus, this minimum and maximum can be more than 100% if the partial uncertainty is higher than the total uncertainty (due to the effects of different uncertainties extinguishing each other). The partial uncertainty caused by the inclusion of the map uncertainty is calculated by extracting the uncertainty of a Monte Carlo simulation focussed on both the biomass and the soil uncertainty from the total uncertainty. The remaining uncertainty is interpreted as due to the uncertainty in the map.

Table 14.9 *Partial uncertainties per category as percentage of the total uncertainty*

Greenhouse gas source and sink categories	Biomass 2014	Soil 2014	Map 2014
4. Total LULUCF	**(8%, 15%)**	**(65%, 111%)**	**(17%, 0%)**
A. Forest land	**(103%, 130%)**	**(16%, 21%)**	**(0%, 0%)**
1. Forest land remaining forest land	(98%, 147%)	(0%, 0%)	(4%, 0%)
2. Land converted to forest land	(90%, 74%)	(77%, 66%)	(4%, 22%)
B. Cropland	**(73%, 105%)**	**(87%, 90%)**	**(1%, 0%)**
1. Cropland remaining cropland	(0%, 0%)	(116%, 106%)	(0%, 4%)
2. Land converted to cropland	(77%, 131%)	(43%, 55%)	(29%, 0%)
C. Grassland	**(30%, 30%)**	**(125%, 103%)**	**(0%, 0%)**
1. Grassland remaining grassland	(0%, 0%)	(127%, 100%)	(0%, 8%)
2. Land converted to grassland	(79%, 102%)	(49%, 65%)	(23%, 0%)
D. Wetlands	**(95%, 126%)**	**(67%, 81%)**	**(3%, 0%)**
1. Wetlands remaining wetlands			
2. Land converted to wetlands	(95%, 126%)	(67%, 81%)	(3%, 0%)
E. Settlements	**(14%, 45%)**	**(44%, 123%)**	**(58%, 0%)**
1. Settlements remaining settlements	(0%, 0%)	(137%, 83%)	(0%, 9%)
2. Land converted to settlements	(14%, 78%)	(26%, 139%)	(73%, 0%)
F. Other land	**(1%, 76%)**	**(2%, 109%)**	**(98%, 0%)**
1. Other land remaining other land			
2. Land converted to other land	(1%, 76%)	(2%, 109%)	(98%, 0%)
G. Harvested wood products	**(123%, 12%)**	**(0%, 0%)**	**(0%, 86%)**

In analysing these uncertainties we see that the partial uncertainty can be similar in size. But that the relative contribution of the partial uncertainty can be highly biased. Uncertainty in biomass is mainly responsible for the uncertainty in forest land, and the land converted to the other land uses. Although more on the maximum of the range than on the minimum of the range. This is due to the relatively large biomass on forested lands, and the effect that this biomass has on the emissions of land converted.

The uncertainty in soil parameters has a large impact on the total emissions. All of the maximum range can be accounted for by these uncertainties. While this is only a small contribution to the uncertainty related to forest land, it is the main source of uncertainty for the Cropland and Grassland category. As such it also has a major contribution to the land converted to other land uses. For Other land and Settlements this contribution is mainly to the minimum range, rather than the maximum range.

The uncertainty that cannot be explained by the uncertainty in biomass and soil parameters is attributed to the uncertainty in the land use maps. As the confusion matrix of the land use maps is biased, the effect of this uncertainty on the total uncertainty is biased. Especially the other land and the settlement category experience a skewed uncertainty with the minimum range mainly determined by the uncertainty in the land use maps.

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Justification

This report provides the complete methodological description and gives background information on the Dutch National System for Greenhouse Gas Reporting of the LULUCF sector for the UN Framework Convention on Climate Change and Dutch submission of LULUCF under the Kyoto Protocol. It was prepared as part of the work for the Netherlands Release and Transfer Register. Methodologies are elaborated and applied within the working group on LULUCF and are reviewed by the task force on Agriculture of the Release and Transfer Register. The methodologies follow the 2006 IPCC Guidelines and the 2013 IPCC Supplementary Guidance for LULUCF reporting under the Kyoto Protocol.

Annex 1   Data files used

A1.1   National Forest Inventories

For calculating carbon stock changes in forest biomass data from three National Forest Inventories are used, covering the period 1990-2013: HOSP, NFI-5 and NFI-6.

HOSP
The HOSP (Hout Oogst Statistiek en Prognose oogstbaar hout) inventory was designed in 1984 and conducted between 1988 and 1992 and 1992-1997 (Schoonderwoerd and Daamen 1999). For the LULUCF calculations only the data from the time period 1988-1992 were used, as these best represent the situation in the base year 1990. The HOSP was not a full inventory and its methodology was also different from earlier and later forest inventories. It was primarily designed to get insight in the amount of harvestable wood, but it still provides valuable information on standing stocks and increment of forest biomass. In total 3,448 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, and together they represented an area of 310,736 ha. From this total number of plots, 2,500 measurement plots representing 285.000 ha were selected for re-measurements in subsequent years. After 1997 only 2 annual re-measurements were carried out on about 40% of the original sample plots (Schoonderwoerd and Daamen 2000).

QA/QC
Instructions for the measurement in the HOSP were defined in a working paper (Anonymous 1988). According to Hinssen (2000) these instructions were very clear, leaving little room for alternative interpretations, which should guarantee consistent results over time. In every measurement year 2-3 days were included to randomly check measurements carried out during that year. Trees that were measured during a census were also always measured during subsequent censuses. The project coordinator regularly checked results from the database. Suspicious data and errors were checked in the field and results of these checks were discussed with the field staff and if needed the measurement instructions were improved (Daamen and Stolp 1997).

NFI-5, Meetnet Functievervulling bos (MFV)
The fifth National Forest Inventory (NFI-5) in Dutch is also known as 'Meetnet Functie Vervulling Bos' (MFV). It 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).

QA/QC
The density of sample points in the monitoring network resulted in an estimated confidence level of plus or minus 10% in the most forest rich provinces (Dirkse *et al.* 2007). The confidence levels and quality of the methodology were tested in a pilot study by Dirkse and Daamen (2000). Further justification for the methodologies used during the collection of data for the NFI-5, and the subsequent analysis of the data is provided in an Annex to Dirkse *et al.* (2007).

NFI-6
Between September 2012 and September 2013 the sixth National Forest Inventory (NFI-6; Zesde Nederlandse Bosinventarisatie, NBI6) was conducted (Schelhaas *et al.* 2014). This inventory was implemented with the aim to also support reporting of carbon stock changes in forests to the UNFCCC and Kyoto Protocol. To facilitate the direct calculation of carbon stock changes between the NFI-5 and NFI-6, the methodology of the NFI-6 closely followed the methodology of the NFI-5 (see Schelhaas *et*

al. 2014). Measurements were done on 3190 sample plots, of which 1235 were re-measurements of permanent NFI-5 sample plots.

QA/QC
The field measurements were carried out using a digital tree calliper that directly recorded the measurements in a database. The software then directly compared and validated the information with information from the NFI-5 inventory. In this way erroneous and impossible values would be signalled and could be checked and corrected while still in the field. After uploading of the data from the callipers into the inventory database the data were again checked for impossible combinations of values and missing values.

A1.2   Soil information

Soil map
The soil map of the Netherlands with a scale of 1:50.000 provides detailed information on important characteristics of the soil profile up to a depth of 120 cm. The units applied in this soil map follow those provided in the Dutch system for soil classification (Systeem voor Bodemclassificatie, see de Bakker and Schelling 1989) complemented with a code for the groundwater table. The information used in the map is collected between 1960 and 1995 (de Vries et al. 2003) and was dated at 1977, the average year for all mapping units.

QA/QC
A validation of the peat areas by de Vries et al. (2010) showed that as a result of the oxidation of organic soils, particularly in the drained agriculture areas the extent of peat and peaty soils was decreasing. It appeared that areas with shallow peat layers and peaty soils are changing soil type. Peat soils change into peaty soils and peaty soil become more mineral soils. In response to this finding, in 2009 additional research started to assess and improve the reliability of the information for peat areas in the Netherlands for which the information was possibly outdated (de Vries et al. 2014). This work included a total area of 300,000 ha and focussed on all peaty soils and areas with shallow peat soils. Based on the results up to 2014 (in de Vries et al. 2014) the soil map was updated (see Chapter 3.5).

Soil information system
Soil information that is collected for the purpose of soil mapping is collected and saved in a soil information system (Bodemkundig Informatie Systeem, BIS) of Wageningen UR. BIS contains about 330.000 descriptions of soil profiles that provide for specific locations an overview of the development of layers in the profiles. A dataset with samples for national soil mapping (Landelijke Steekproef Kaarteenheden – LSK, Finke *et al.* 2001) is also part of the BIS system. Sampling locations were assigned using a stratified sampling scheme. The samples were taken during 1990 – 2001 and include groundwater table and soil chemical properties. With the assumption that 50% of organic matter contains of carbon, the soil carbon content can be inferred from information on soil organic matter, thickness of soil layers and bulk density functions (de Groot et al. 2005; Kuikman et al. 2003). The LSK data were used to assess the variability in the soil characteristics within the mapped units using the soil classification system.

Soil carbon map
The soil carbon map provides spatially explicit information on soil carbon content in the upper 30 cm of the soil. The soil carbon map is derived based on the sources mentioned in A1.2.1 the soil map, and A1.2.2 BIS and LSK and with additional information from additional monitoring of forest soils including chemical analyses of litter, humus profiles, mineral soil information and groundwater quality. Average soil carbon stocks were assessed for the top 30 cm soil layer. Because in organic soils oxidation can occur also in deeper soil layers (Kuikman *et al.* 2003), for soils containing more than 50% organic matter in the upper 80 cm, the carbon stock in the top 120 cm were calculated. The spatially explicit soil carbon map then was generated from the calculated carbon content per strata based on hydrological and soil characteristics applied to the 1:50,000 soil map (A1.2.1)

QA/QC
In de Groot et al. (2005) the results based on the LSK and LGN 1990 were compared against results based on the standard procedure in the IPCC guidelines. The results indicated that the methodology using the soil carbon map should be the preferred methodology. The system was reviewed in 2006 by external experts (van den Wyngaert et al. 2006), which resulted in different improvements that are described in van den Wyngaert et al. (2009).

Lesschen *et al.* (2012) provides more insight in quantifying potential changes in carbon stocks in Dutch soils. Based on a new stratification of the LSK information the carbon stock for the most important land use and soil types were assessed. The results showed that overall all emissions and removals are compensated among the most important land use changes. The total net CO2 emissions from mineral soil therefore are around zero, which is the same as currently reported by the Netherlands. Since soil types and soil properties change over time as a result of soil and water management, regularly updated soil maps will be needed for accurate calculation of emissions from soils.

Annex 2   Land-use maps

A2.1   Land-use statistics

Table A2.1 gives for the 1990, 2004, 2009, 2013 and 2017 per land use category that was identified on the land use maps, its area (in ha) and coverage as percentage of the total land area of the Netherlands

Table A2.1 *Land use statistics based on the 1990, 2004, 2009, 2013 and 2017 maps.*

Land use	1990		2004		2009		2013		2017	
	Area (ha)	% of total	Area (ha)	% of total	Area (ha)	% of total	Area (ha)	% of total	Area (ha)	% of total
Forest	362,100	8.7	370,041	8.9	373,480	9.0	375,743	9.0	365,577	8.8
Cropland	1,019,352	24.5	939,617	22.6	924,863	22.3	944,340	22.7	870,310	21.0
Grassland	1,458,115	35.1	1,360,149	32.8	1,342,361	32.3	1,295,607	31.2	1,354,759	32.6
Trees outside forest	20,806	0.5	22,207	0.5	22,092	0.5	21,575	0.5	21,240	0.5
Heath land	49,567	1.2	47,915	1.2	49,128	1.2	50,102	1.2	52,288	1.3
Wetland	773,208	18.6	781,651	18.8	787,506	19.0	796,218	19.2	795,355	19.2
Reed	20,843	0.5	27,126	0.7	25,947	0.6	26,255	0.6	26,696	0.6
Settlements	409,457	9.9	566,330	13.6	589,121	14.2	605,512	14.6	627,156	15.1
Other land	39,562	1.0	37,973	0.9	38,512	0.9	37,656	0.9	39,628	1.0
Total	4,153,009	100	4,153,009	100	4,153,009	100	4,153,009	100	4,153,009	100

A2.2   Land-use maps

The land-use maps 1990, 2004, 2009, 2013 and 2017 are presented on the next pages (Figures A2.1 to A2.5). More information on these maps is provided in Chapter 3 and in Kramer et al. (2007), Kramer and van Dorland (2009), Kramer et al. (2009), Kramer and Clement (2015), Kramer and Clement (2016) and Kramer (2019).

1990 land-use map

- ☐ other grassland
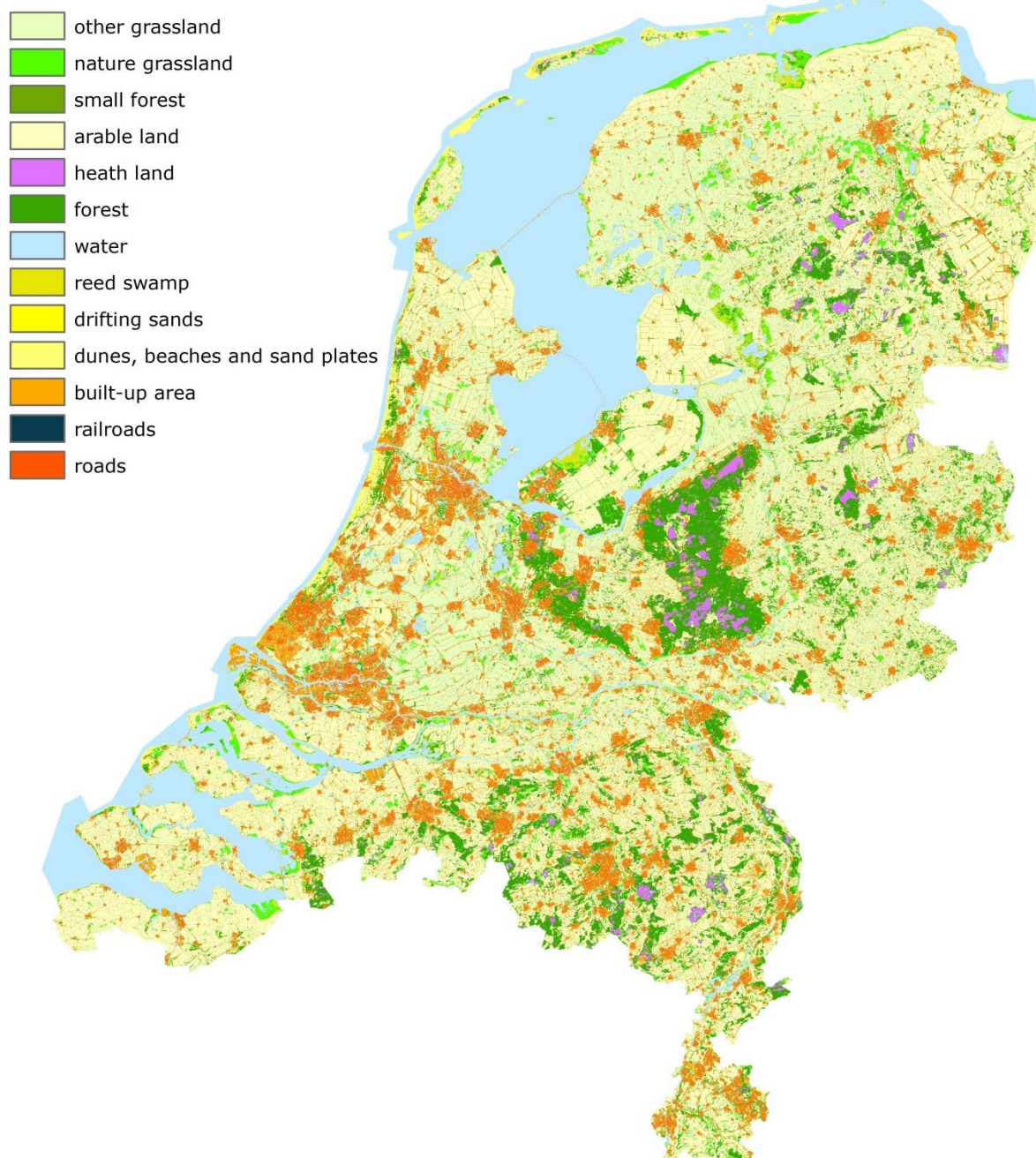- ☐ nature grassland
- ☐ small forest
- ☐ arable land
- ☐ heath land
- ☐ forest
- ☐ water
- ☐ reed swamp
- ☐ drifting sands
- ☐ dunes, beaches and sand plates
- ☐ built-up area
- ☐ railroads
- ☐ roads
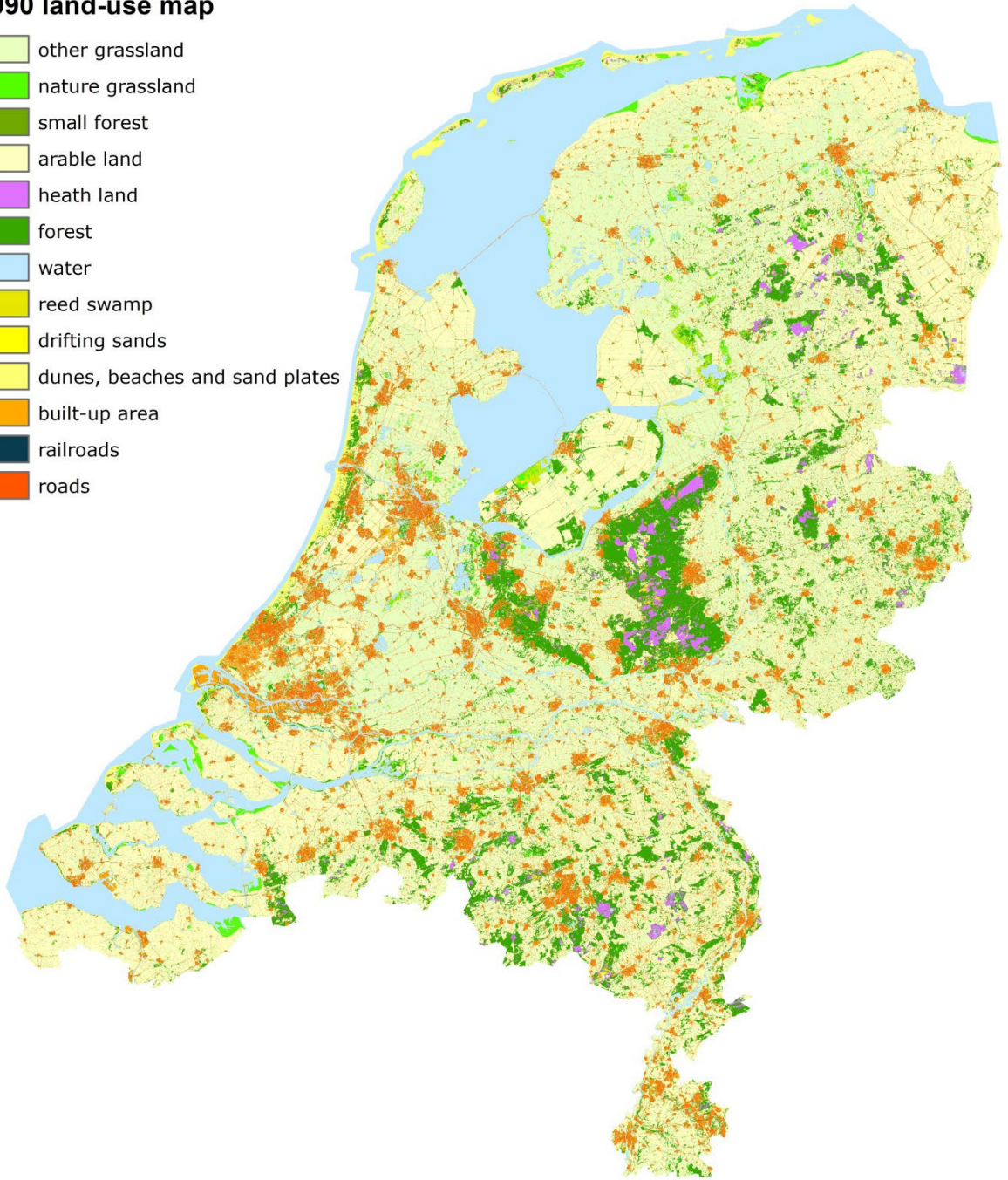
Figure A2.1 *Land-use map of 1 January 1990*

2004 land-use map

- □ other grassland
- ■ nature grassland
- ■ small forest
- □ arable land
- ■ heath land
- ■ forest
- □ water
- ■ reed swamp
- ■ drifting sands
- □ dunes, beaches and sand plates
- ■ built-up area
- ■ railroads
- ■ roads

Figure A2.2 *Land-use map of 1 January 2004*

2009 land-use map

	other grassland
	nature grassland
	small forest
	arable land
	heath land
	forest
	water
	reed swamp
	drifting sands
	dunes, beaches and sand plates
	built-up area
	railroads
	roads

Figure A2.3 *Land-use map of 1 January 2009.*

2013 land-use map

- ☐ other grassland
- ☐ nature grassland
- ☐ small forest
- ☐ arable land
- ☐ heath land
- ☐ forest
- ☐ water
- ☐ reed swamp
- ☐ drifting sands
- ☐ dunes, beaches and sand plates
- ☐ built-up area
- ☐ railroads
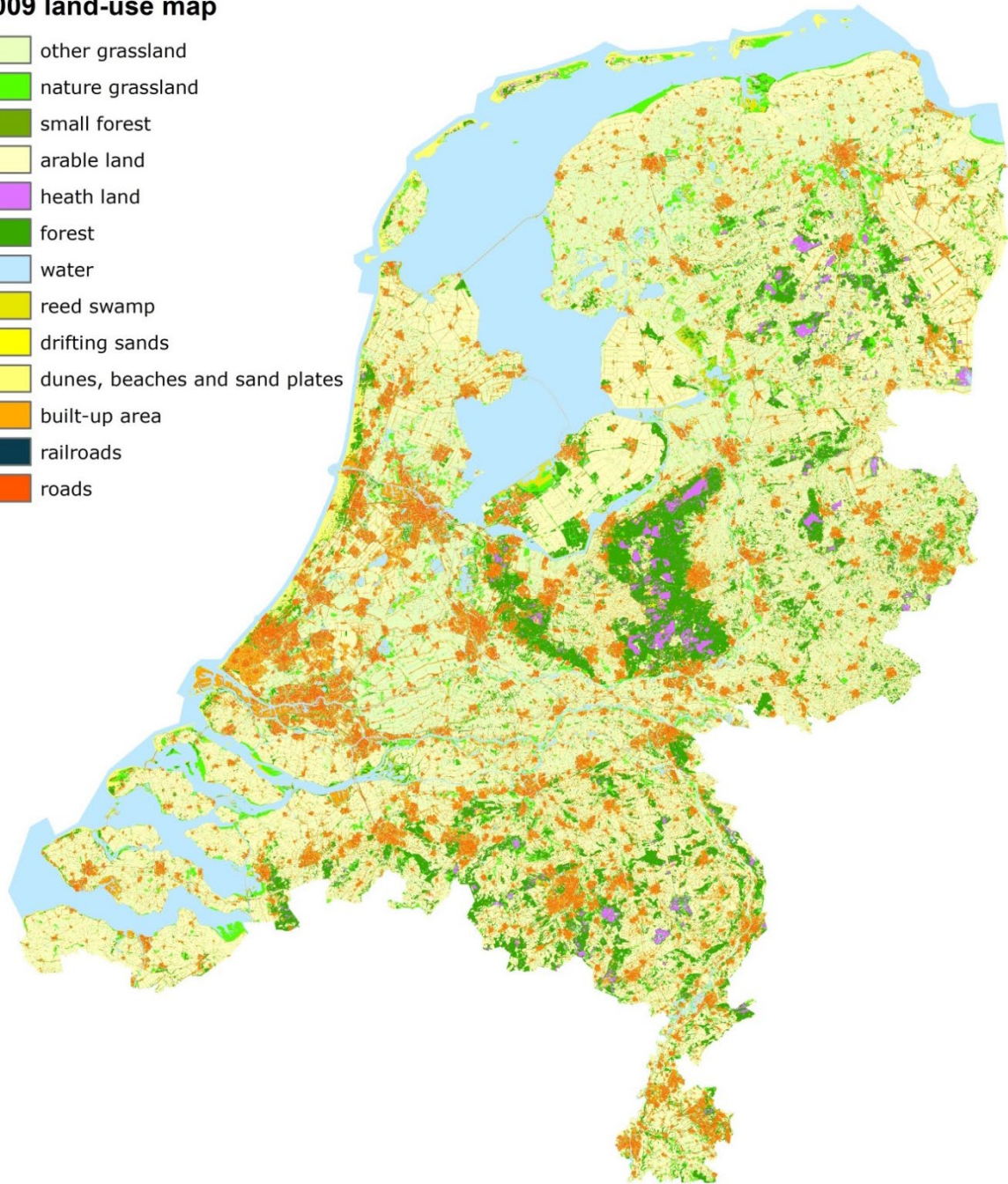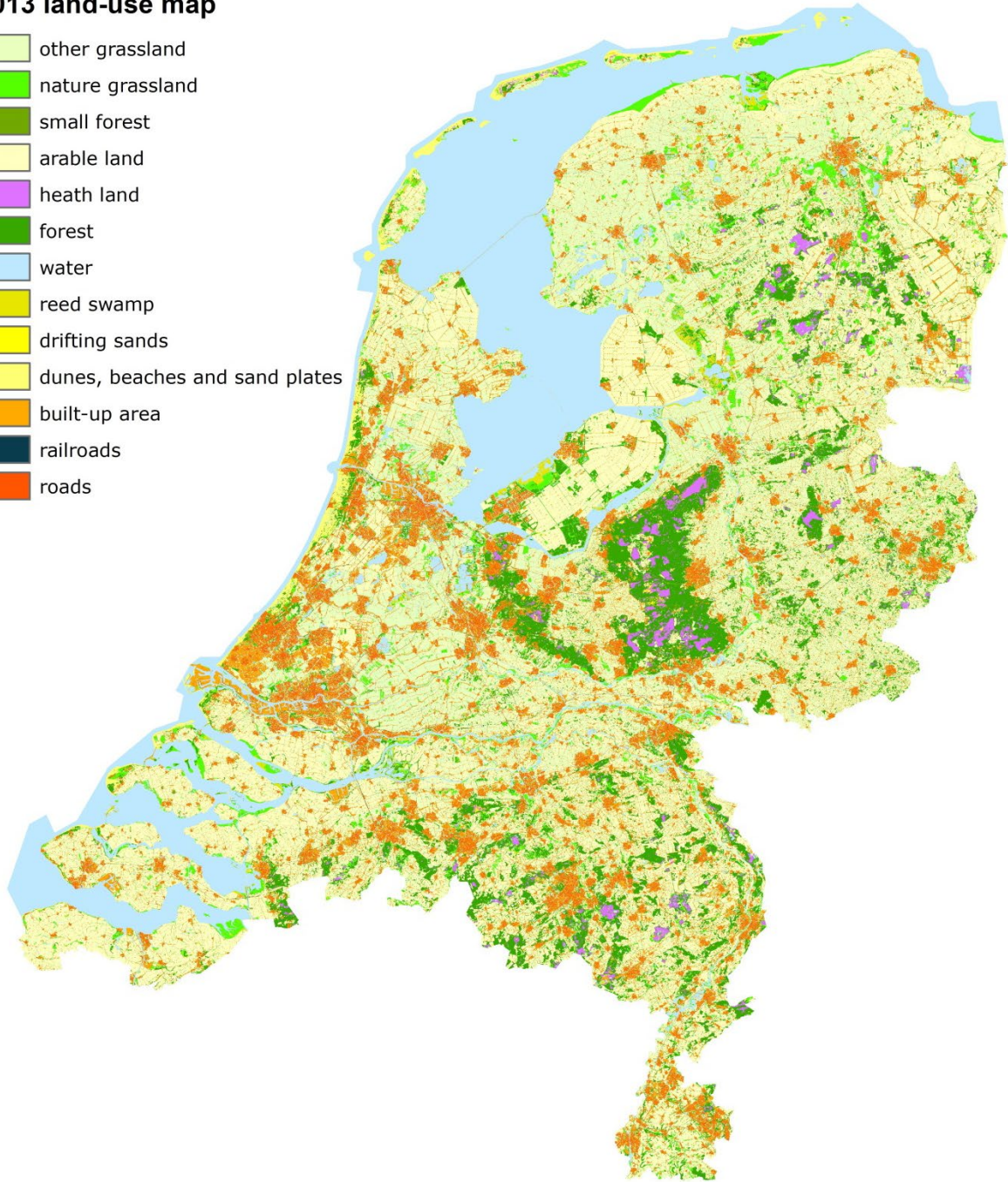- ☐ roads

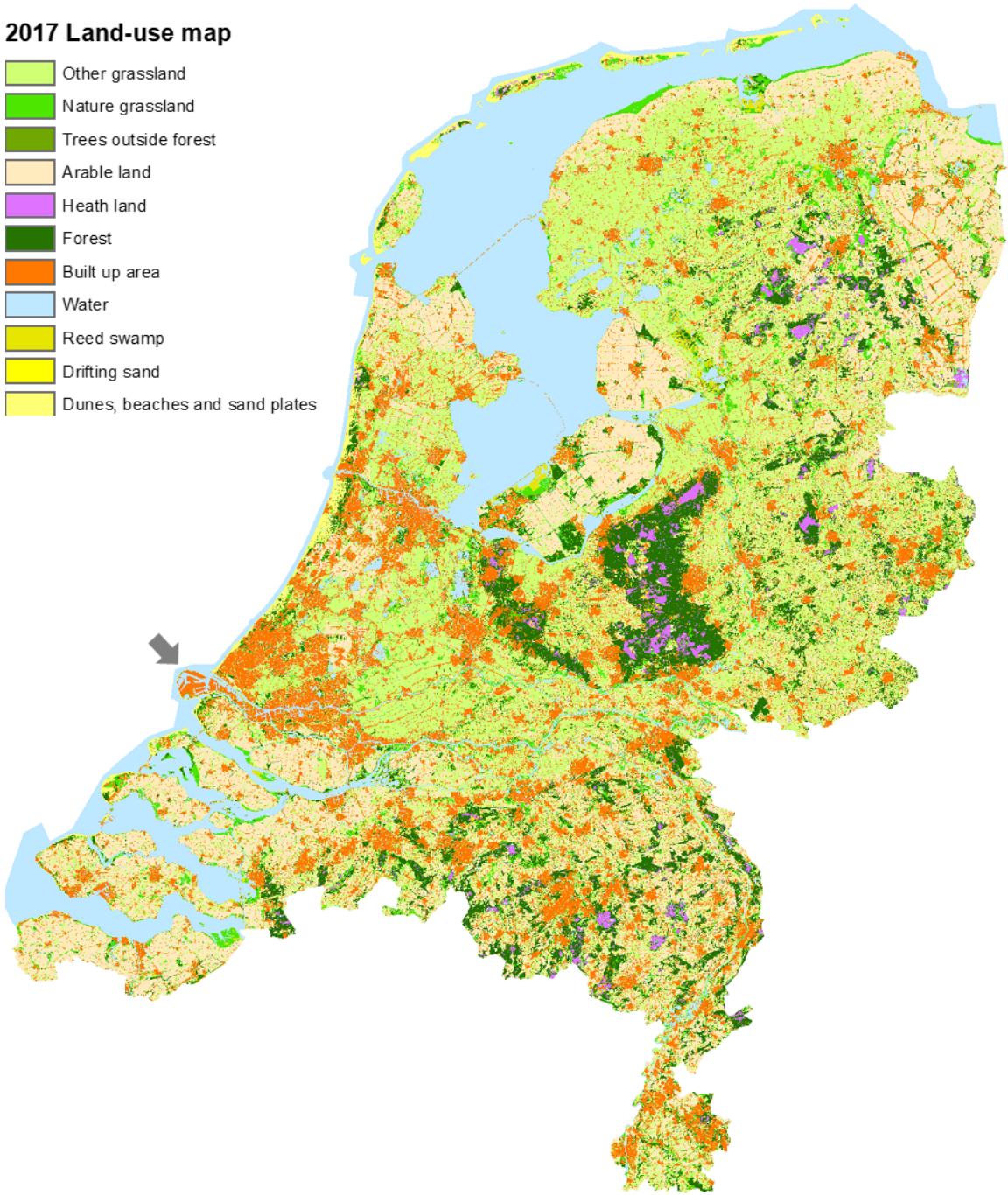**Figure A2.4** *Land-use map of 1 January 2013.*

2017 Land-use map

- Other grassland
- Nature grassland
- Trees outside forest
- Arable land
- Heath land
- Forest
- Built up area
- Water
- Reed swamp
- Drifting sand
- Dunes, beaches and sand plates

Figure A2.5 Land-use map of 1 January 2017. The grey arrow indicates the location of the newly reclaimed area (Maasvlakte 2) – compare with the 1990 map (Figure A2.1). On the 2013 map (Figure A2.4) the area is already partly changed from open water to Other Land and Settlements.

Annex 3   Allometric equations

Biomass expansion equations used for the calculations of stem volume (Table A.3.1; Dik, 1984), aboveground biomass (Table A.3.2; Nabuurs *et al.*, 2005). See Nabuurs *et al.* (2005) for information on the selection of the most suitable equations and a more detailed description of the database and list of studies included.

Table A.3.1   *Allometric equations to calculate trees' total stem volume from diameter (D, in cm) and height (H, in m). The equation is in the form: $D^a * H^b * EXP(c)$.*

Scientific_name	a	b	c
Abies grandis	1.7722	0.96736	-2.45224
Acer pseudoplatanus	1.89756	0.97716	-2.94253
Acer spp	1.89756	0.97716	-2.94253
Alnus glutinosa	1.85749	0.88675	-2.5222
Alnus spp	1.85749	0.88675	-2.5222
Betula pendula	1.8906	0.26595	-1.07055
Betula spp	1.8906	0.26595	-1.07055
Broadleaved other	1.8906	0.26595	-1.07055
Chamaecyparis lawsoniana	1.85298	0.86717	-2.33706
Coniferous other	1.845967	1.00218	-2.76177
Fagus sylvatica	1.55448	1.5588	-3.57875
Fraxinus excelsior	1.95277	0.77206	-2.48079
Larix decidua	1.8667	1.08118	-3.0488
Larix kaempferi	1.87077	1.00616	-2.8748
Larix spp	1.8667	1.08118	-3.0488
Picea abies	1.75055	1.10897	-2.75863
Picea sitchiensis	1.78383	1.13397	-2.90893
Picea spp	1.75055	1.10897	-2.75863
Pinus contorta	1.89303	0.98667	-2.88614
Pinus nigra	1.924185	0.920225	-2.74628
Pinus nigra var nigra	1.95645	0.88671	-2.7675
Pinus other	1.89303	0.98667	-2.88614
Pinus sylvestris	1.82075	1.07427	-2.8885
Piunus nigra var Maritima	1.89192	0.95374	-2.72505
Populus spp	1.845388	0.95807	-2.71579
Pseudotsuga menziesii	1.90053	0.80726	-2.43151
Quercus robur	2.00333	0.85925	-2.86353
Quercus rubra	1.83932	0.9724	-2.71877
Quercus spp	2.00333	0.85925	-2.86353
Thuja plicata	1.67887	1.11243	-2.64821
Tsuga heterophylla	1.76755	1.37219	-3.54922
Ulmus spp	1.94295	1.29229	-4.20064

Table A.3.2   *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 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 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 petraea	Austria	Hochbichler, 2002

Table A.3.3   *Allometric equations used to calculate for single trees their belowground 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 4   Harvest statistics

A4.1   Introduction

Roundwood harvests from forests are calculated based on the wood balance inferred from National Forest Inventories in combination with information on roundwood harvests in FAO statistics.

The roundwood harvested from forests consists of two major components; roundwood harvested for industrial purposes, reported as Industrial Roundwood in the FAO statistics (item code 1865), and roundwood harvested for fuelwood, reported under Wood fuel (item code 1864). The quantity of industrial roundwood production in the FAO statistics is determined annually through a questionnaire to the major woodworking industries.

Until 2015 the category Wood fuel consisted mainly of fuelwood used by households. This amount is very difficult to estimate, not only due to the fact that it concerns many households with very variable consumption patterns, but also because wood fuel can originate not only from roundwood from the forest, but also from large branches and residues in the forest, as well as landscape and garden maintenance. Before 2003, the amount of Wood fuel originating from roundwood harvested in the forest was estimated annually by an expert. For the period 2003-2013 a fixed amount of 290,000 m3 underbark was applied, also based on expert judgement. For 2014, this amount was estimated at 357,000 m3, to account for increased use of wood fuel also in more industrial applications.

In 2016, while preparing the NIR over 2015 it was observed that total roundwood production in FAO statistics almost doubled (from 1.25 million m^3 in 2014 to 2.25 million m^3 in 2015, see figure A4.1). A check with the organisation that prepares the Joint Forest Sector Questionnaire that is used for reporting forestry statistics to various UN statistics, including the FAO forest production statistics, learned that this was a result of a new method to assess the amount of wood fuel production in the Netherlands. While until 2015 the produced amount of wood fuel was based on an expert judgement, from 2015 onwards the results of a new household survey were included, with an estimated total amount of Wood fuel consumed of 1,397,000 m^3. This includes all sources in and outside forests, and no estimation is given how much of this quantity is roundwood harvested from the forest.

The information on industrial roundwood as generated through the Joint Forest Sector Questionnaire and reported in the FAO statistics is considered to be reliable and therefore will be used as such. However, given the uncertainties associated with fuel wood in the FAO statistics total volumes of roundwood harvests are estimated using information on the wood balance from National Forest Inventories. Subsequently the fuel wood harvests are calculated as the difference between the total roundwood harvests and industrial roundwood harvest.

A4.2   Analyses of roundwood production

With observations from permanent plots that were assessed in both the NFI-5 (measured 2001-2005) and NFI-6 (2013) national forest inventories, it was possible to generate a wood balance providing the total amount of roundwood that is annually felled in the forest. For the period 2003-2013 this was estimated at 1.267 million m^3 overbark per year (Schelhaas et al. 2014). Further investigation, however, indicated that this estimate was probably too low because it does not correct for the growth of the trees in the period between the initial measurement and felling. Trees felled in 2003 have not grown until harvest, but trees that were harvested in 2013 had an additional 10 years of growth before felling. Hence, on average the felled trees have grown 5 years before they were harvested. If this is included the annually felled volume is estimated at 1.528 million m^3 roundwood overbark (+20.6%). Of the felled roundwood 6% is left in the forest, and 12% of the overbark volume is bark

(see Chapter 4.2.1). With these conversions the estimated volume of annually produced roundwood is 1.264 million m^3 underbark for the period 2003-2013. For this same period 2003-2013, the FAO reports an average annual production of 761,543 m^3 (underbark) of industrial roundwood. The difference with the total amount of roundwood then results in an average production of 502,400 m^3 (underbark) of wood fuel.

Since the wood balance from the forest inventories can only give an average total production, the estimated average harvest for wood fuel is the same over the whole period between de NFIs. However, because the wood harvested as industrial round adds to the HWP pool every year it would be important to maintain the annual variation in the reported FAO statistics for industrial roundwood. Therefore, for each year the average annual fuel wood production (i.e. 502,400 m^3) is added to the industrial roundwood production in that year as provided by the FAO statistics (Figure A4.1 and Table A4.1).

As long as no new information from forest inventories is available, the estimated average amount of wood fuel production is maintained from the period before.
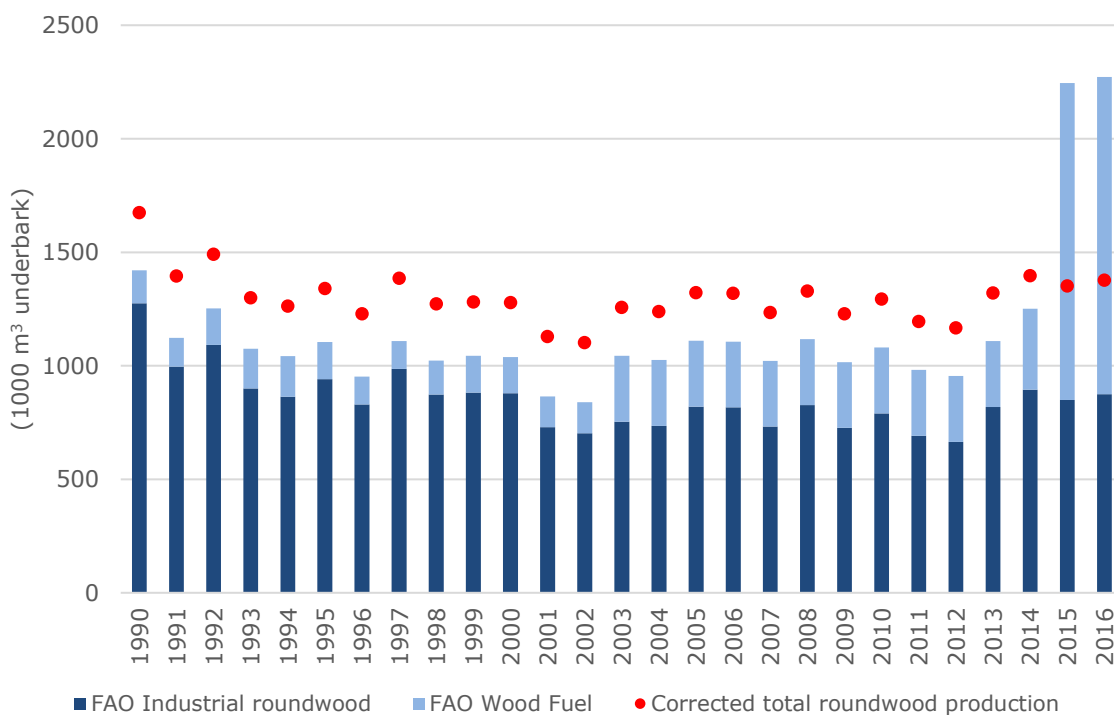
Figure A4.1. *Annual production of roundwood in the Netherlands. Dark bars represent production of industrial roundwood from FAO statistics, light coloured bars represent the amount of wood fuel from FAO statistics. The two together are the total volume of harvested roundwood from FAO statistics. The dots represent the total roundwood production with application of the approach using NFI data.*

Given the underestimate of Wood fuel harvested from the forest for the period 2003-2013, it seems likely that also the volume of harvested wood fuel for the period 1990-2002 is underestimated in the FAO statistics. We lack an inventory with permanent sample plots for this entire period. Before 2000, the HOSP system was in use to provide roundwood production estimates, based on permanent sample plots that were re-measured every 5 years. Reporting was rather irregular, and there is no good documentation available of procedures to arrive at these estimates, and definitions of the figures it produced. A concise overview is given by the "Compendium voor de Leefomgeving" (CLO 2007), with numbers for annual roundwood felling in the forest for the years 1990, 1995, 1996, 1997, 1998, 1999, 2002 and 2005. For each of these years we estimated the production of Wood fuel as described above. The value for 1990 yielded a negative amount of Wood fuel and was therefore discarded. Perhaps this

is influenced by a large storm damage that occurred that year. We also omitted the year 2005 because that is already covered in the correction for the period 2003-2013. For the remaining years, we estimate an average amount of 399,000 m³ Wood fuel (underbark) must have been produced, compared to a reported amount of 143,000 m³.

Table A4.1 *Volumes of industrial roundwood harvests in FAO statistics, estimated volumes of wood volumes based on the wood balance from the NFI's and the resulting total harvested roundwood volume (1000 m³ underbark).*

Year	FAO Industrial roundwood	Wood fuel based on wood balance from NFI's (1000 m³ underbark)	Total roundwood
1990	1275	399(1	1674
1991	996	399(1	1395
1992	1092	399(1	1491
1993	900	399(1	1299
1994	863	399(1	1262
1995	941	**399(1**	1340
1996	829	**399(1**	1228
1997	986	**399(1**	1385
1998	873	**399(1**	1272
1999	882	**399(1**	1281
2000	879	399(1	1278
2001	729	399(1	1128
2002	703	**399(1**	1102
2003	754	**502(2**	1256
2004	736	**502(2**	1238
2005	820	**502(2**	1322
2006	817	**502(2**	1319
2007	732	**502(2**	1234
2008	827	**502(2**	1330
2009	726	**502(2**	1229
2010	791	**502(2**	1293
2011	692	**502(2**	1194
2012	665	**502(2**	1167
2013	818	**502(2**	1321
2014	894	*502(2*	*1397*
2015	849	*502(2*	*1351*
2016	952	*502(2*	*1454*
2017	819	*502(2*	*1321*
2018	772	*502(2*	*1274*

1. Calibrated based on the calibrated average for 1995-1999 and 2002 from CLO (2007) data. The years on which the average is based are provided in bold.
2. Average based in the wood balance from the forest inventories for 2003-2013. In bold the years on which the average was based. In italics the years that will be updated once the information of the next NFI (ongoing, expected by 2021) becomes available.

Implementation in LULUCF reporting
For the period 1990-2002, the amount of Wood fuel produced as reported in the FAO statistics (149,000 m³) will be replaced by the calibrated amount for the years where we have information (399,000 m3). For the period 2003-2013 we replace the amount of Wood fuel produced as reported in the FAO statistics (290,000 m³) by the calibrated amount (520,000 m³). We use this calibrated amount also for the years after 2013 as a preliminary estimate. After the completion of NFI7 in 2021, we will replace this estimate by the calibrated amount, that can be deduced in the same way as described above. See Table A4.1 for a comparison of the numbers reported in NIR 2018 and new corrected numbers.

Annex 5 Overall description of the forests and forest management in the Netherlands and the adopted national policies

A5.1   Dutch forests

The forested area in the Netherlands in 2017 was 365.5 kha, which is 9% of total area included under LULUCF. Current forest stands are mostly planted mature stands. After almost all forests had been degraded or cut from the Middle Ages until the 19th century, from the end of the 19th century onward reforestation began, resulting in the forest area to date. The largest part of the forested area in the Netherlands was planted using regular spacing and just one or two species in even-aged stands, with wood production being the main purpose. A change towards multifunctional forests that serve multiple purposes (e.g. nature conservation, recreation and wood production) was started in the 1970s, and has had an impact on the management and appearance of these even aged stands.

Dutch forests are dominated by Scotch Pine (32%) that was introduced to reclaim heathland and inland driftsands in the 19th century and first half of the 20th century. The dominance of unmixed coniferous stands is gradually decreasing in favour of mixed and broadleaved stands. In the NFI-6 about 50% of the Dutch forests is categorised as mixed (i.e. dominant species makes up less than 80% of the stand) (Schelhaas et al. 2014). Natural regeneration plays an important role in the transformation process from the even-aged, pure stands into stands with more species and more age classes.

A5.2   Sustainable forest management

Most of the forest area in the Netherlands is considered to be managed according to sustainable forest management principles. In general, forest in the Netherlands is protected by a set of laws and (mostly spatial planning) regulations both on a national, provincial and municipal level. The whole forest area in the Netherlands is protected by the forest act which aims to prevent the forest area from decreasing. Only after thorough weighing of different public interests it can be decided to change the land-use destination from forest land to other land-uses like infrastructure or settlement. In such cases the deforestation needs to be compensated with afforestation of an equal area elsewhere. The exception to these rules is when conversion to priority nature takes place on the basis of ecological arguments, like on the basis of Natura 2000 management plans. In such cases forest conversion can take place without compensation.

Additionally sustainable forest management is one of the criteria in the nature subsidy scheme (below) that is in place in the Netherlands and from which most of the forest owners receive subsidies (FAO 2014). Apart from laws, regulations and subsidies, the maintenance and enhancement of forest resources is also fostered through for instance policy documents, education, communication and information, monitoring and research and development of knowledge (Hendriks 2016).

Third party independent forest certification shows an increasing trend in the Netherlands (FAO 2014). By the end of 2017 about 47% (171 kha)[9] of the Dutch forest area was certified. More than 98% of this certified forest area was FSC certified, and the remaining certified forest area had a PEFC

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[9] http://www.bosenhoutcijfers.nl/nederlands-bos/boscertificering/ (accessed on 22 November 2018)

certificate. In the Netherlands there is no obligation for either public or private forest owners to have a forest management plan. The availability of long term management plans is assumed for the total forest area owned and managed by public organisations and nature conservation organisations, and for about one third of the private forest owners (FAO 2014). Since forest management plans are required by FSC and PEFC certification all certified forests will have one.

The national government also has adopted policies that directly or indirectly stimulate sustainable production and use of wood. For instance the national government commits to procure 100% sustainable timber through a set of clear criteria for procurement. The Dutch Timber Procurement Assessment Committee (TPAC) assesses whether timber certification systems meet these criteria and advises the responsible Dutch Ministry of Infrastructure and Environment (I&M) on the outcome. Three certification systems have been accepted at this moment: PEFC, FSC and MTCS (see Hendriks 2016). These rules apply both to domestically produced timber as well as to imported timber.

A5.3 Nature policy and subsidies

Over the past decades, forest policy in the Netherlands has been integrated into the nature policy, which reflects the change towards multi-purpose forests in which more functions are combined (e.g. nature, recreation). The development of a national nature network is a central theme of the nature (and forest) policy. Implementation of nature policy including the development and preservation of the national nature network has been decentralised from the central government to the provincial governments. The national nature network is a cohesive network of high-quality wetland and terrestrial nature reserves, including forests. Up to 1 January 2017 already 594 kha of the network was completed (based on IPO 2017). The aim is to extend the network to 640 kha by 2027.

Subsidies are an important instrument for provinces to realise these nature development goals. Through the currently prevailing subsidy scheme for nature and landscape (Subsidiestelsel Natuur en Landschap, SNL), the provinces grant subsidies for the conservation and development of nature reserves, including forests, that are part of the National Nature Network and for agricultural nature management.

These subsidies are also an important source of income for forest owners. Forest owners covering in total 80% of the Dutch forest area receive a SNL subsidy. Of this subsidised forest area, 60% falls under the scheme for forests with production function, i.e. forest with explicitly integrated nature conservation and timber production objectives. In the other 40% that is subsidised as natural forests, harvests are limited to 20% of the increment.

A5.4   Forest management and wood removals

The Dutch timber market is fairly homogeneous. Sawmills in the Netherlands can only handle stems of up to 60 cm diameter. As a result that is an important factor guiding forest management and maximum diameter of felled trees. Furthermore, forest managers have received very similar training, while there is only a limited number of contractors who take care of timber harvesting in Dutch forests.

Harvesting is mainly targeting stemwood, while some larger branches of broadleaved species may be removed as fuel wood. Due to concerns about soil fertility extraction of felling residues is limited. The majority (95%) of harvesting is done using harvesters and forwarders. In occasional cases, like the harvest of individual trees with large diameters, manual operations are performed.

For the forests that are subsidised under the SNL natural forest scheme, harvesting activities are limited to 20% of the increment. These are generally aimed at removing exotic species or improving forest structure. Forests with a production function usually integrate wood production with other functions like nature conservation and recreation. Harvesting in these forests therefore is usually

limited to thinnings and small group fellings (<0.5 ha). Recently, however, also larger regeneration fellings (up to 5 ha) are applied in order to favour regeneration of species demanding more light.

In multifunctional forest, harvesting rates are on average 5.7 m^3 per ha per year, while in natural forests on average 2.9 m^3 is harvested per hectare per year (Schelhaas et al. 2018). The growing stocks on average increase annually by 2.0 m^3 per hectare in multifunction forests to 2.9 m^3 per hectare for natural forests (Schelhaas et al. 2018).

A5.5   New developments

The ongoing trend of a transition to a more circular bio-economy will increase the demand for woody and non-woody biomass. As a result, in the near future the sustainable production of biomass will be a prominent challenge to address. In the Netherlands currently a number of policy developments and programmes are relevant. For instance, the National Biomass Vision 2030 (Ministerie van Economische Zaken 2015) states that an increase in the supplies of biomass is needed for sustainable green growth. This would imply a need for an increase in the productivity in forestry as well as for increased import (see Nabuurs et al. 2016). As part of the national program for a national circular economy, transition agendas are being drawn up (Ministry of Infrastructure and the Environment and Ministry of Economic Affairs 2016). For forestry and wood the agendas for biomass & food and for construction are relevant. Furthermore in the 2013 energy accord (SER 2013) between the Dutch Government and social and private partners an agreement was reached on the increased use of (woody) biomass for energy production. A stimulating policy to implement this is now under development. Woody biomass for large scale energy production will however most probably be imported from abroad.

Also the forest and wood sector in the Netherlands is developing plans to address the challenges ahead. In October 2016 they presented an action plan for investments and development of the forest and wood sector and related carbon storage possibilities. Amongst suggestions for improvements in forest management, the action plan also proposes actions potentially adding up to planting 100,000 ha (~25% increase in the current forest area) of new forest in the Netherlands and increasing the use of wood as substitution for fossil-energy-intensive materials in, for instance, construction. In general afforestation in the Netherlands is hampered particularly because of high competition on land area for other purposes and the associated high prices for land. Currently this action plan is being considered within the context of the National Climate Agreement (see further below).

On 28 June 2019 the Dutch Government agreed with other public, social and private parties on a National Climate Agreement (Klimaatakkoord)[10] on actions to reduce emissions and increase removals of greenhouse gasses in the Netherlands. Additionally the government has adopted a Climate Act[11], establishing a framework for the development of policies aimed at an irreversible and step-by-step reduction of Dutch greenhouse gas emissions in order to limit global warming and climate change. The act has entered into force on 1 September 2019 and asks for a Climate Plan in which the Government should share the main lines of climate policies up to 2050 and more detailed plans for reaching an intermediary 2030 target. The target of the Climate Act and Climate Plan is to reduce greenhouse gas emissions in the Netherlands by at least 49 percent in 2030 compared to 1990. The basis for this Climate Plan will be actions that were agreed on in the climate agreement.

The National Climate Agreement divides efforts and responsibilities among 5 economic sectors and the partners involved to meet its goals. The forest sector (including the wood chain), as part of the agriculture and land use sector also will have to deliver its share to achieve the CO_2 reduction goal. Measures aim at preventing deforestation, increasing carbon removals in existing systems and expansion of forests and trees outside forests. Success depends on the ability of the sector to mobilize forest owners to take effective measures and to organize the appropriate incentives together with the provincial and national government and other stakeholders. For this the government of the Netherlands invests in developing and sharing knowledge that is needed for further improving the

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[10] https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/klimaatakkoord (in Dutch)
[11] https://zoek.officielebekendmakingen.nl/stb-2019-253.html (in Dutch)

climate mitigation function of landscapes and forests. For this purpose, since 2018 practical climate smart forest management principles are being implemented and tested in a number of pilots. The results of these pilots are shared in an online toolbox[12] for climate smart forest and nature management.

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[12] https://www.vbne.nl/klimaatslimbosennatuurbeheer/(in Dutch)

Annex 6 EFISCEN model setup and calibration

A6.1 EFISCEN setup for LULUCF work

Model: EFISCEN V4.1, release 11 April 2014. For a general description of the EFISCEN model, see Schelhaas et al. (2007).

Input data: based on the 6th Dutch NFI (NFI-6), measurements done in 2012 and 2013, assumed starting date for EFISCEN 1 January 2013. Data retrieved from the web [13], downloaded 16 April 2104, description in Schelhaas et al. (2014).

Data are aggregated to 14 tree species:

1 Quercus_rubra	(AE=Amerikaanse eik)
2 Betulus_sp	(BE=berk)
3 Fagus_sylvatica	(BU=beuk)
4 Alnus_sp	(ZE=zwarte els)
5 Fraxinus_excelsior	(ES=es)
6 Quercus_petraea,Quercus_robur	(EI=inlandse eik)
7 Other_broadleaves	(OL=overig loofhout)
8 Populus_sp	(PO=populier)
9 Salix_sp	(WI=wilg)
10 Pseudotsuga_menziesii	(DG=Douglas)
11 Pinus_sylvestris	(GD=grove den)
12 Other_pinus	(ON=overig naald)
13 Larix_sp	(JL=Japanse lariks)
14 Picea_sp	(FS=fijnspar)

Using Table A6.1 the tree species groups as identified in the NFI-6 tree where aggregated to match the classification of species groups used in the EFISCEN model.

Table A6.1 *Aggregation of the NFI-6 tree species groups to species groups used in the EFISCEN model. The NFI-6 species refers to the grouping of species as described in Appendix 4 of Schelhaas et al. (2014)*

ID	NFI-6 species	EFISCEN species group
1	AE	AE
2	BE	BE
3	BU	BU
4	CD	ON
5	DG	DG
6	ED	OL
7	EI	EI
8	ES	ES
9	FS	FS
10	GD	GD
11	IL	OL
12	JL	JL
13	KV	KV
14	OD	ON

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[13] www.probos.nl/publicaties/overige/1094-mfv-2006-nbi-2012

ID	NFI-6 species	EFISCEN species group
15	ON	ON
16	PO	PO
17	ST	OL
18	UL	OL
19	WI	WI
20	XX	XX
21	ZE	ZE

Additionally the data of the NFI-6 were classified into 4 owner groups that are distinguished within the EFISCEN model (Table A6.2). These 4 groups are; 1) State Forest Service, 2) Other State owned, 3) Nature and 4) Private. Areas with unknown ownership are distributed over the other owners according to their share in the total area (but taking account of species and age class).

Table A6.2 *Aggregation table used to classify the owner types identified in the NFI-6 into the 4 owner types used in the EFISCEN model.*

NFI owner eigcat_code_nieuw	Bezitsvormgroep	bezitsvormtype	Eigenaarscategorie	EFISCEN owner
100	Bedrijf	Bedrijf - overig	Bedrijf	Private
101	Bedrijf	Financieel bedrijf	Bedrijf	Private
102	Bedrijf	Landgoederen	Landgoed	Private
103	Bedrijf	NUTS bedrijf	Bedrijf	Private
104	Bedrijf	Recreatie	Bedrijf	Private
105	Bedrijf	Vastgoed bedrijf	Bedrijf	Private
200	Particulier georganiseerd	Landgoederen	Landgoed	Private
201	Particulier georganiseerd	Stichting	Overig particulier georganiseerd	Private
202	Particulier georganiseerd	Vereniging	Overig particulier georganiseerd	Private
203	Particulier georganiseerd	Kerkelijk/welzijn	Overig particulier georganiseerd	Private
204	Particulier georganiseerd	Gemeenschappelijk bezit	Overig particulier georganiseerd	Private
205	Particulier georganiseerd	Provinciale Landschappen	Natuurbeschermings Organisaties	Nature
206	Particulier georganiseerd	Natuurmonumenten	Natuurmonumenten	Nature
207	Particulier georganiseerd	Waterleidingduinen	Natuurbeschermings organisaties	Nature
208	Particulier georganiseerd	Natuurbeschermings organisaties	Natuurbeschermings organisaties	Nature
300	Overheden	Ministerie van Defensie	Ministerie van Defensie	OtherState
301	Overheden	Kroondomein	Ministerie van Financiele Zaken	OtherState
302	Overheden	Ministerie van Financiele Zaken - overig bezit	Ministerie van Financiele Zaken	OtherState
303	Overheden	Ministerie van Veiligheid en Justitie	Overig staatseigendom	OtherState
304	Overheden	Ministerie van Binnenlandse Zaken	Overig staatseigendom	OtherState
305	Overheden	Staat - overig	Overig staatseigendom	OtherState
306	Overheden	Staatsbosbeheer	Staatsbosbeheer	StateForestService
307	Overheden	Provincies	Provincies	OtherState
308	Overheden	Gemeenten	Gemeenten	OtherState
309	Overheden	Waterschap	Overig publiek bezit	OtherState
310	Overheden	Recreatieschap	Overig publiek bezit	OtherState
311	Overheden	Hoogheemraadschap	Overig publiek bezit	OtherState

NFI owner eigcat_code_nieuw	Bezitsvormgroep	bezitsvormtype	Eigenaarscategorie	EFISCEN owner
312	Overheden	Bureau beheer landbouwgronden	Overig publiek bezit	OtherState
313	Overheden	Publiek - overig	Overig publiek bezit	OtherState
600	Particulier	Privepersoon	Privebezit	Private
999	Onbekend	Onbekend	Onbekend	Unknown

The SQL query used to generate the data is:

```
SELECT [EFISCEN boomsoortgroep].[EFISCEN groep],
X_opname_nieuw_nbi_verzamelde_gegevens.Leeftijdsklasse,
Count(X_opname_nieuw_nbi_verzamelde_gegevens.plotnummer) AS CountOfplotnummer,
Avg(X_opname_nieuw_nbi_verzamelde_gegevens.vha) AS AvgOfvha,
Avg(X_opname_nieuw_nbi_verzamelde_gegevens.ivha) AS AvgOfivha
FROM ((X_opname_nieuw_nbi_verzamelde_gegevens INNER JOIN NBI_Boomsoort ON
X_opname_nieuw_nbi_verzamelde_gegevens.hoofdboomsoort = NBI_Boomsoort.code) INNER
JOIN [EFISCEN boomsoortgroep] ON NBI_Boomsoort.Groepen = [EFISCEN
boomsoortgroep].[NBI groep]) INNER JOIN NBI_Eigenaar ON
X_opname_nieuw_nbi_verzamelde_gegevens.eigcat_code = NBI_Eigenaar.eigcat_code_nieuw
WHERE (((X_opname_nieuw_nbi_verzamelde_gegevens.Leeftijdsklasse)>-1))
GROUP BY [EFISCEN boomsoortgroep].[EFISCEN groep],
X_opname_nieuw_nbi_verzamelde_gegevens.Leeftijdsklasse;
```

Data are thus grouped on the tree species that dominate the stand (hoofdboomsoort), but tree species composition at the plot can deviate. Age is derived from the year of establishment of the stand (kiemjaar). Age class (Leeftijdklasse) is added to the query X_opname_nieuw_nbi_verzamelde_gegevens via the following statement: Leeftijdsklasse: Int((2013-[kiemjaar])/10)

Each plot is assumed to represent 117.0784 ha, thus assuming that all plots visited are representative for the whole area, ignoring a possible small bias for plots that could not be measured (access denied or impossible). The total area of simulation is thus 373480 ha.

Area with unknown owner is distributed over the other owners according to their share in the total area (but taking account of species and age class).

EFISCEN has no explicit initialisation of areas under regeneration. Areas (plus volume and increment, if available) with age zero, but with a dominant species are added to the first age class. Areas without a dominant species (clearcuts) are distributed over all species within the owner group according to the relative occurrence of the species, and added to the first age class.

Calculations to derive the initial situation can be found in the file EFISCEN init query.xlsx. The derivation of the growth functions can be found in the same file.

Creation of initial matrices is done using P2009, using default parameters and procedures.

Growth functions are fit on the species level, aggregated over the owners. Fits can be found in the file EFISCEN init query.xlsx in the tabs named with the respective species abbreviation.

Harvest rate
EFISCEN uses the 2013 harvests as a basis. Using a bark percentage of 12% of over bark volume, which is in line with the other LULUCF calculations, the removal quantity for 2013 is estimated in volumes over bark. No changes in the removal level are assumed for the EFISCEN simulations, and thus apply this quantity as required volume of removals for all years in the simulation.
For 2013 the total amount of removals is estimated at 1.022 million m^3 underbark (pers. com. Caspar de Groot, Probos). Using a bark percentage of 12% of overbark volume, the removal quantity for 2013

is estimated at 1.160992 million m³ overbark. We assume no changes in the removal level, and thus apply this quantity as required volume of removals for all years in the simulation.

Not all volume felled is removed from the forest. Analogous to earlier LULUCF calculations, we assume that an additional 6% of the removals is left in the forest. EFISCEN uses the ration removals over fellings, which is thus set at 0.943396226 (=1/1.06).

In line with earlier simulations done for the Netherlands, we assume 45% of the total removals to originate from thinnings. Felling and thinning ages are copied from earlier studies.

Check of the initialisation procedure
Table A6.3 shows area, average volume and average increment per species in the NBI6 database and according to EFISCEN after initialisation. Area and average volume are a direct result of the initialisation procedure and show small differences due to rounding in the procedures. Increment is the result of different processes in the model and often shows larger deviations from the measured values. By adjusting certain parameters in the model, it is possible to influence the increment level to have a more accurate simulation of the increment. These parameters are allowed to vary in a certain range, based on the experience of the user. Generally, a deviation of 0.5 m³/ha/yr is considered as acceptable.

Table A6.3 *Area, average volume and average increment per species in the NBI6 database and according to EFISCEN after initialisation.*

	NBI6 data			EFISCEN initial situation			difference		
	area	Vol-ume	Incre-ment	area	Vol-ume	Incre-ment	area	Vol-ume	Incre-ment
Soort	ha	m3/ha	m3/ha/yr	ha	m3/ha	m3/ha/yr	ha	m3/ha	m3/ha/yr
AE	9381	209.5	7.75	9378	210.1	7.81	-3	0.6	0.06
BE	26729	123.7	4.55	26723	123.9	4.56	-6	0.2	0.02
BU	16632	287.9	7.08	16629	288.7	7.20	-3	0.8	0.12
ZE	9634	169.1	6.65	9631	169.3	6.67	-3	0.2	0.02
ES	14184	219.9	9.87	14185	220.2	9.55	1	0.3	-0.32
EI	69460	225.3	6.11	69457	226.4	6.11	-3	1.0	0.00
OL	14145	168.6	6.84	14142	168.8	6.49	-3	0.2	-0.35
PO	13331	202.4	7.56	13327	202.6	7.72	-4	0.1	0.17
WI	6798	161.9	7.65	6794	166.5	7.45	-4	4.5	-0.20
DG	20471	309.3	13.70	20467	310.1	13.98	-4	0.8	0.27
GD	120574	203.3	6.09	120579	204.1	6.06	5	0.8	-0.03
ON	18688	275.9	9.74	18681	276.2	9.86	-7	0.4	0.11
JL	19649	223.6	8.77	19647	223.7	9.16	-2	0.1	0.39
FS	13803	277.5	12.02	13793	277.1	12.21	-10	-0.4	0.19
Totaal	**373480**	**216.5**	**7.30**	**373433**	**217.2**	**7.32**	**-47**	**0.7**	**0.02**

A6.2   Calibration of the mortality parameters for EFISCEN used in LULUCF

Background
EFISCEN was set up for the Netherlands using the NFI-6 data (see above). In this setup, the mortality parameters were not updated, only the initialisation and the increment functions. This resulted in too low simulated mortality as compared to the inventory results. Here we give a quick analysis of mortality patterns in the inventory data and derive new mortality parameters for inclusion in EFISCEN.

Data

A combination of NFI-6 and NFI-5 measurements is used, from the database as downloaded from the web (see above). Species, age (aggregated to age classes of 10yr width) and volume are derived from the NFI-5 measurements, while mortality was calculated from the trees that were reported to have died between NFI-5 and NFI-6. Also from NFI-6 we derived the harvesting status, distinguishing between plots where at least one tree had been felled (harvest) and trees where no trees were felled (no harvest). No correction has been made to estimate how much dead trees could have grown before they died. Mortality was expressed as m^3/ha/yr, dividing the total volume of the trees that were reported to have died by the actual measurement interval. Tree species were grouped according to the main species per plot as reported in NFI-5, in the same groups as used for the EFISCEN setup. Mortality was then expressed as a %, calculated as the annual mortality volume, divided by the volume of living trees in NFI-5. Only for the derivation of mortality parameters in EFISCEN we changed the interval to 5yr, i.e. all other reported patterns are % per year.

Patterns - species

There is a clear difference in mortality rate between plots with harvest and plots without harvest (Figure A6.1). For most species, the mortality is higher if no harvest was reported. For Beech and Ash there is hardly a difference while for other broadleaves the pattern is reversed. Short-lived broadleaves are most often unmanaged (57% of the plots did not have harvesting) while they have the highest mortality rate when not managed (Table A6.4). Conifers are more often managed and have the lowest mortality rate.
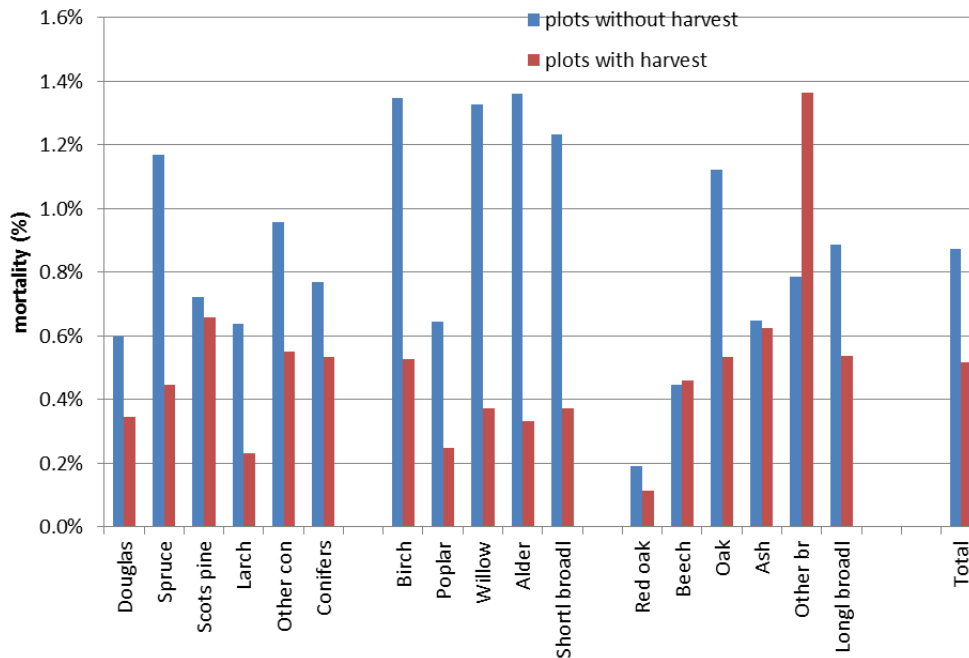

Figure A6.1 *Mortality per tree species, separated in plots with and without harvest*

Table A6.4 *Overview of number of plots and average mortality rate.*

	plots without harvest		plots with harvest		all plots		
	N	mort%	N	mort%	N	mort%	%unmanaged
Conifers	255	0.77%	462	0.53%	717	0.62%	36%
Longlived broadleaves	155	0.89%	208	0.54%	363	0.69%	43%
Shortlived broadleaves	88	1.23%	63	0.37%	151	0.87%	58%
Total	501	0.89%	735	0.52%	1236	0.67%	41%

Patterns – age

For the conifers, a peak in mortality appears in the first age class in the plots with management (Figure A6.2). However, this is based on only one observation. Also the peak in age class 13 in unmanaged plots is based on 1 observation. Mortality rate seems to decrease slightly with age, and is somewhat higher in unmanaged plots than in managed plots. Also for long-lived broadleaves there seems to be a decreasing trend with age, with some outliers where observations are few (age class 14 and up). Short-lived broadleaves seem to have an increasing mortality rate with age, which is much more pronounced in unharvested plots than in the harvested plots.
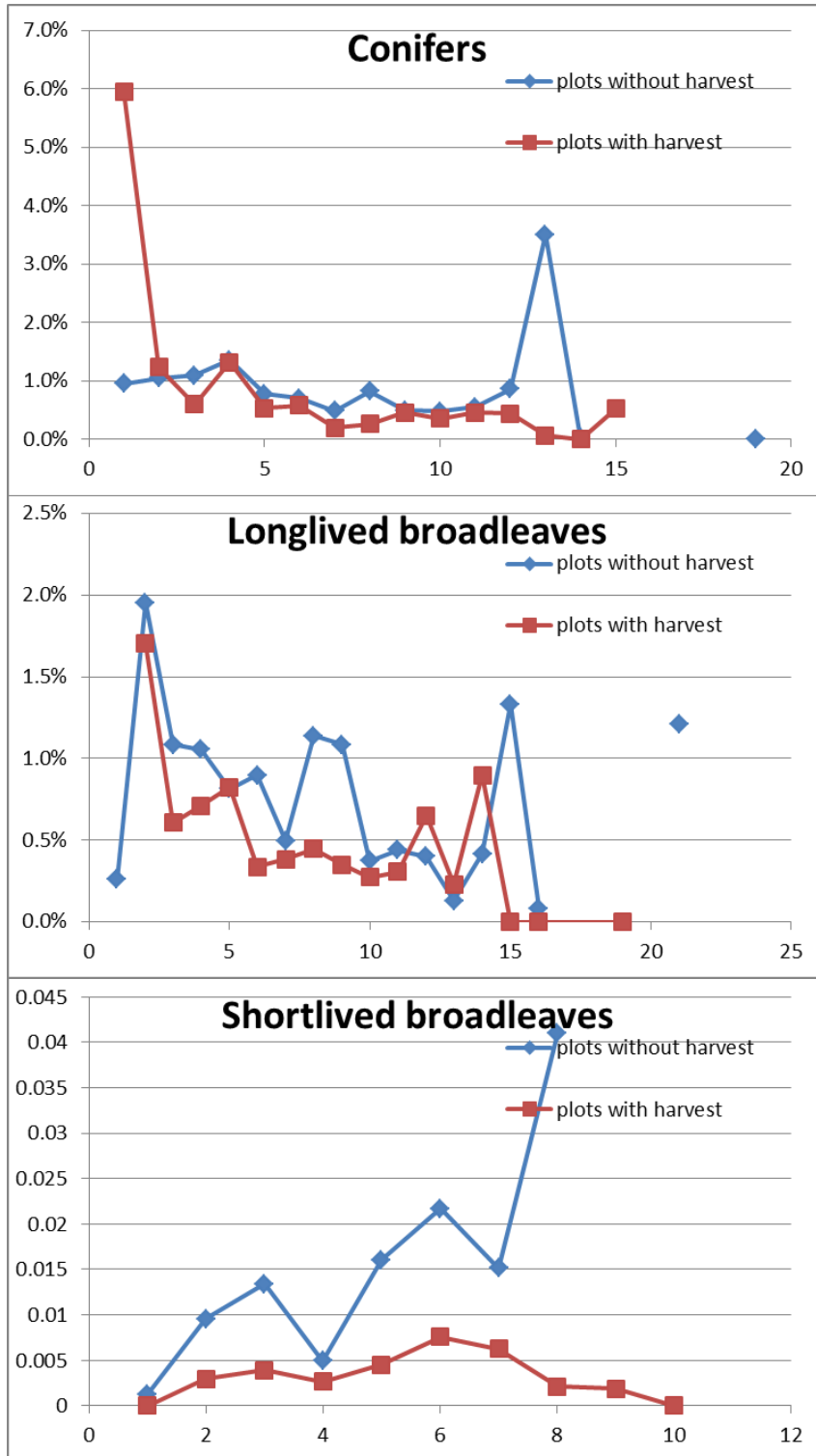
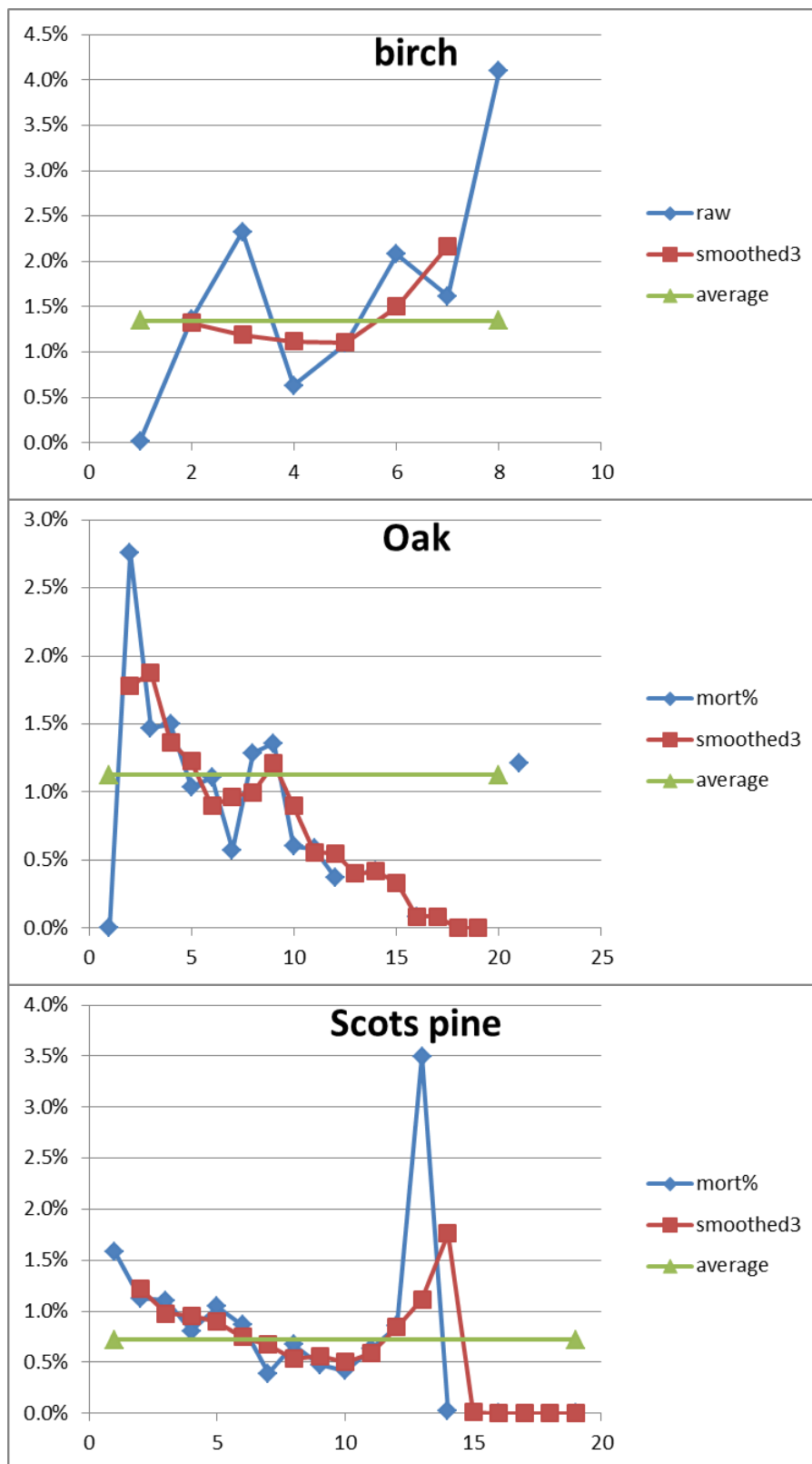**Figure A6.2** *Mortality rates per 10-year age class for different species groups*

EFISCEN parameters

In EFISCEN, mortality is only applied in case no management takes place. Therefore we only use the observations in unmanaged plots to derive the mortality rates. Ideally, each species would have an individual mortality curve over age, derived from observations in unmanaged plots. However, for most species, the number of observations is too little to derive mortality curves over age (Table A6.5). Only for birch, oak and Scots pine we had a reasonable number of observations, which seemed sufficient to derive an age pattern. The curves are shown in Figure A6.3. Besides the raw data, we show a smoothed curve, calculated as the weighted average of the observations in the current age class, the one above and the one below. I.e., the value for age class 3 is the weighted average of the classes 2-4, etc. For birch the raw data seem to suggest an increasing line, while the smoothed curve suggest a U-shape, consistent with literature. Also for Scots pine a U-shape is visible. For oak, the mortality seems to decrease with age. For all species, there are little observations for high ages and the shape of the curve is uncertain. Even for birch, the total number of observations is already rather low.

For the current implementation of EFISCEN, we decided to use for all species the average mortality rate, without an age pattern. For the usual time span EFISCEN is applied (30-40 years), this should be sufficient. For longer runs, or for runs with a high share of unmanaged forest, an age pattern should be included. Figure A6.3 can give a start for deriving age-dependent curves. For other species, the shape of these curves could be used as basis, and/or more data should be compiled, for example from the Dutch Forest Reserves database. The values in Table A6.5 are valid for a period of about 10 years. For implementation in EFISCEN, these values are divided by 2 to arrive at a 5-year time step.

Table A6.5 *Mortality rates and number of observations per species (same as Figure A6.1, blue bar). For implementation in EFISCEN, mortality rates are*

species group	plots without harvest	
	N	mort%
Douglas	12	0.6%
Spruce	13	1.2%
Scots pine	187	0.7%
Larch	10	0.6%
Other con	33	1.0%
Conifers	255	0.8%
Birch	51	1.3%
Poplar	15	0.6%
Willow	5	1.3%
Alder	17	1.4%
Shortlived broadleaves	88	1.2%
Red oak	13	0.2%
Beech	22	0.4%
Oak	97	1.1%
Ash	17	0.6%
Other br	6	0.8%
Longlived broadleaves	155	0.9%
Total	501	0.9%

Figure A6.3 *Mortality rates per 10-yr age class for birch, oak and Scots pine*

EFISCEN results

The new mortality rates as derived above are a factor 1-5 higher than the current values (Table A6.6). The simulated value for the whole forest increases from 0.35 m³/ha/yr to 1.16 m³/ha/yr (Table A6.7), close to the observed value of 1.18 m³/ha/yr. However, the simulated values per species do not correlate very well. The harvest level in EFISCEN is given as a total, leaving the allocation per species to internal EFISCEN routines. EFISCEN distributes this harvest level equally over the opportunities per species, as defined by the age ranges were thinning and final felling can take place. However, harvest

is in practice concentrated in certain species as Douglas fir, Norway spruce and larch, while harvest in for example birch and beech is much lower than could be expected from their presence in the forest. Consequently, harvest in some species is overestimated in EFISCEN leading to lower mortality rates, and the reverse. This could be solved by applying species-specific demand for harvest, but this is outside the scope of this work.

The new mortality parameters decrease the increment by about 0.3 m^3/ha/yr (Figure A6.5). The new parameters have an important effect as well on the simulation of growing stock (Figure A6.4).

Table A6.6 *New mortality rates as compared to the old ones as present in the simulations.*

| species group	plots without harvest			
	N	mort%	EFISCEN new	EFISCEN old
Douglas	12	0.6%	0.02983	0.0141
Spruce	13	1.2%	0.05856	0.0126
Scots pine	187	0.7%	0.03608	0.0121
Larch	10	0.6%	0.03199	0.0142
Other con	33	1.0%	0.04783	0.0118
Conifers	255	0.8%		
Birch	51	1.3%	0.06737	0.0154
Poplar	15	0.6%	0.03224	0.0172
Willow	5	1.3%	0.06646	0.0112
Alder	17	1.4%	0.06810	0.015
Shortl broadl	88	1.2%		
Red oak	13	0.2%	0.00951	0.0115
Beech	22	0.4%	0.02234	0.0086
Oak	97	1.1%	0.05618	0.0112
Ash	17	0.6%	0.03246	0.0155
Other br	6	0.8%	0.03932	0.0115
Longl broadl	155	0.9%		
Total	501	0.9%		

Table A6.7 *Simulated mortality (m^3/ha/yr) for the first time step in EFISCEN using the old parameter set (old) and the new parameter set, and average mortality as calculated from the NFI database.*

Species	EFISCEN old	EFISCEN new	NFI
Red oak	0.31	0.26	0.26
Birch	0.25	1.11	1.25
Beech	0.33	0.86	1.01
Alder	0.29	1.32	1.22
Ash	0.44	0.92	1.22
Oak	0.33	1.64	1.34
Other broadleaves	0.23	0.79	2.47
Poplar	0.44	0.82	0.53
Willow	0.21	1.27	1.52
Douglas fir	0.64	1.35	0.84
Scots pine	0.31	0.92	1.25

Species	EFISCEN old	EFISCEN new	NFI
Other conifers	0.41	1.65	1.92
Larch	0.41	0.93	0.53
Norway spruce	0.45	2.08	1.29
Total	0.35	1.16	1.18
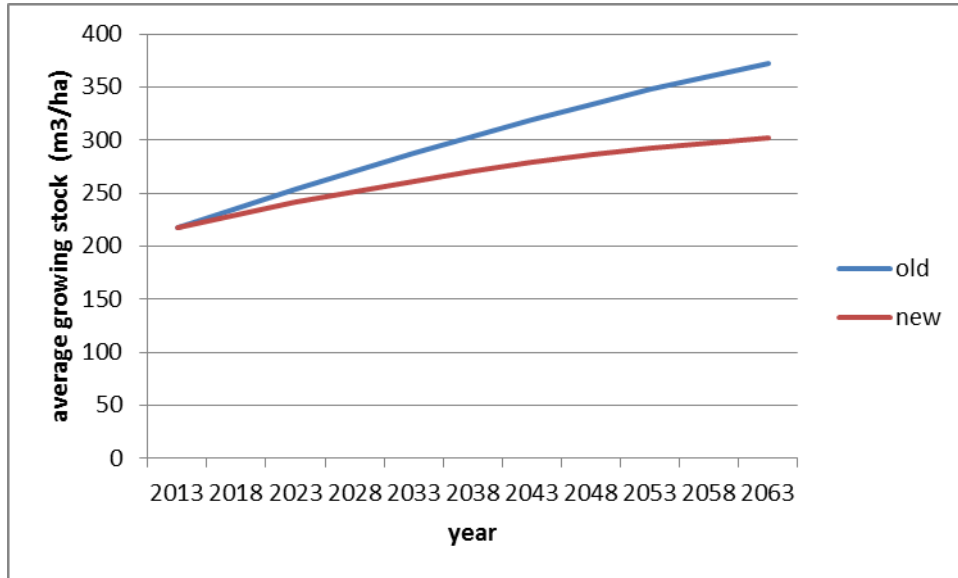
Figure A6.4 *Development of average growing stock with old and new mortality parameters*
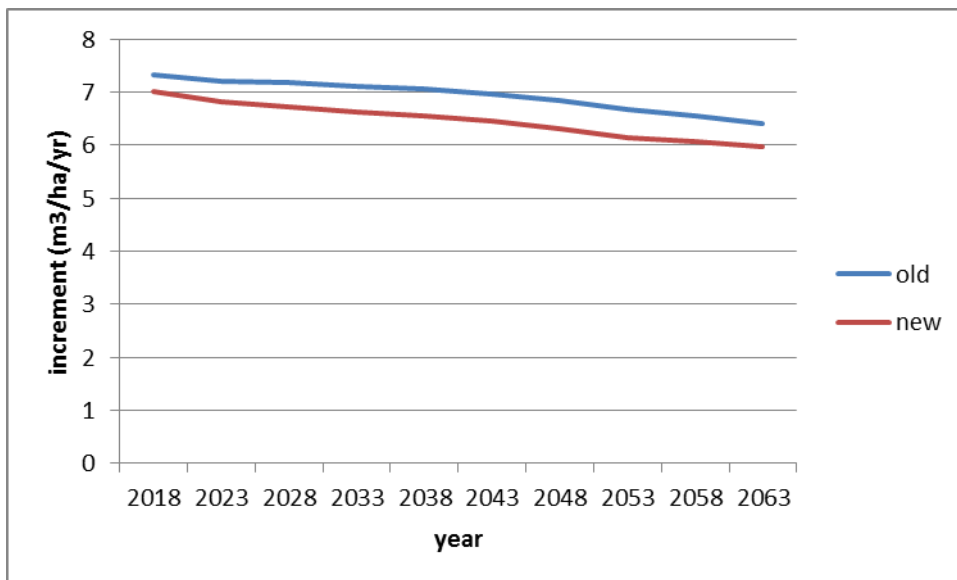
Figure A6.5 *Development of average increment with old and new mortality parameters*

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