Greenhouse gas reporting of the LULUCF sector in the Netherlands

Methodological background

WOt-technical report 52

E.J.M.M. Arets, J.W.H van der Kolk, G.M. Hengeveld, J.P. Lesschen,
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Abstract
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This report provides a complete methodological description of the Dutch National System for Greenhouse gas Reporting of the LULUCF sector for the UN Framework Convention on Climate Change (UNFCCC). The methodologies follow the IPCC 2006 guidelines for Agriculture, Forestry and Other Land-Uses (AFOLU). Based on these guidelines, this report provides detailed descriptions and motivations of the used methods, activity data, and emission factors for calculation of the emissions and removals as reported in the National Inventory Report (NIR). The structure of the report follows the structure for national inventory reports as laid out in the appendix to Decision 24/CP.19 of the UNFCCC.

Keywords: Greenhouse gas reporting, LULUCF, National inventory report, National system greenhouse gases, Netherlands, UNFCCC

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Preface

This report provides a complete description and background information of the Dutch National System for Greenhouse gas reporting of the LULUCF sector for the UN Framework Convention on Climate Change (UNFCCC) for its submissions from 2015 onwards.

Previously separate protocols existed with more detailed description and justification of the methodologies that was complementary to the descriptions in the NIR. Besides the protocols the LULUCF sector also maintained a more detailed background document. From the 2015 submission onwards the protocols will be abandoned and instead the information from the previous protocols was merged and updated into this methodological background document.

In comparison to the previous reports the structure of the report is updated to better reflect the structure for national inventory reports as laid out in the appendix to Decision 24/CP.19 and to follow the guidance in Decision 6/CMP9 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 was updated following 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 and 26 (Arets *et al.* 2013; Arets *et al*. 2014) 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.* (2007; 2008; 2009; 2011a; 2011b; 2012).

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Inhoud

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 is the only sector that has two types of tables in the Common Reporting Format (CRF, i.e. tables used to harmonize the structure of the reported emissions), one for the Convention (CRF sector 4) and one for KP-LULUCF and is also reported in two different chapters in the National Inventory Reports (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. The LULUCF part of the National System has been used for the NIR since 2005. Detailed background information on methods and assumptions have been documented in several publications, i.e. Nabuurs *et al.* (2003, 2005), Van den Wyngaert *et al.* (2007, 2008, 2009, 2011a, 2011b & 2012), De Groot *et al.* (2005), Kuikman *et al.* (2003, 2005) and Arets *et al.* (2013, 2014).

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 post 2012 reporting (starting from the NIR 2015 onwards) under the Convention. Compared to 2012, the methodologies are updated to 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.

Due to errors in the CRF reporting software for the NIR 2015 no information on KP-LULUCF was submitted. In the future this methodological report will also provide 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.

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.

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 6th National Communication of the Netherlands that was submitted in December 2013.

The Netherlands is a densely populated country. In 2012, the population amounted to 16.7 million people, with approximately 496 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 2.2 in 2012.

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 so-called 'temperate zone'. The 30-year annual average temperature in the centre of the country is 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.

Agriculture in the Netherlands focuses on livestock production (especially dairy cows and pigs), crop production and horticulture; of which greenhouse horticulture is the most important subsector. Cultivated organic soils are an important source of GHG emissions in the Netherlands. About 290,000 ha (or 6% of the total land area) of The Netherlands are covered by peat soils (excluding peaty soils, see Chapter 11). About 223,000 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 2012 was 397.32 kha, which therefore amounts to 9.6% of 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. 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
4B Cropland
4C Grassland
4D Wetlands
4E Settlements
4F Other Land

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 the 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 this category 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 and 2009-2013. 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 and 2013 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 four land use maps with the organic soil map (Kuikman *et al.*, 2005) allowed estimating the areas of organic soils for reporting categories Forest Land [4A], Cropland [4B] and Grassland [4C].

The 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 and 2013. 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 MFV dataset (2001-2005; 3622 plots; Dirkse *et al.* 2007) and the 6th Netherlands Forest Inventory (NBI6; 2012-2013; 3190 plots; Schelhaas *et al*. 2014). The accumulation of carbon in dead wood is based on measured values in the first two inventories, combined with some general parameters. Carbon stored in litter is estimated from a combination of national data sets (see Chapter 4). Land use changes from forests according to the definition to trees outside forests involve a loss of dead wood and litter (Chapter 4).

The carbon balance for areas changing from **Forest Land to other land use categories** is based on the mean national stocks as calculated from the NFI data for living biomass and the combined data sets for forest litter. The carbon balance for areas changing to Forest Land is based on national mean growth rates for young forests derived from the NFI data (Chapter 4).

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 1).

Carbon stock changes in living biomass are not estimated for Cropland remaining Cropland. For carbon stock changes in living biomass in Grassland remaining Grassland the Netherlands applies the Tier 1 method assuming there is no change in carbon stocks (IPCC 2006b).

This report provides for a method 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*. in press). Ground surface lowering was estimated from either ditch water level or mean lowest groundwater level (Kuikman *et al.*, 2005, De Vries *et al*. in press).

Emissions of N_2O and CH_4 as a result of fertilisation or drainage 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 seldom 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.

Table 1.1

Carbon stock changes reported in the National System per land use (conversion) category for the 2014 submission.

From→ To↓	FL	CL	GL	WL	Sett	OL
FL	BG-BL+DW-FF	BG-BL+MS	BG-BL+MS	BG+MS	BG+MS	BG+MS
CL	BG-BL-DW-Litt+MS		BG-BL+MS	BG+MS	BG+MS	BG+MS
GL	BG-BL-DW-Litt	BG-BL+MS	-WF	BG+MS	BG+MS	BG+MS
WL	-BL-DW-Litt+Soils	-BL+Soils	-BL+Soils	+Soils	+Soils	+Soils
Sett	-BL-DW-Litt+Soils	-BL+Soils	-BL+Soils	+Soils	+Soils	+Soils
OL	-BL-DW-Litt+Soils	-BL+Soils	-BL+Soils	+Soils	+Soils	+Soils

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; WL: Wetland; Sett: Settlement; OL: Other Land.

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 emission and removals are reported (Table 1.1). Details on the methodology per land use category can be found in Chapters 4-9. Methodology for assessing emissions from soils is given in Chapter 11.

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 workflow of how the different input sources and intermediary calculations are combined to get to the required output data. The basis of this workflow 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.

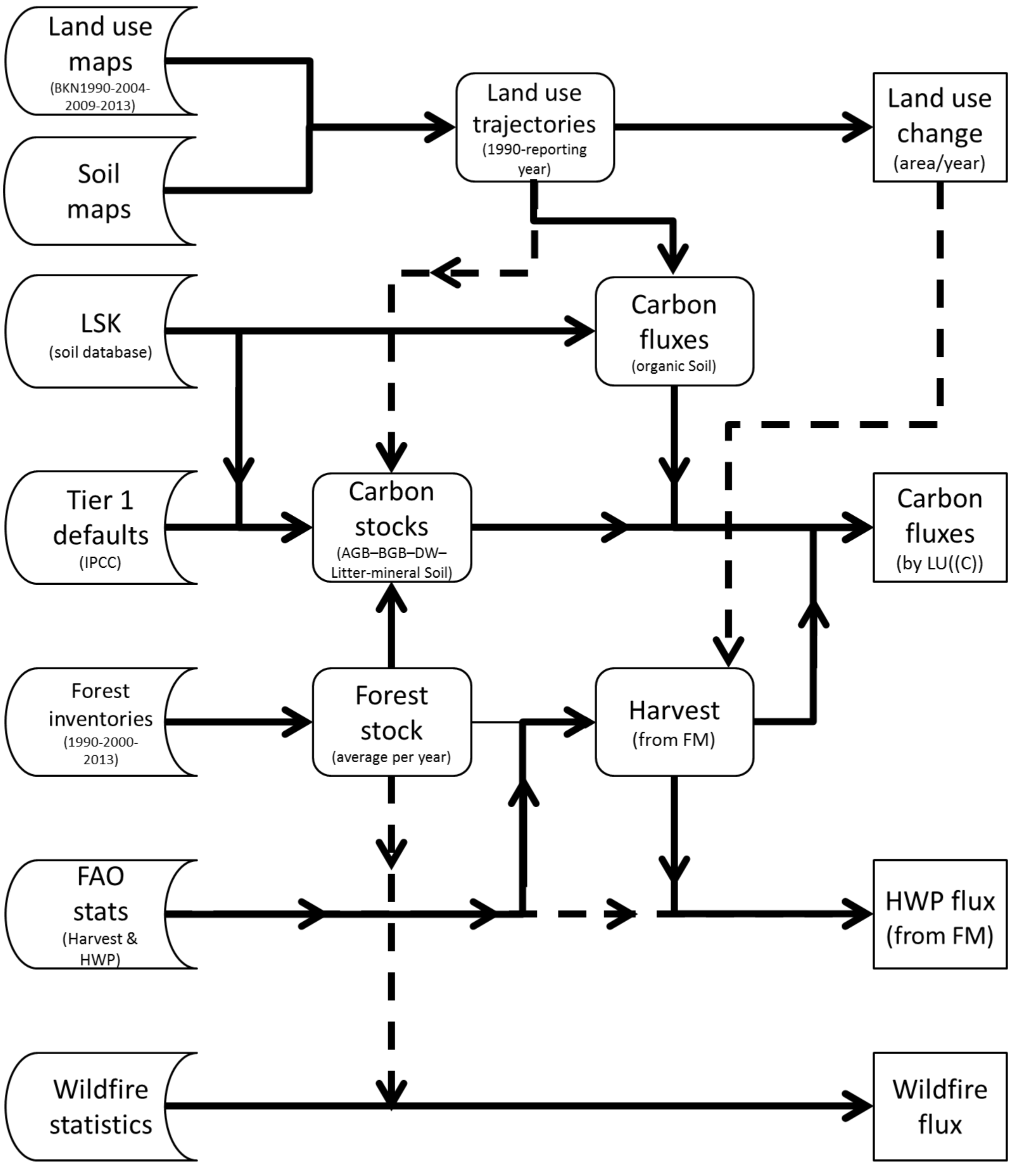

Figure 1.1. *High level overview of the workflow and used aggregation of information for calculating the greenhouse gas emissions and removals from the input sources (left), intermediary calculations (middle, rounded squares) and the resulting outputs (right, squares).*

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 and nature) 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 (Ch. 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.'

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.

The topographic map classes (see Chapter 3, Table 2.2) that are reported under Forest Land are deciduous forest, coniferous forest, mixed forest, poplar plantations and willow coppice. In urban areas and transportation infrastructure and built-up areas groups of trees are mapped as forest only if they have a minimum surface of 1000 m^2.

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). So in practise it cannot be avoided that small areas (below 0.5 ha) fulfilling al other elements of the forest definition are included under forest land.

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 (Ch. 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 rangelands and pasture land that are not considered Cropland. 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. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, consistent with national definitions (Ch. 3.2 in IPCC 2006b).

Also many shrublands with high proportions of perennial woody biomass may be considered to be a type of grassland and countries may elect to account for some or all of these shrublands in the Grassland category (Ch. 6.1 in IPCC 2006b).

The Netherlands currently reports under grassland any type of terrain which is predominantly covered by grass vegetation (equivalent to one general class of grasslands on the topographic maps, Ch. 3). It is stratified in:

- 'Grasslands', i.e. all areas predominantly covered by grass vegetation (whether natural, recreational or cultivated).
- 'Nature', i.e. all natural areas excluding grassland. 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.

No spatially explicit distinction is made between agricultural intensively and extensively managed Grasslands and 'Nature'. Nevertheless, for Grasslands the emissions from organic soils are reported (Chapter 11).

Apart from pure grasslands, all orchards (with standard fruit trees, dwarf varieties or shrubs) are included in the Grassland category. 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, reported as Nature, includes all land that is covered (mostly) with heather vegetation or rough grass species. Most of these were created in the Netherlands as a consequence of ancient grazing and sod cutting on sandy soils. As these practices are not part of the current agricultural system anymore, conservation management is applied to halt the succession to forest and conserve the high landscape and biodiversity values associated it.

2.5 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 (Ch. 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.

2.6 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 (Ch. 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.

2.7 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 (Ch. 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* (Par. 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 four maps representing the land use on 1 January 1990, 2004 (Kramer *et al*. 2007), 2009 and 2013 (Kramer and Clement 2015). These maps thus represent land use changes from 1990 until 2012.

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.

3.2 Source maps

The land use maps are based on maps that are used for monitoring nature development in the Netherlands, 'Basiskaart Natuur' (BN). These maps were based on different topographic maps of the Dutch Kadaster (Land Registry Office). The source material for BN1990 consists of the topographic map 1:25,000 (Top25) and digital topographic map 1:10,000 (Top10Vector, see Table 2.1 for more details). The paper TOP25 maps were converted to a digital high resolution raster map. The source material for BN2004 consists of the digital topographic map 1:10,000 (Top10Vector).

The source materials for BN2009 and BN2013 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 2.1). 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 1 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 2.1
Characteristics of the maps BN1990, BN2004, BN2009 and BN2013.

Characteristics	BN1990	BN2004	BN2009	BN 2013
Name	Historical Land use Netherlands 1990	Base map Nature 2004	Base map Nature 2009	Base map Nature 2013
Aim	Historical land use map for 1990	Base map for monitoring nature development	Base map for monitoring nature development	Base map for monitoring nature development
Resolution	25 m	25 m	25 m	25 m
Coverage	The Netherlands	The Netherlands	The Netherlands	The Netherlands
Base year source data	1986-1994	1999-2003	2004-2008	2009-2012
Source data	Hard copy topographic maps at 1:25,000 scale and digital topographic maps at 1:10,000	Digital topographic maps at 1:10,000 and additional sources to distinguish specific nature types	Digital topographic maps at 1:10,000 and additional sources to distinguish specific nature types	Digital topographic maps at 1:10,000 and additional sources to distinguish specific nature types
Number of classes	10	10	10	10
Distinguished classes	Grassland, Arable land, Heath land/peat moor, Forest, Buildings, Water, Reed marsh, Sand, Built-up area, Greenhouses	Grassland, Nature grassland, Arable land, Heath land, Forest, Built-up area and infrastructure, Water, Reed marsh, Drifting sands, Dunes and beaches	Grassland, Nature grassland, Arable land, Heath land, Forest, Built-up area and infrastructure, Water, Reed marsh, Drifting sands, Dunes and beaches	Grassland, Nature grassland, Arable land, Heath land, Forest, Built-up area and infrastructure, Water, Reed marsh, Drifting sands, Dunes and beaches

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 2.2.

Table 2.2
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 and of 2009 and 2013 using 25 m × 25 m grid cells. 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 2.3). 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 2.4), while the overlay of the 2009 and 2013 maps results in a land use change matrix over 4 years (1-1-2009 to 1-1-2013; Table 2.5).

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, 3.5 and 3.6, and annual changes in Tables 3.7, 3.8 and 3.9). The definitions of the UNFCCC land use categories are given in Chapter 2.

Table 2.3
Land Use and Land Use Change Matrix for 1990-2004 aggregated to the six UNFCCC land use categories (in ha)

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

Table 2.4

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

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

Table 2.5

Land Use and Land Use Change Matrix for 2009-2013 aggregated to the six UNFCCC land use categories (in ha)

	BN 2009						
BN 2013	Forest land	Cropland	Grassland	Wetland	Settlement	Other land	Total
Forest land	380,255	2,791	9,672	763	3,346	494	397,320
Cropland	1,535	793,892	145,410	304	3,198	1	944,340
Grassland	7,778	116,002	1,194,126	6,180	20,653	970	1,345,709
Wetland	863	1,410	10,849	801,539	4,477	1,825	820,962
Settlement	4,907	10,740	30,915	1,311	557,312	328	605,512
Other land	235	28	516	1,846	135	34,897	37,657
Total	*395,573*	*924,863*	*1,391,488*	*811,941*	*589,121*	*38,515*	*4,151,500*

Table 2.6

Annual changes in land us for the period 1990-2004 aggregated to the six UNFCCC land use categories (in ha yr^{-1}).

	From						
To	Forest land	Cropland	Grassland	Wetland	Settlement	Other land	Total
Forest land		1,040	1,610	87	181	47	2,964
Cropland	115		14,043	43	116	1	14,316
Grassland	1,279	12,628		649	785	182	15,523
Wetland	130	487	1,332		99	185	2,233
Settlement	716	5,842	5,590	203		45	12,395
Other land	58	14	65	199	9		345
Total	2,297	20,012	22,639	1,181	1,189	459	47,776

Table 2.7

Annual changes in land us for the period 2004-2009 aggregated to the six UNFCCC land use categories (in ha yr^{-1}).

	From						
To	Forest land	Cropland	Grassland	Wetland	Settlement	Other land	Total
Forest land		461	1,765	93	1,231	48	3,598
Cropland	97		21,309	35	873	0	22,316
Grassland	1,283	21,696		1,927	4,625	101	29,632
Wetland	166	359	2,122		607	178	3,431
Settlement	1,339	2,746	7,541	288		27	11,941
Other land	48	5	209	152	47		462
Total	2,933	25,267	32,947	2,496	7,383	355	71,380

Table 2.8

Annual changes in land us for the period 2009-2013 aggregated to the six UNFCCC land use categories (in ha yr^{-1}).

	From						
To	Forest land	Cropland	Grassland	Wetland	Settlement	Other land	Total
Forest land		698	2,418	191	837	124	4,267
Cropland	384		36,353	76	800	0	37,612
Grassland	1,945	29,001		1,545	5,163	243	37,896
Wetland	216	353	2,712		1,119	456	4,856
Settlement	1,227	2,685	7,729	328		82	12,050
Other land	59	7	129	462	34		690
Total	3,830	32,743	49,341	2,601	7,952	905	97,371

The total area of land use change in the period 1990 to 2004 was about 6,700 km^2, which is around 16% of the total area, in the period 2004 to 2009 3,569 km^2 (8.6%) changed, and in the period 2009-2013 3,895 km^2 (9.3%) changed. Note, however, that the time intervals differ among these periods, which results in apparent higher dynamics of land use change from 478 km^2 yr^{-1} over 1990-2004 to 713 km^2 yr^{-1} over 2004-2009 and to 974 km^2 yr^{-1} over 2009-2013. 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).

From 2013 onwards the annual changes as presented in Table 2.8 are used to extrapolate the land use changes. These values will be used until the new land use map is available (expected for the year 2017)

3.5 Organic and mineral soils

The areas of organic and mineral soils have to be reported separately under forest land, cropland, and grassland. Two types of organic soils are recognised; peat soils and peaty soils ('*moerige gronden*' in Dutch). For peat soils, the most recent data available is a peat map (De Vries 2004) that only indicates presence and absence of peat. For the mineral soils and the peaty soils an older soil map of the Netherlands (De Vries *et al*. 2003) is used. For reporting both maps were combined, with the peat map being leading for peat soils and the soil map for peaty and mineral soils. Peat and peaty soils have their specific emission factor, 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 2.9. 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 2.9

Land use on organic and mineral soils in 1990, 2004, 2009 and 2013

Land use	Soil	1990	2004	2009	2013
Forest land	organic soils area (ha)	21,403	24,511	24,997	25,050
	mineral soils area (ha)	361,485	367,719	370,556	372,250
	% organic	6	6	6	6
Cropland	organic soils area (ha)	100,882	93,668	94,479	93,431
	mineral soils area (ha)	918,458	845,941	830,376	850,902
	% organic	10	10	10	10
Grasslands	organic soils area (ha)	305,761	290,508	284,366	281,762
	mineral soils area (ha)	1,152,340	1,069,626	1,057,981	1,013,832
	% organic	21	21	21	22
Other land uses	organic soils area (ha)	50,568	69,927	74,771	78,371
	mineral soils area (ha)	1,240,528	1,389,526	1,413,898	1,435,828
	% organic	4	5	5	5

3.6 From land use change matrix to activity data

From overlays of the successive land use maps and soil and peat 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 1/20th 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.

Effectively this means that a sequence without land use changes occurring in the time series will result in a single trajectory, whereas a sequence with four different land use categories in the year 1990, 2004, 2009 and 2013 will result in 14 * 5 * 4 = 280 trajectories to account for the different potential years the land use changes may have occurred in between the map years. For sequences with 1 or 2 land use changes, the number of trajectories depends on the years between which the land use change has taken place.

To minimise computation time, a minimum area for which a trajectory is representative is used. The trajectories below this limit are not used as such in further calculations, but the area represented by the other land use trajectories is scaled to the full area of the Netherlands. This minimum area is set at 0.03125 ha (or half a pixel). As a result of this, rare land use change trajectories covering a total area of about 70 km^2 or 0.16% of the total land area of the Netherland are not explicitly taken into account (see Table 2.10 for an overview of how different land use change sequences are impacted by this minimum area).

Table 2.10

Occurrence of different number of land use changes based on the four land use maps, the area covered by those groups of land use change trajectories. If there were 3 land use changes this means that land use changed between all four land use maps.

Number of LU-changes	Area (km^2)		Area > 0.0325 ha (km^2)		Area rare trajectories (km^2)		Reporting area (km^2)	
0	30553	(74 %)	30553	(74 %)	0	(0 %)	30605	(74 %)
1	7942	(19 %)	7941	(19 %)	1	(0 %)	7955	(19 %)
2	2725	(7 %)	2699	(7 %)	26	(1 %)	2704	(7 %)
3	294	(1 %)	250	(1 %)	44	(15 %)	251	(1 %)

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.

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[1]).

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 from 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.

[1] 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

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):

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 National forest inventories

The basic approach to assess carbon emissions and removals from forest biomass follows the 2006 IPCC Guidelines where a stock-difference approach is suggested. It combines activity data from land use maps and emission factors from national forest inventories (Figure 4.1). 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 MFV data (2001-2005) and the NBI6 data (2012-2013). Information between 2013 and 2020 was based on projections using the EFISCEN model (see below).

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 MFV (Meetnet Functie Vervulling Bos) inventory was designed as a randomized continuous forest inventory. In total 3622 plot recordings with forest cover were available for the years 2001, 2002, 2004 and 2005 (2003 was not inventoried because of a contagious cattle disease). Apart from the live and dead wood characteristics, in 2004 and 2005 litter layer thickness was measured in stands on poor sand and loss (Daamen and Dirkse, 2005).

Between September 2012 and September 2013 the Sixth Dutch Forest Inventory (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 MFV and NBI6, the methodology of the NBI6 closely followed the methodology of the MFV (see Schelhaas *et al.*, 2014). Measurements were done on 3190 sample plots, of which 1235 were re-measurements of MFV sample plots.

By 2020 a new NFI is planned. The data from that NFI will be used similarly as the NBI6 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 (see description towards the end of Section 4.2.2). These projected carbon stocks in living biomass then subsequently are used to calculate carbon stock changes between the most recent NBI6 and the projected carbon stocks. 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).

4.2.2 Forest Land remaining Forest Land (4.A1)

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. Carbon in the forest is derived from the growing stock volume, making use of other forest traits routinely determined in forest inventories. With the three repeated measures changes in biomass and carbon stocks were assessed for the periods 1990-2003 and 2003-2012. The annual changes during the years between 1990-2003 and 2003-2012 are determined using linear interpolation.

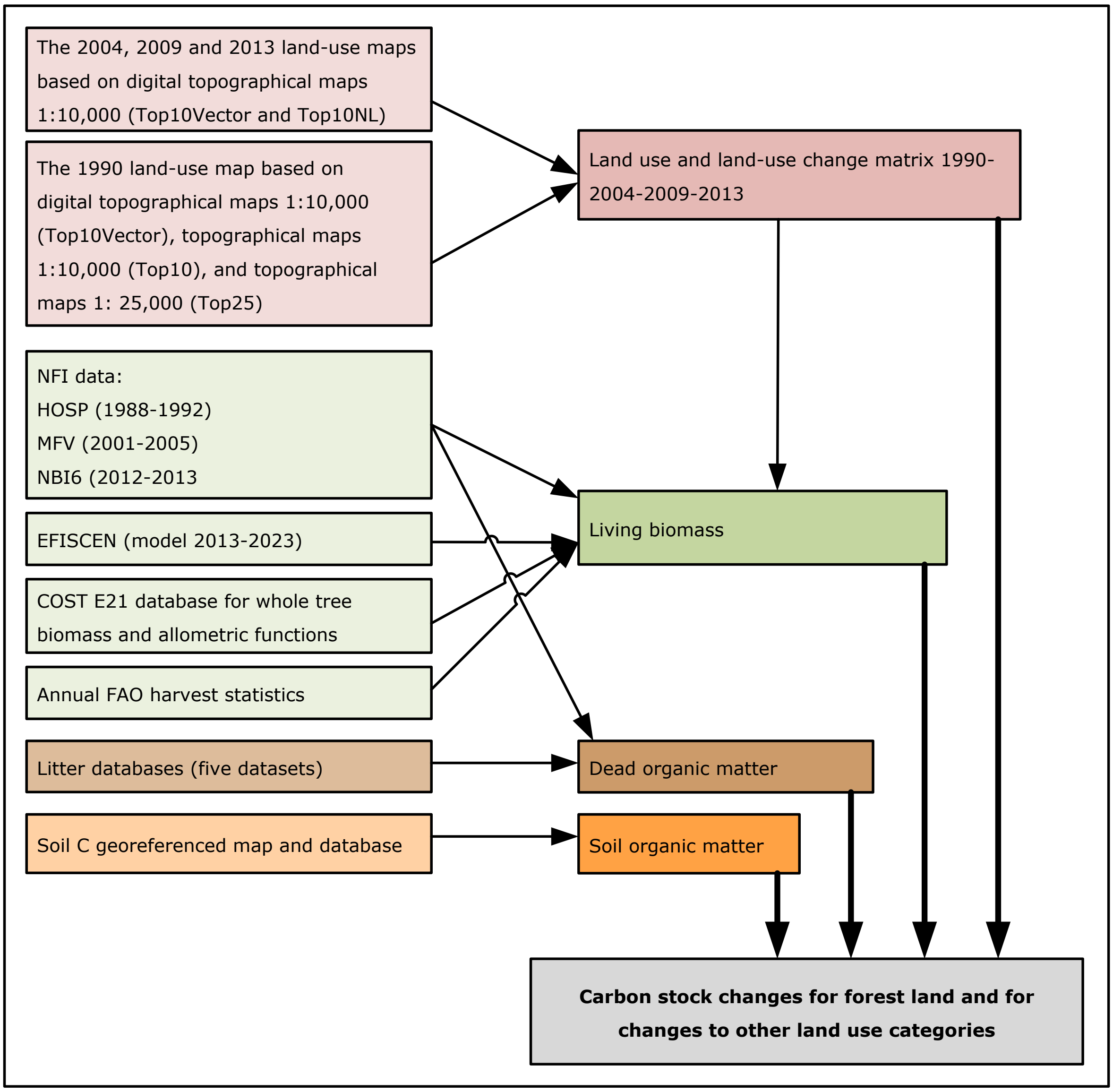

Figure 4.1. *Sources for the allocation of Forest Land and the calculations of carbon stock changes from Forest Land.*

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 functions (BCEF) for each plot in the NFI's 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 MFV (n=7544) and NBI6 (n=7365) both diameter and height was measured. With these data for this subsample of trees average biomass conversion and expansion factors (BCEF) were calculated by tree species group (Table 4.1) using a set of biomass expansion functions (Annex 2, Table A.2.1 and A.2.2 – 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). Subsequently for all plots in the NFI datasets, biomass is calculated using the dominant tree species group's specific BCEFs.

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 BCEF's (tonnes biomass m^{-3}) and average root-to-shoot ratios are calculated (

2. Table 4.2). These inventory specific BCEFs reflect the shifts in species composition seen over the years.

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 (

3. 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 all 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 d.m. ha^{-1}) are estimated for each year.
6. Using the relative share of coniferous and broadleaved forests and the differentiated T1 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 d.m. 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, MFV and NBI6.

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 year, average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonne ha^{-1}), BCEF (tonne d.m. per m^3 stemwood volume), net annual increment (NAI; m^3 ha^{-1} yr^{-1}), below-ground biomass (AGB; tonne ha^{-1}), root to shoot ratio (R), share of conifer biomass in the total forest biomass, mass (tonne ha^{-1}) of standing deadwood (DWs) and lying deadwood (DWL). The EFISCEN data are based on a model projection (see paragraph on EFISCEN projections 2013-2020 below).

NFI	Year	GS	AGB	BCEF	NAI	BGB	R	Share	DW Biomass	
								Conifers	DWS	DWL
HOSP	1990	158	112.8	0.714	7.62	20.6	0.18	0.44	0.84	0
MFV	2003	195	143.2	0.736	7.53	25.8	0.18	0.42	1.33	1.53

NBI6	2012	217	165.5	0.764	7.30	29.9	0.18	0.37	1.88	1.93
EFISCEN	2023	253	192.2	0.759	7.20	35.4	0.18	0.39	1.95	1.93

Effects of wood harvests on biomass gains and losses
The effect of harvesting wood on carbon in the remaining forest biomass is already implicitly included in the carbon stock differences between the different NFIs. The gross gains in biomass between the inventories were thus higher than calculated from the NFIs' stock differences. Therefore the carbon in the biomass of the harvested wood in a given year was added to the carbon stock changes in living biomass. At the same time this same amount of carbon was reported under carbon stock losses from living biomass, resulting in a net change as determined from the carbon stock differences between the forest inventories. As a consequence, the net stock change is gradual, but the gains and losses are more erratic.

Information on annual volume of wood harvesting is only available at the national level and is taken from the FAO harvest statistics (www.fao.org). Most recent years are included as soon as available from FAO-stat. Until these data are available, estimates are obtained from the organisation that is responsible for preparing the Dutch statistics for the Joint Forest Sector Questionnaire. Wood production is given as production round wood 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 round wood 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 round wood 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 round wood to total wood (1.06 m^3 wood / m^3 round wood year^{-1})

For each year, first the amount of timber recovered from deforestation is estimated by the area deforested multiplied with the average forest growing stock. This volume of wood is subtracted from the overall nationally harvested wood volume. Subsequently the remaining harvest is then allocated to forest management activities. 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). All harvests were calculated as thinnings.

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).

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; MFV litter inventory). The data from Van den Burg (1999) were collected between 1950 and 1990 and were used only to estimate bulk density based on organic matter content. The data from De Vries and Leeters (2001) were collected in 1990 and their median was used until now as a generic national estimate. They also provide species specific values of (mostly) conifer species. However, they sampled sandy soils only. The Forest Classification dataset was designed to provide abiotic attributes for a forest classification in 1990, not to sample the mean litter in forests. However, it is the only database that has samples outside sandy areas. Schulp and co-workers intensively sampled selected forest stands in 2006 and 2007 on poor and rich sands with the explicit purpose to provide conversion factors or functions. They based their selection of species and soils on the MFV forest inventory. During the last two years of the MFV 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 MFV inventory. These were compared to each other and the available data from De Vries and Leeters (2001). From these, a hierarchy was developed to accord mean litter stock values to any of the sampled plots of the HOSP (1988-1992) and MFV (2001-2005) inventories.

The followed hierarchy was:

1. For non-sandy soils the only source of information was the Forest Classification database. Though sampled around 1990, it was used for 1990 and 2004 alike. As such it is considered a conservative estimate for any changes occurring. The use of the same dataset in 1990 and 2004 means that changes in total litter stock on non-sandy soils only occur through changes in forest area and tree species composition. Peaty soils were kept outside the analysis.

2. For sandy soils with measured litter layer thickness (i.e. only from the MFV in the years 2004 and 2005), regressions for rich and poor sands based on data from Schulp and co-workers were used to convert them into litter carbon stock estimates. For sand rich in chalk (five plots) the regression equation of rich sand was used.

3. For sandy soils in the MFV without measured litter layer thickness, but with all other information, a regression was developed from the 951 plots with measured litter layers to estimate the carbon stock from plot location and stand characteristics. However, as this estimate was completely based on data from the MFV alone, we did not use it for the HOSP plots.

4. For sandy soils with missing data for the regression equation mentioned in point 3 of this hierarchy, or for the sandy soils in the HOSP inventory, the following procedure was used:
    a. For reasons of consistency with the non-sandy soils, if a mean estimate was available for the tree species from the Forest Classification database that was accorded to the plots.
    b. If no such estimate was available, the species specific estimate from the study of De Vries and Leeters (2001) was accorded. In this study, only median values were given and the mean value was taken as midway between the 5% and the 95% percentile.
    c. If no such estimate was available, the mean 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.

The difference between 2004 (MFV litter layer thickness measurements) and 1990 (Forest Classification database; De Vries and Leeters 2001) was estimated and a mean annual rate of carbon accumulation was calculated. A Monte Carlo uncertainty analysis was carried out with random carbon litter stocks assigned to plots from a distribution rather than from the mean values. The results of the Monte Carlo analysis consistently showed a carbon sink in litter; however the magnitude was very uncertain. As such, it was assumed to be the more conservative estimate to set the accumulation of carbon in litter in Forest Land 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.

Carbon stock changes in soils

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

EFISCEN projections 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 6th Dutch NFI (NBI6). Input data from the NBI6 are grouped on basis of the tree species that dominate the stand (hoofdboomsoort), but tree species composition at the plot can deviate.

Data are aggregated to the following 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,Q._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 4.3 the tree species groups as identified in the NBI6 tree where aggregated to match the classification of species groups used in the EFISCEN model.

Additionally the data of the NBI6 where classified into 4 owner groups that are distinguished within the EFISCEN model. 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).

Age is derived from the year of establishment of the stand (kiemjaar). Each plot is assumed to represent 117.1 ha, thus assuming that all plots visited in the NBI6 are representative for the whole area, ignoring a possible small bias for plots that could not be measured (access denied or impossible).

Table 4.3.
Aggregation of the NBI6 tree species groups to species groups used in the EFISCEN model. The NBI6 species refers to the grouping of species as described in Appendix 4 of Schelhaas et al. (2014)

ID	NBI6 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
15	ON	ON
16	PO	PO
17	ST	OL
18	UL	OL
19	WI	WI
20	XX	XX
21	ZE	ZE

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 (clear cuts) are distributed over all species within the owner group according to the relative occurrence of the species, and added to the first age class. Growth functions are fit on the species level, aggregated over the owners.

Projected harvests in the EFISCEN model
The 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.

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.

4.2.3 Land converted to Forest Land (4.A2)

Removals and emissions of CO_2 from forestry and changes in woody biomass stock are estimated based on country-specific Tier 2 methodology. The approach chosen follows the IPCC 2006 Revised

Guidelines and its updates in the Good Practice Guidance on Land Use, Land Use Change and Forestry (IPCC, 2003). The basis assumption is that the net flux can be derived from converting the change in growing stock volume in the forest into carbon and that young plots (< 20 years) in the national forest inventory are representative for newly reforested/afforested plots.

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

The increase in living biomass in land converted to Forest land is estimated based on the data from the national forest inventories, using the following set of assumptions:
1. At time of regeneration, growth is close to zero.
2. Between regeneration and twenty years of age, the specific growth curve is unknown and is approximated by a linear relationship.
3. The exact slope of this linear function is best approximated by a linear regression on the mean growth rates per age as derived from the NFI. One mean value for each age is taken to avoid confounding effects of the age distribution of the NFI plots (some of which are not afforested but regenerating after a clear cut).
4. The emission factor is calculated for each annual set of afforested plots separately. Thus the specific age of the re/afforested plots is taken into account, and a general mean value is reached only at a constant rate of afforestation for more than twenty years.

5. Between 1990 and 2003, rates are based on the HOSP inventory. From 2003-2013 these rates are based on the MFV inventory and from 2013 onwards the relationships is based on data from the NBI6 ().

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.

4.2.4 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

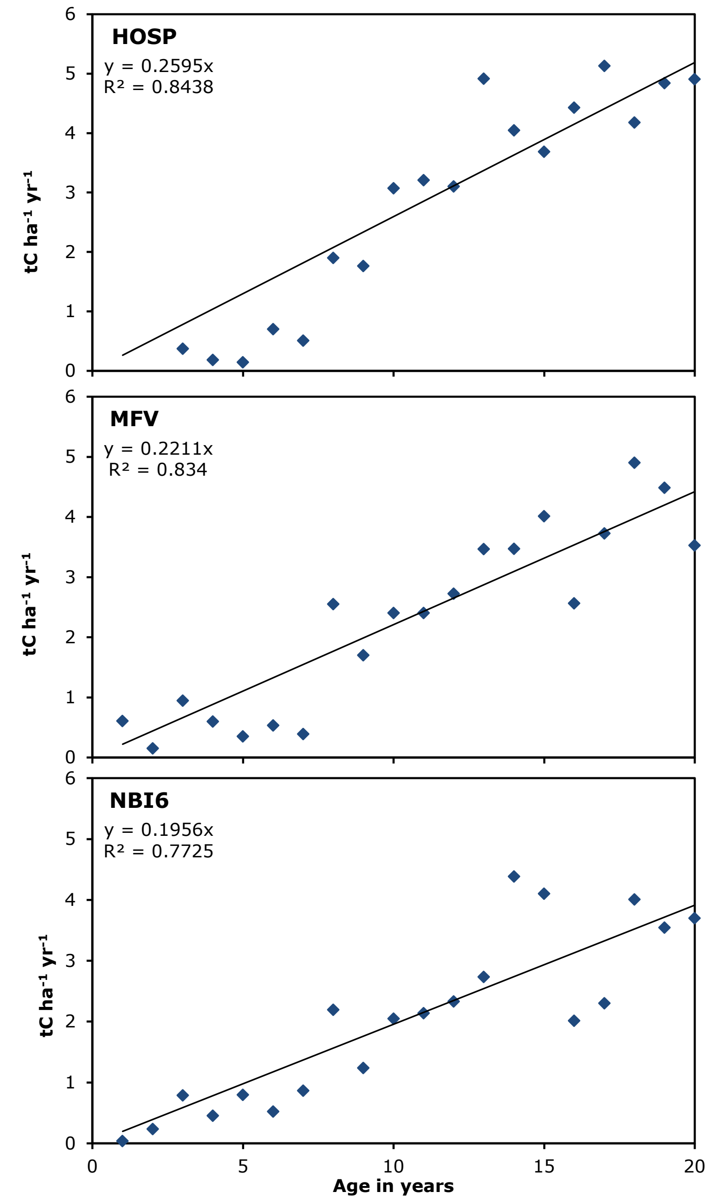

Figure 4.2. *Regression between age and carbon emission (as calculated from increment data and IPCC expansion and conversion factors) for the HOSP, MFV and NBI6 data*

litter is lost. National averages are used as there is no record of the spatial occurrence of specific forest types.

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 4.2.2). 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 4.2.2. The systematic increase reflects the increasing attention for more nature oriented forest management.
- The average carbon in litter is based on a national estimate using best available data for the Netherlands as described in Section 4.2.2. Emission factors for litter between 1990 and 2003 are based on the calculated litter values based on the HOSP (1990) and the MFV (2003) as described in Section 4.2.2. From 2003 onwards, the changes in carbon stocks from litter are kept constant.

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 4.4 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 m^3 ha^{-1} yr^{-1} is considered as acceptable.

Table 4.4

Area, average volume and average increment per species in the NBI6 database and according to EFISCEN after initialisation

Species	NBI6 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 (IPCC 2006b). 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 ground water table in organic soils under Cropland, however, are explicitly calculated for areas of Cropland remaining Cropland (see Chapter 11).

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 methodology 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 4.2.4.

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 subcategories are distinguished:

1. 4.C1 Grassland remaining Grassland

   This category is further differentiated in:
   - 'Grasslands', i.e. all areas predominantly covered by grass vegetation (whether natural, recreational or cultivated)
   - 'Nature', i.e. all natural areas excluding grassland (natural grasslands and grasslands used for recreation purposes). Depending on the year, nature areas cover about 3-5% of the total Grassland area.

   The annual production of biomass in grasslands 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 remaining Grassland the Netherlands applies the Tier 1 method assuming there is no change in carbon stocks (IPCC 2006b).

   Like for living biomass, also no carbon stock changes in mineral soils are expected. Therefore for Grassland remaining Grassland also no net carbon stock changes in mineral soils are calculated. Emissions from lowering the ground water table in organic soils under Grassland, however, are explicitly calculated for areas of Grassland remaining Grassland (see Chapter 11).

2. *4.C2 Land converted to Cropland*
   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). 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 are calculated based on the methodology provided in Chapter 11.

6.2 Methodological issues

Carbon stock changes in biomass
Carbon stock change due to changes in biomass in land use conversions to and from Grasslands were calculated based on Tier 1 default carbon stocks (Table 6.1) for total biomass in combination with root-to-shoot ratios (Table 6.2) to allocate total carbon stock to above- and belowground compartments. Annual land use change rates were multiplied with the negative carbon stocks to calculate the loss in case of Grasslands converted to other land use categories. Annual land use change rates were multiplied with the positive carbon stocks to calculate the gains in case of lands converted to Croplands and Grasslands.

Table 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 DM 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 d.m.

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)

Additional methodology to calculate carbon stock changes in biomass for Forest Land converted to Grassland is provided in Section 4.2.4.

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

7 Wetlands [4.D]

7.1 Description

The definition for the land use category Wetlands is provided in Section 2.5. 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 4.2.4. 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

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8 Settlements [4.E]

8.1 Description

The definition for the land use category Settlements is provided in Section 2.6. 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 soils under Settlements remaining Settlements.

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 4.2.4. 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 2.7. 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 follow the guidance Section 2.8 in 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 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: sawnwood, wood-based panels, other industrial roundwood, and paper and paperboard.

From the land use change calculations under Forest Land (Chapter 4), the fraction of harvest from deforestation is used. By definition all harvest is allocated to D and FM land.

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.)

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.

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

Lesschen *et al.* (2012) used the same 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 10.1 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 10. the calculated average carbon stocks for grassland, cropland and forest are shown.

Table 10.1
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	Podzolgrond	7393	246
River clay soil	Rivierkleigrond	2652	111
Peat soil	Veengrond	3369	208
Marine clay soil	Zeekleigrond	7751	299
Sandy soil with lime	Kalkhoudende zandgrond	958	75

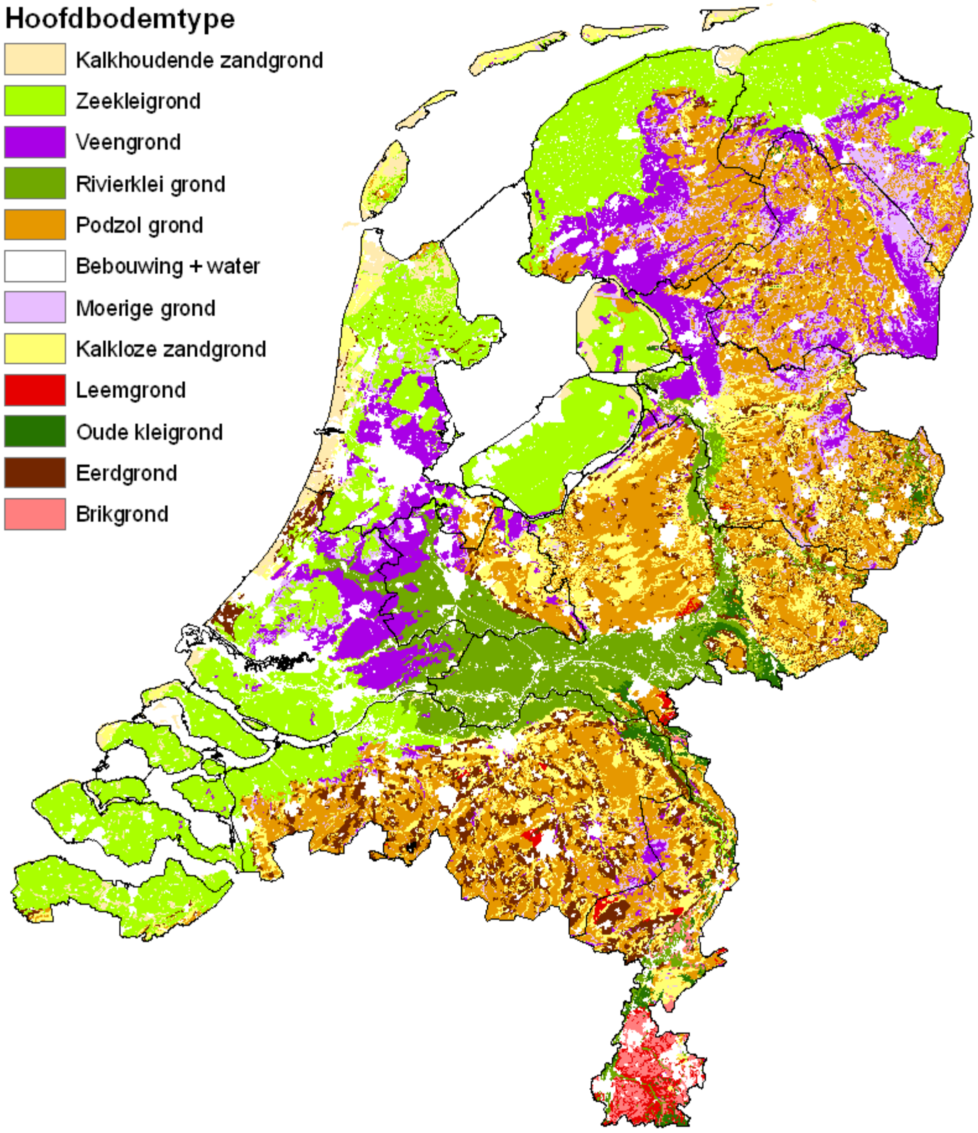

Figure 10.1. *Distribution of the main soil types in the Netherlands (Lesschen et al., 2012). Legend is in Dutch, see Table 10.1 for corresponding English names for the soil types.*

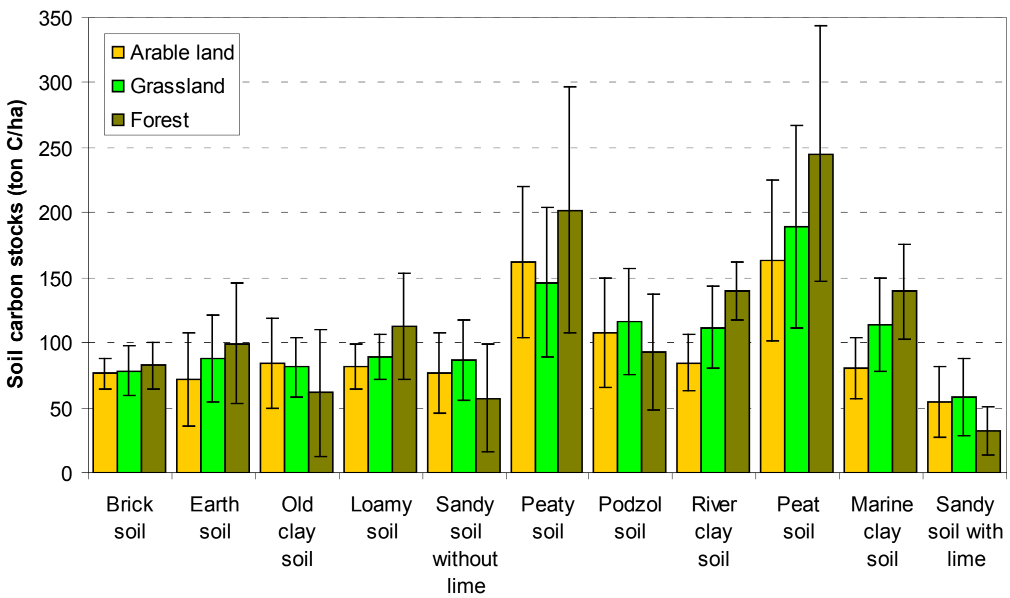

Figure 10.2*. Average soil carbon stocks per land use soil type combination. The error bars indicate the standard deviation (Lesschen et al., 2012).*

The LSK data set only contains data on soil carbon stocks for the land uses grassland, cropland and forest. For the other land uses no data about soil carbon is available in the LSK database or other studies. Therefore, estimates had to be made. Especially for settlements it is important to estimate carbon stocks, since 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 (25x25 m grid cells) it can be assumed that in reality a large portion of that grid cell is indeed paved. Using the following assumptions an average soil carbon stock under 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 (IPCC default) the corresponding carbon stock of the previous land use
- The remainder 50% consists mainly of grassland and wooded land for which the reference soil carbon stock is assumed.

For wetlands no change in carbon stocks in mineral soils is assumed upon conversion to or from forest.

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 FLU, FMG and FI 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 FI 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:

$$E_{\min} = \frac{C_{t=20} - C_{t=0}}{t} * A_{\min\_x, t=20} \qquad (10.1)$$

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 10.2 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 10.2
Average carbon stock changes per soil type for land use conversions to and from Forest Land (tonnes C ha^{-1} $year^{-1}$)

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

11.3 Organic soils

As from the NIR 2015 the definition of organic soils has been broadened and also emissions from peaty soils (shallow peat soils) are included. 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.

Previously, only peat soils, which have a peat layer of at least 40 cm within the first 120 cm, were included, but with this new definition also the peaty soils, in Dutch called '*moerige gronden*', which have a peat layer of 5-40 cm within the first 80 cm, are included. Based on the available data sets, two different approaches for the emission factors have been developed. For CO_2 emissions from cultivated organic soils[2] the methodology is described in Kuikman *et al.* (2005). This method is based

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

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*. in press). 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 was based on the Dutch soil map (De Vries *et al*. 2003; De Vries 2004). This resulted in 223,147 ha of peat soils under agricultural land use in the Netherlands.

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

$$C_{em} = R_{GSL} \cdot \rho_{peat} \cdot f_{ox} \cdot [OM] \cdot [C_{OM}] \cdot f_{conv} \qquad (10.2)$$

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 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 10.3.

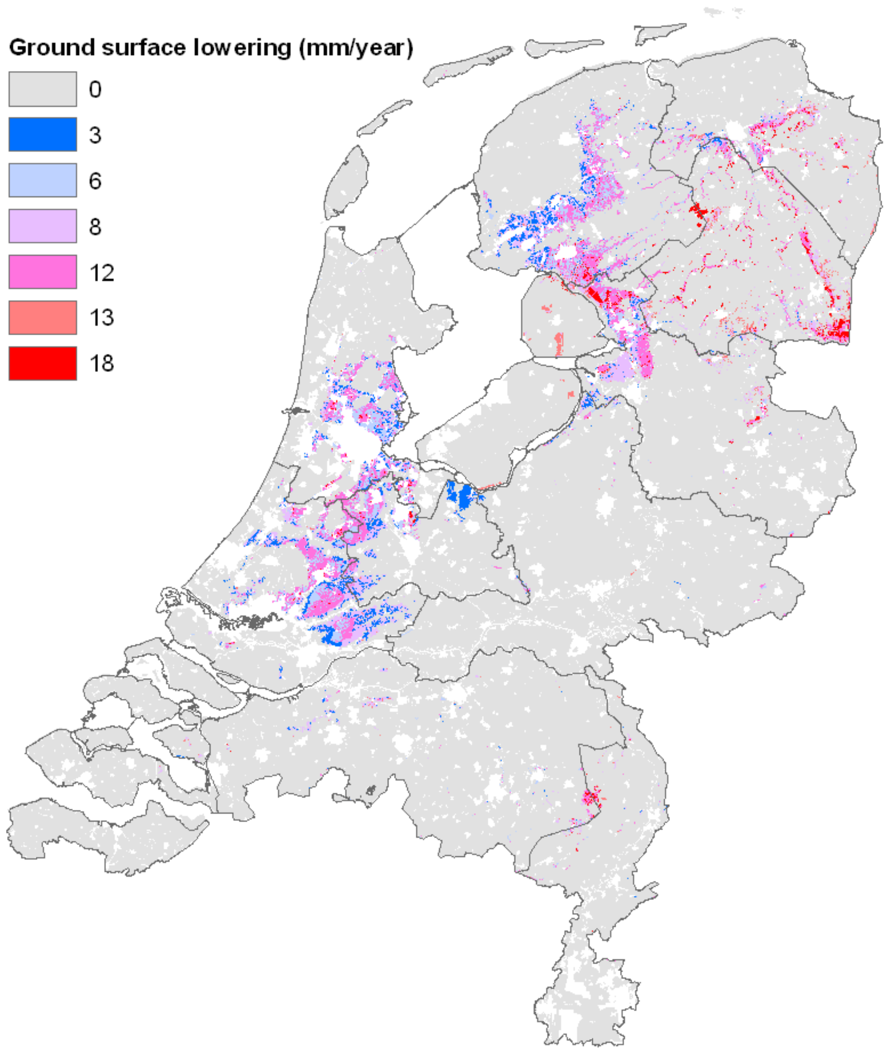

Figure 10.3. *Location of peat soils and their average ground surface lowering*

Table 10.3

Carbon emissions as resulting from classification of peat soils in the Netherlands, estimated mean ground surface lowering (gsl) and surface (in ha), based on 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 Table 10.3 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 1.158 Mtonnes of C, which is an annual emission of 4.246 Mtonnes of CO_2. This has been converted to an annual emission factor of 19.03 tonnes CO_2 ha^{-1}

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*. (in press).

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 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 soil map was presented in 2015 and after implementation will also be used in future 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. Finally, this resulted in an average overall emission factor of 13.02 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.

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.

11.4 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. 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.

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 10.4). 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 10.4
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. Therefor the total emissions from forest fires are reported in CRF Table 4(V) under wild fires for forests remaining forests.

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 10.4). On average this is 210 ha yr^{-1} (Table 10.4).

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

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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 LUUCF sector for the UN Framework Convention on Climate Change. 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 is reviewed by the task force on Agriculture of the Release and Transfer Register. The methodologies follow the 2006 IPCC Guidelines. The work was supported and supervised by Nico Bos of the Ministry of Economic Affairs and Harry Vreuls of the Netherlands Enterprise Agency (RVO). The authors would like to thank Isabel van den Wyngaert and Gert-Jan van den Born (Netherlands Environmental Assessment Agency) who contributed to earlier versions of the report and its predecessors.

Annex 1 Land use maps

A1.1 Land use statistics

Table A1.1 gives for BN2004, BN2009 and BN2013 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 A1.1
Land use statistics based on the BN2004, BN2009 and BN2013 maps.

Code	Land use	2004		2009		2013	
		Area (ha)	% of total	Area (ha)	% of total	Area (ha)	% of total
10	Other grassland	1,233,176	29.7	1,201,729	28.9	1,163,210	28.0
11	Nature grassland	126,973	3.1	140,632	3.4	132,397	3.2
20	Arable land	939,617	22.6	924,863	22.3	944,340	22.7
30	Heath land	47,915	1.2	49,128	1.2	50,102	1.2
40	Forest	392,248	8.9	395,572	9.0	397,320	9.6
70	Water	780,139	18.8	785,994	18.9	794,706	19.1
80	Reed swamp	27,126	0.7	25,947	0.6	26,256	0.6
90	Drifting sands	2,971	0.1	3,766	0.1	3,786	0.1
91	Dunes, beaches and sand plates	35,002	0.8	34,747	0.8	33,870	0.8
101	Built-up area	326,353	7.9	349,284	8.4	361,397	8.7
102	Railroads	6,195	0.1	6,561	0.2	6,876	0.2
103	Roads	233,784	5.6	233,279	5.6	237,240	5.7
	Total	4,151,500		4,151,500		4,151,500	

A1.1 Land use maps

The land use maps BN1990, BN2004, BN2009 and BN2013 are presented on the next pages. More information on these maps is provided in Chapter 3 and can also be found in Kramer and Clement (2015); Kramer *et al*. (2007); Kramer *et al*. (2009); Kramer and Van Dorland (2009).

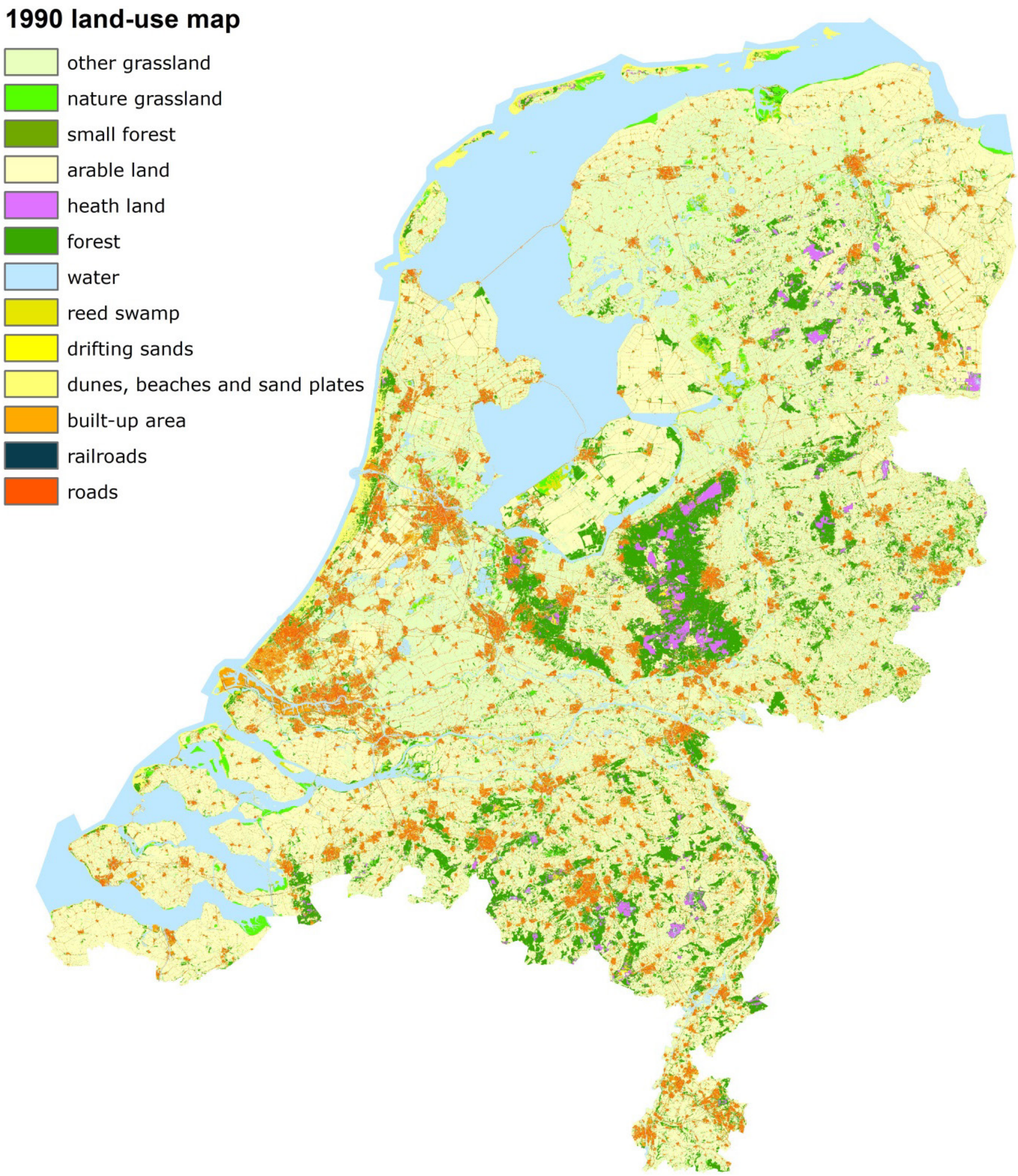

Figure A1.1 *Land use map of 1 January 1990*

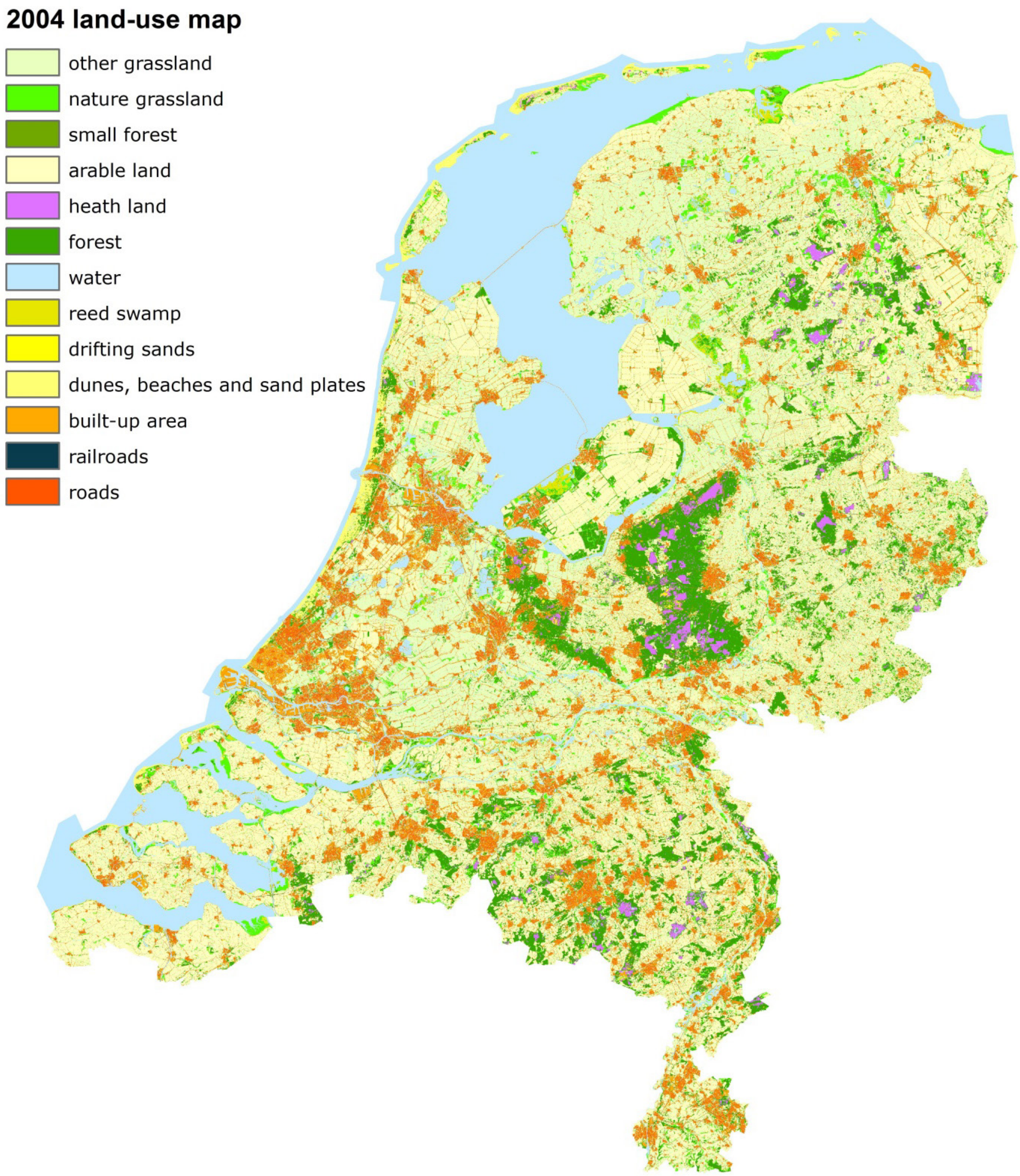

Figure A1.2 *Land use map of 1 January 2004*

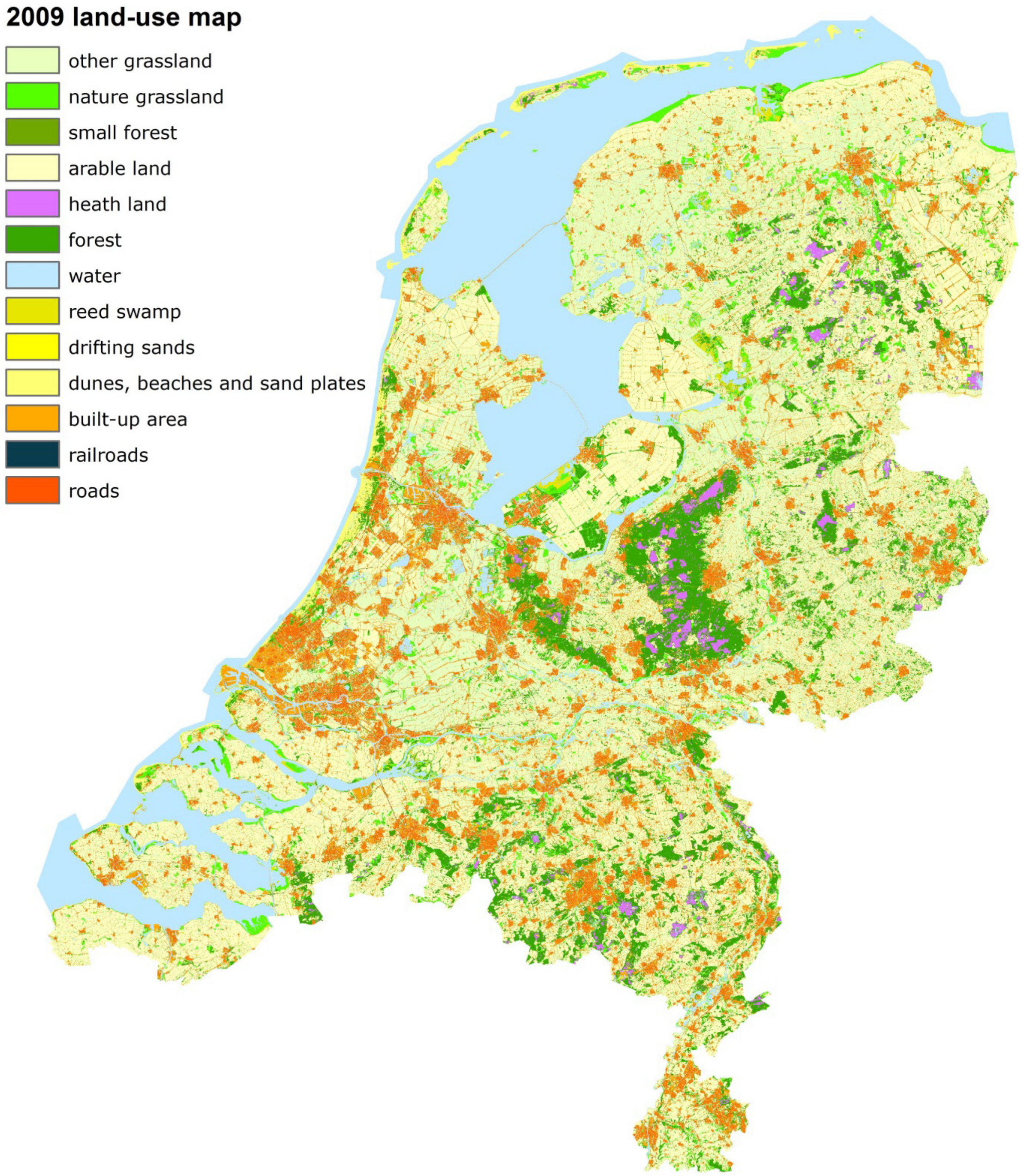

Figure A1.3 *Land use map of 1 January 2009.*

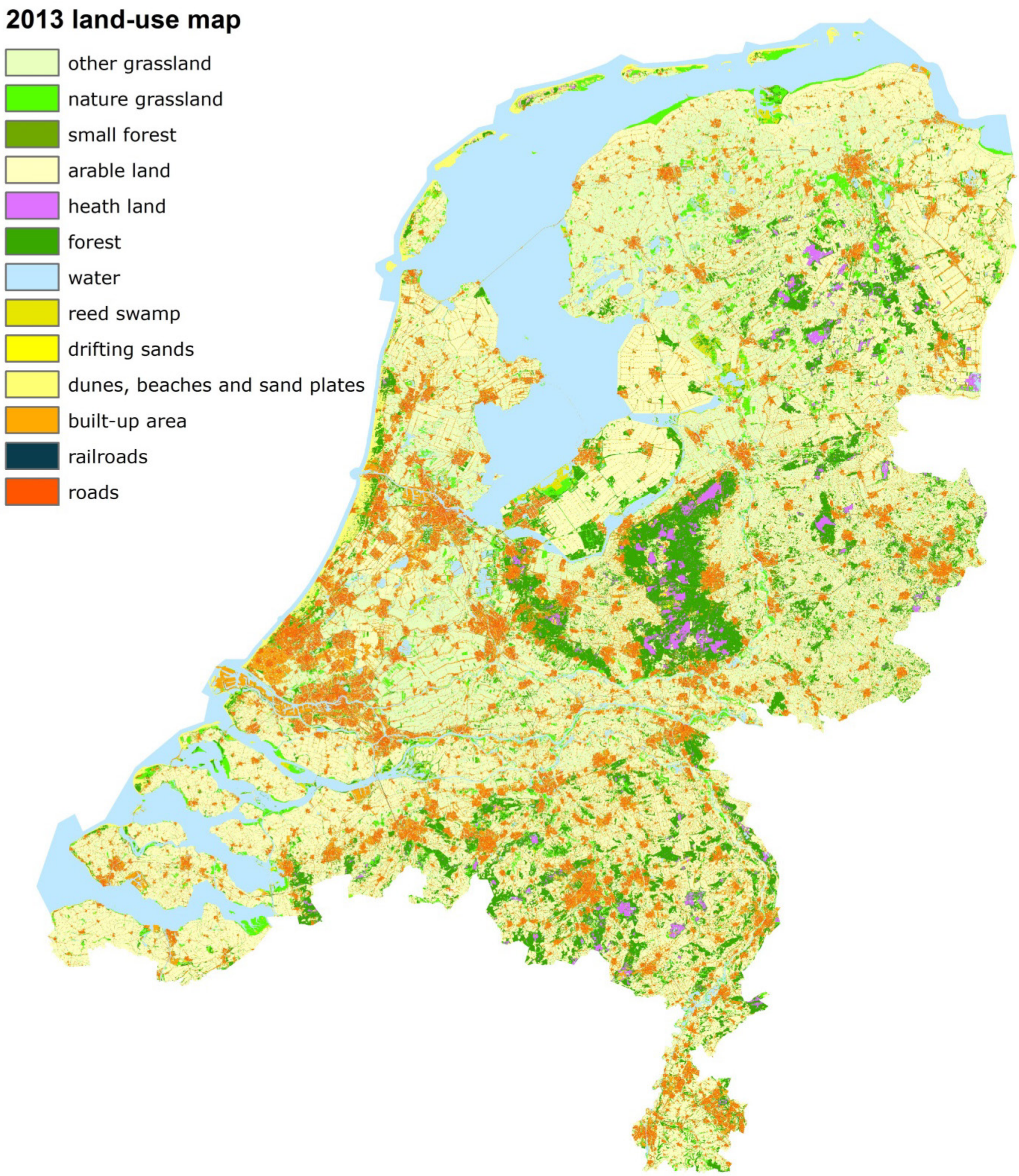

Figure A1.4 *Land use map of 1 January 2013.*

Annex 2 Allometric equations

Biomass expansion equations used for the calculations of stem volume (Table A.2.1; Dik, 1984), aboveground biomass (Table A.2.2; Nabuurs *et al.*, 2005) and belowground biomass (Table A.2.3; Nabuurs *et al.*, 2005).

Table A.2.1.
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.2.2.

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.2.3.

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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