Protocol 9072
5A: CO_2 Forest land

IPCC Category:	5A Forest Land
NFR Code:	n.a.
NOSE Code:	n.a.
NACE Code: 2008	n.a.
HGN basis:	Forest and trees outside forest
GPG Code:	Forest Land

Foreword

Under the Kyoto Protocol, the Netherlands is required to set up and maintain a national system to monitor its greenhouse gas emissions. One of the elements of this system is a transparent and verifiable description of the methods and processes used in this monitoring system. These methods must meet international guideline criteria, which have been defined by the United Nations (UN) and the European Union (EU).

The Netherlands meets the aforementioned requirement, for example, by defining a series of Monitoring Protocols, which describe the methods and work processes used to determine greenhouse gas emissions and the amounts of carbon sinks available. Protocols have been written for about 40 greenhouse gas sources or sinks. This document describes the protocol for one of these sources or sinks.

The protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was coordinated by PBL (Planbureau for the Leefomgeving, or the Netherlands Environmental Assessment Agency), but on 1 January 2010 this coordination task was taken over by RIVM (the Netherlands institute for public health and the environment). Other institutions that have contributed to the protocols include NL Agency; Ministry of Agriculture, Nature and Food Quality; and the Ministry of VROM (Housing, Spatial Planning and the Environment).

1 Scope and significance of emission sources/activities

1.1 Scope and definition

The IPCC source/sink category 5 ‘Land Use, Land-Use Change and Forestry’ (LULUCF) consists of six land-use categories:
5A Forest Land
5B Cropland
5C Grassland
5D Wetlands
5E Settlements
5F Other Land

This protocol takes the definition from the Good Practice Guidance for Land Use, Land-use Change and Forestry 2003, (IPCC 2003) – further referred to as GPG 2003 – and concerns the emissions and stocks of soil carbon in

5A: Forest Land

5A1 Forest Land remaining Forest Land (FF)

This concerns changes in the carbon stocks in the area that has been used as forest land for the past 20 years or more[1].

5A2 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 resulted from other land-use categories.

5.B.2 - 5.F.2: Forest Land converted to another land-use category

This concerns changes in the carbon stocks for areas that were used as forest land and are converted to any other land use.

Emissions should be depicted in Gg and should be subdivided according to:

- CO_2 (net)
- CH_4
- N_2O
- NO_x
- CO

No estimates (NE) are given for gases other than CO_2 because these emissions can be considered negligible (see Section 2.2). Emissions from the other land-use categories under IPCC category 5 are described in a separate protocol (5B-5G), CO_2 from total land-use categories.

The Netherlands follows the (new) guidelines under the *Good Practice Guidance on Land Use, Land-Use Change and Forestry* (IPCC, 2003) for reporting under the UNFCCC. Category 5A1 refers to ‘Forest land remaining forest land’, and 5A2 refers to ‘Land that is converted to forest land’. Eventual deforestation is shown by the increase in all other forms of land use, for example, ‘Forest that has been converted into cropland’. These can be found in the categories 5B2.1, 5C2.1, 5D2.1, 5E2.1 and 5F2.1

The definition of land use for forests is essential because this determines the spatial area within which carbon flux occurs. The method of determining the various types of land use is specified in Protocol 9083, CO_2 from total land-use categories (see also Section 2.1).

5A1 Forest land remaining Forest land (FF)

'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 from such pools.' (IPCC, 2003: GPG for LULUCF page 3.23)

5A2 Land converted to Forest land (LF)

'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 5A2.1 through 5A2.5 of the *IPCC Good Practice Guidance*. The conversion involves a change in land use.' (IPCC, 2003: GPG for LULUCF page 3.51)

[1] Due to lack of historical material prior to 1990, reporting for 5A2 starts with the year 1990 and all forest in the year 1990 is allocated to 5A1

Land that is converted to forest land should, in theory, remain in this category for 20 years. After this it falls 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 2.1).

5.B.2 - 5.F.2: Forest Land converted to another land-use category

The 2009 submission on land converted from Forest Land reports (for the first time) at a highly disaggregated level from each subcategory of Forest Land to each other category of land use. In the previous submissions, the total emissions associated with Forest Land converted to other land-use categories was reported (in its entirety) under Grassland.

Expanding forest lands retain carbon. This retention (carbon flux) can change as a result of changes in three components (carbon pools), i.e. (IPCC, 2003, page 3.15):

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 following variables from Forest Land and for land-use change to other categories. In the 2009 submission, emissions from litter are estimated and reported for the first time.

From→ To↓	Forest Land	Other land-use category
Forest Land	Biomass (increase, decrease) + DOM (Dead wood, Litter)	Biomass increase
Cropland	Biomass decrease + DOM (Dead wood, Litter)	
Grassland	Biomass decrease + DOM (Dead wood, Litter)	
Wetland	Biomass decrease + DOM (Dead wood, Litter)	
Settlement	Biomass decrease + DOM (Dead wood, Litter)	
Other land	Biomass decrease + DOM (Dead wood, Litter)	

Greenhouse gas emissions occur from these pools of emissions. Theoretically, there is also a fourth carbon pool: that of wood products. However, this is not reported, as it is assumed that the wood-cutting leads to a direct emission, and thus to the reduction of carbon stocks in the living biomass.

Only CO_2 is reported. Emissions of NO_x, CH_4 and CO related to Forest Land are not estimated in CRF Tables 5(I-V) because these emissions are negligible (see also Protocol 9083, CO_2 from total land-use categories).

1.2 Significance and influences

1.2.1 Contribution to total national emissions

For the Netherlands, CO_2 under category 5A is a carbon sink of 2-3 megatons per year.

1.2.2 Developments that infuence emissions

There are no relevant developments known

2 Method, emission factors and activity data

2.1 Calculation method

2.1.1 Forest Land and subcategories

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, subdivided into managed and unmanaged units, and also by ecosystem type, as specified in the IPCC Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category (IPCC, 2003, 2006).

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

- 'Forest' or 'Forest according to the Kyoto definition' (FAD)[2], i.e. all forest land that complies with the following (stricter than the IPCC) definition chosen by the Netherlands for the Kyoto protocol:
    - forests are patches of land exceeding 0.5 ha with a minimum width of 30 m;
    - with tree crown cover 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 plantations established for forestry purposes (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 also includes:
    - Forest nurseries and seed orchards that 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 covering an area of over 0.5 ha and a width of over 30 metres.

  This excludes tree stands in agricultural production systems, for example in fruit plantations and agro-forestry systems.'
- 'Trees outside Forests' (TOF), i.e. wooded areas that comply with the previous forest definition except for their surface (=< 0.5 ha or less than 30 m width). These represent fragmented forest plots as well as groups of trees in parks and nature areas and most woody vegetation lining roads, fields etc… These areas comply with the GPG-LULUCF definition of Forest Land (i.e. they have woody vegetation) but not with the strict forest definition set by the Netherlands.

2 This definition deviates from that of the FAO specification of tree crown cover (FAO 10%)

2.1.2 Calculation method Forest Land remaining Forest Land (5A1)

Step 1: allocation of areas

Land use is determined using the digital and digitised topographical TOP10 map and Top 25 maps (see Protocol 9083, CO_2 from total land-use categories) for the year 1990 and 2004, which allows the land-use matrix to be completed as per recommendations in GPG 2003. Areas are thus obtained for the six main categories of land use, as well as for the *gross* land-use changes in (and between) these categories.

In the future, updates of the digital land-use map will become available regularly (2-4 years) and these will suit the future LULUCF process in their aim to present accurate information on land-use changes. At the moment changes after 2004 are obtained by linear extrapolation. Appendix 1 provides an overview of the TOP10 Vector classes and GPG categories.

The differences between the two aforementioned years also show the change in the forest area between 1990 and 2004, and the differentiation between the total areas for 5A1, 5A2 and for 5B2.1, 5C2.1, 5D2.1, 5E2.1 and 5F2.1

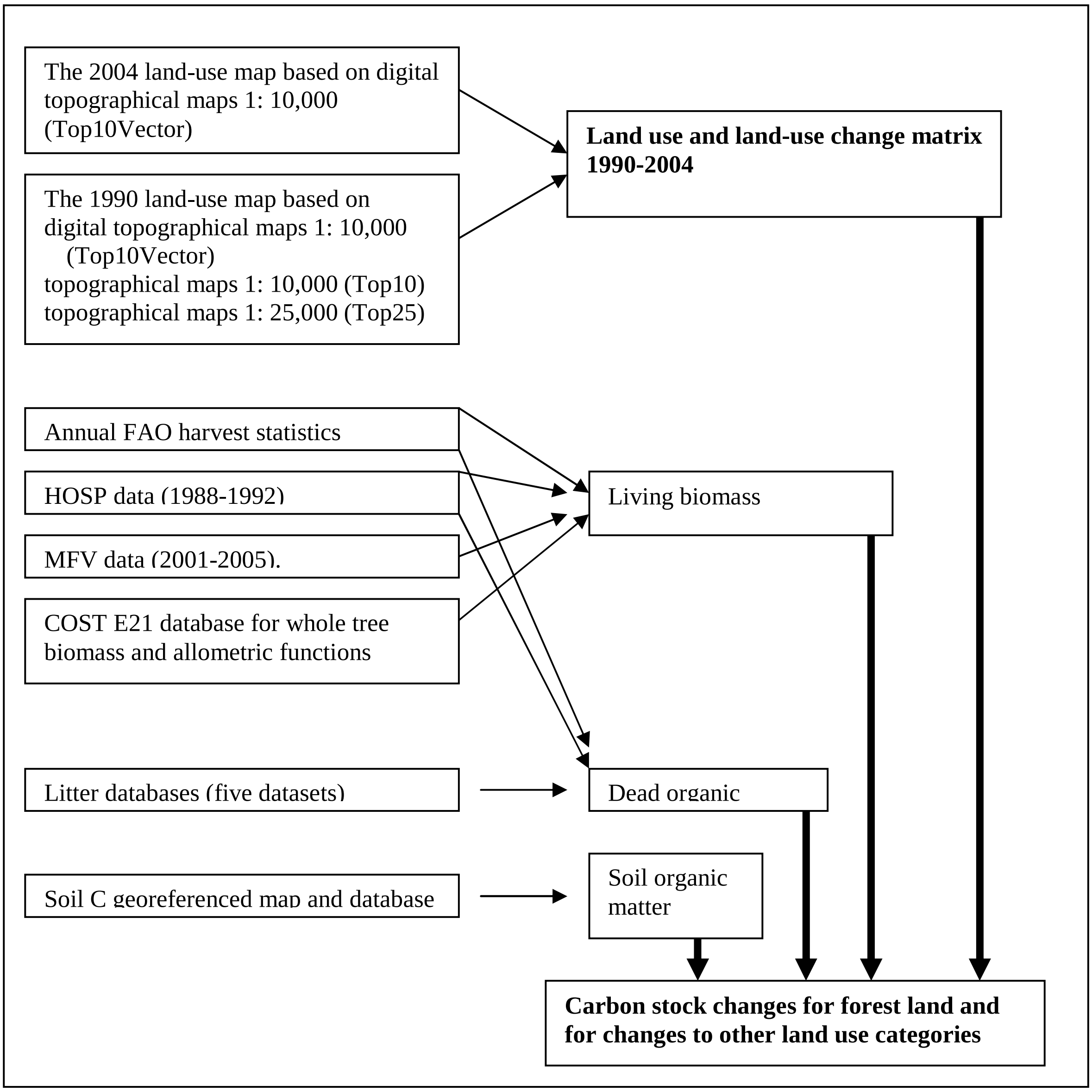
Step 2: annual changes in carbon flux

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

A tier 2 method[3] is used for the carbon pools at inventory plot level, conform GPG LULUCF (page 3.24 and thereafter). A detailed description of the method is included in Nabuurs *et al.* (2005) with updates in Wyngaert *et al.* (2007, 2008, 2009). Figure 1 shows the various sources for the allocation of Forest Land and the calculations of carbon flux.

[3] GPG for LULUCF, page 3.25: In general:
Tier 1: Tier 1 applies to countries in which either the subcategory (forest land remaining forest land or biomass carbon pool) is not a key category, or where little or no country-specific activity data and emission/removal factors exist
or can be obtained.
Tier 2: Tier 2 applies where forest land remaining forest land or biomass carbon is a key category. Tier 2 should be used in countries where country-specific estimates of activity data and emission/removal factors are available or can be gathered at expenses that weigh favourably against expenses required for other land-use categories.

Figure 1: Sources for the allocation of Forest Land and the calculations of carbon flux



1. Living biomass

With respect to biomass, the Netherlands uses the IPCC method 1 to calculate the C changes in biomass. These calculations are implemented per inventory plot.

Two types of National Inventories were available for the Netherlands: the so-called Hosp data (1988-1992) and the MFV data (2001-2005). The HOSP (Hout Oogst Statistiek en Prognose oogstbaar hout) inventory was designed to gain insight into the amount of harvestable wood. Both forest inventories yielded the initial data needed to allow a plot level calculation of the increase in volume of living and dead wood.

The amount of wood harvested was available only at the national level and was downscaled to plot level according to the probability of harvesting as calculated from plot age and growing stock volume. The volumes harvested per year are taken from the FAO harvest statistics. The wood production is given as production roundwood in m^3 underbark. The total annual volume removed from the forest includes bark as well as losses during harvesting and is calculated from roundwood underbark as follows:

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

With

H_{NL}	Annually extracted total volume overbark from forests in NL (m^3 $year^{-1}$)
H_{NLub}	Annually extracted volume roundwood underbark from forests in NL (m^3 $year^{-1}$)
$f_{\frac{ob}{ub}}$	Conversion from underbark to overbark (1,136 m^3o.b. / m^3u.b.)
$f_{\frac{tw}{rw}}$	Conversion from roundwood to total wood (1,06 m^3 wood / m^3 roundwood $year^{-1}$)

The total biomass and the resulting net C-flux to living biomass are calculated from the tree biomass at certain time periods (t and t+1), the tree density and the carbon fraction in the biomass. This is shown in the following formula.

$$\Delta C_{FF_G} = \sum_{1}^{n} (A_i \bullet G_{TOTALi}) \bullet CF$$

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

where:

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

and

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

This figure is substantiated in the following seven steps:

1. Determining the age of each plot
   The age of the plot is calculated based on the year of regeneration and the year in which the observation is made :

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

With

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

2. Determining dominant height
   Based on the dominant height and the age of the plot, the asymptote of the dominant height can be calculated indefinitely using the following formula:

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

where:

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

3. Determining the dominant height for the following year
   The aforementioned relationship can then be used to calculate the expected dominant height for the following year:

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

4. Determining the standing stock
   The expected volume of the 'standing stock' for the following year is calculated using the current volume and the annual growth rate, as indicated in the formula:

$$V_{plot}(t+1) = V_{plot}(t) + Ic_{V\,plot}(t)$$

where:

$V_{plot}(t)$	Volume of 'standing stock' at age t ($m^3\ ha^{-1}$)	[HOSP/MFV]
$Ic_{Vplot}(t)$	Annual volume expansion at age t ($m^3\ ha^{-1}\ year^{-1}$)	[HOSP/MFV]

5. Determining average tree volume
   The average tree volume is calculated from the volume of 'standing stock' and the tree density, using the following formula:

$$\overline{V}_{it+1} = \frac{V_{it+1}}{nt_{it+1}}$$

where:

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

6. Determining the average diameter
   The dominant height is used as the height for all trees in the plot. The (small) systematic underestimate of D that results from this is considered negligible compared to the errors that are made by using the average plot values in non-linear formulas.

   The average heights and volumes resulting from this approach allow the average diameter to be calculated for time t and t+1, using the following calculation:

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

where:

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

7. Determining the biomass of an average tree per plot
   The conversion from plot characteristics to whole tree carbon was based on allometric relations from the COST E21 database converting plot diameter and height to above-ground and below-ground biomass. The above-ground and **below-ground biomass** of the average tree per plot are calculated using selected allometric formulas from the literature, based on diameter and (optional) height. See Nabuurs *et al.* (2005) for a more detailed description of the database and a list of studies included, as well as Wyngaert *et al*. (2009).

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

where:

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

2. Dead organic matter

<u>Dead wood</u>

The stock of dead wood is determined from the HOSP and MFV data.

The net C flux to dead organic material results from the amount of dead material and the decomposition of dead wood. The mortality rate is determined as a fixed fraction (0.4%) of the amount of standing volume. The decomposition of dead wood is determined by the total time required for the decomposition of standing/lying tree trunks. The density of the dead wood varies considerably according to the extent of the decomposition, and the average is set at half the density of living wood for the respective tree type. This is shown in the following formula:

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

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

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

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

<u>Litter</u>

The carbon stock change from changes in the litter layer was estimated using a stock change method at national level. Data for litter layer thickness and carbon in litter were available from five different datasets (data from Schulp and coworkers; De Vries and Leeters, 2001; Van den Burg, 1999; Forest Classification database; MFV litter inventory). These datasets are used in combination: a stepwise approach was used to estimate the national litter carbon stock (and change therein) in a consistent way. 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. To determine the national data, 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. Though litter stocks could be determined with a sufficient reliability, the uncertainty in litter C stock changes in 'Forest land remaining Forest land' was very high. However, in all simulations, the change in litter C stock was a sink, not a source. It was decided to report conservatively, at zero. (Wyngaert *et al*. 2009).

3. Soil organic matter

A rough estimate has been made of the C stock in the mineral soil organic matter. This is around 100 ton C per hectare of forest (Kuikman *et al*., 2002, pp. 20-21). It is assumed that the stock does not change over time.

Results from several studies that report evaluation of changes in organic matter in mineral soils in the Netherlands (see Protocol 9083) were used to conclude that, in general, the mineral soil is not a source of carbon dioxide. In line with the decision for mineral soils we report 'not estimated' (NE) rather than reporting a quantification of the C-stock change for C stock changes in soil organic matter.

2.1.2.1. 5A1 Forest land remaining Forest Land, Forest according to the Kyoto definition (FAD)

All calculations and variables (as presented below) are used for Forest according to the Kyoto definition.

2.1.2.2. 5A1 Forest land remaining Forest Land, Trees outside forest (TOF)

For Trees outside Forest:

- the same biomass increase is assumed as for Forest according to the Kyoto definition;
- no dead wood is assumed.
- no litter layer build up is assumed.
- no harvesting is assumed to take place. Even if this assumption were not completely true, the error would be negligible, as the harvested wood would be counted in the FAO harvest statistics and therefore would be counted under Forests according to the Kyoto definition.

2.1.3 Calculation method for Land converted to Forest Land (5A2)

Step 1: allocation of areas

Land use is determined using the digital and digitised topographical TOP10 map and Top 25 maps (see Protocol 9083, CO_2 from total land-use categories) for the years 1990 and 2004. 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, the area of Land converted to Forest Land starts in 1990 with a small area.

Step 2: annual changes in carbon flux

The build up of carbon in land converted to Forest Land is only reported for biomass. The current estimates of the emissions factor for each year are the outcome of the following steps/assumptions:

1. At time of regeneration, growth is close to zero.
2. Between regeneration and 20 years of age, the specific growth curve is unknown and is approximated by the simplest function, I.e. a linear curve.
3. The exact height of this linear curve is best approximated by a linear regression on the mean growth rates per age as derived from the NFI. One 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 separately for each annual set of afforested plots. 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 20 years.
5. Between 1990 and 2000, rates are based on the HOSP inventory. From 2000 onwards, rates are based on the MFV inventory.

It is assumed that the build up of dead wood starts only after the initial 20 years and is accounted for in Forest Land remaining Forest Land – Forests according to the Kyoto definition. For litter, good data are lacking to relate the build up of carbon to age.

2.1.4 Calculation method 5B2-52F Forest Land converted to other Land-use categories

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

2.2 Emission factors

The emission factors for biomass are described for conversion from forest growth to C-fluxes (see Section 2.1).

Emissions of N_2O and CH_4 as a result of fertilisation or drainage in forests (to be reported in CRF Table 5(I) and 5(II)) are assumed to be 'not occurring' (NO) as these practices do not occur in Dutch forest ecosystems.

CH_4 emissions resulting from forest fires or burning trees are considered negligible because these fires seldom occur. No emissions are estimated for reporting in CRF Table 5(V).

2.3 Activity data

The forest inventory is extremely important in monitoring forest land (see points 1 and 2 above).

The following statistical sources are used (with underlying individual data):

1. HOSP 1988-1999; ceased in 1999: minimum parameters: plot location, tree types, number of trees, diameter, tree height. Organisations responsible: Bosdata, together with EC LNV and Alterra;
2. National Forest Inventory 2000 (MFV); figures for 2000-2004; next period possibly 2009-2012: minimum parameters: plot location, tree type, number of trees, diameter, tree height, dead wood, thickness of litter layer. Responsible: EC LNV and Alterra. It is extremely important to continue this regularly. This may be combined with ICP Forest under a single monitoring system known as ‘Forest Focus’. Alterra is responsible for the data processing;
3. The database for tree biomass and allometric functions. This database is based on literature because there are no figures available for the Netherlands;
4. Mineral C soil: based on country-wide random soil checks (Kuikman *et al*., 2002). This is a one-off study;
5. The litter database covers the years 1950-1991 (Van den Burg, 1999). Work is continuing on an ad hoc basis (De Waal and Hommel) and through studies into forest reserves. MFV supplied more recent data. Organisation responsible for data processing: Alterra;
6. Statistical woodcutting is continuing on an ad hoc basis. Organisation responsible: Probos, commissioned by LNV.
7. Wood density numbers are taken from the literature, as there is little information available from the Netherlands. Documentation is included in (Nabuurs, 2005);

8. Land-use maps are now produced digitally by the Topographical Service. This provides a solid basis. However, additional work is still needed and this occurs within the project for basic mapping of nature. Organisation responsible for is PBL.

3 Working processes

The initial gathering, updating and maintaining of these data are entrusted to the research programme ‘Wettelijke Onderzoekstaken Natuur & Milieu (legislative and research tasks, nature and the environment, www.kennisonline.wur.nl), which is funded by the Ministry of LNV (Agriculture, Nature and Food Quality). The Netherlands Environmental Assessment Agency (PBL) is responsible for implementing these duties, and supplies information according to the agreements with the ER (Emissions Registration, at PBL) via the task force for Agriculture and Land Use. PBL provides the texts that substantiate the National Inventory Report.

The information is supplied annually by Alterra (together with ER) according to a strict set of deadlines, and submitted to the Task force for Agriculture and land use at the ER, or to one of its designated implementers (in 2009, MEP-TNO and Alterra carried out the processing together).

4 Uncertainty and quality

4.1 Estimating uncertainties

A Tier-1 uncertainty analysis is implemented every year before the NIR is submitted by the ER, based on the greenhouse gas inventory and in compliance with IPCC guidelines. The assumptions used, and the results thereof, are described in a background report to the NIR. In addition to this, where included in the QA/QC programme for the relevant period, extra analyses are implemented regularly in specific situations, which include any updating of the Tier-2 uncertainty analyses.

The Tier-2 uncertainty assessment was last updated in 2006. This assessment showed that a Tier-1 uncertainty assessment is sufficiently reliable and that Tier-2 uncertainty assessments need only be implemented at periodic intervals of around 5 years, unless a major change in an important source is sufficient to require earlier reassessment.

- Source-specific uncertainty

The uncertainty estimate $_{total}$ concerns the root of the sum of uncertainty in the data sources used (AD_{onz}) in the square and the uncertainty of the emission factor (EF_{onz}) in the square. The extent of the total uncertainty is here primarily determined by the greatest AD or EF uncertainty.

$$\text{Uncertainty estimate}_{total} = \sqrt{EF_{onz.}^{\ 2} + AD_{onz.}^{\ 2}}$$

The uncertainty estimates concerning the data sources (AD) and emission factors (EF) used, and the total uncertainty estimate, are listed in the following table.

IPCC	Category	Gas	AD $_{onz.}$	EF $_{onz.}$	Uncertainty estimates $_{tot}$
5A1	5A1. Forest Land remaining Forest Land	CO_2	25	61.8	67
5A2	5A2. Land converted to Forest Land	CO_2	25	57.9	63

The activity data used represent area changes, calculated by comparing two topographic maps. The type of land use was determined by using digitised topographical maps (scale 1:10,000), allowing the land-use matrix to be completed conform the recommendations in the

Good Practice guidance on Land Use, Land Use Change and Forestry (IPCC, 2003). Thus, areas were obtained for the six main categories of land use, as well as for the total land-use changes in (and between) these categories. The uncertainty for one topographic map was estimated at 5% (expert judgement). Therefore, the uncertainty in comparing two topographic maps (1990 and 2000), theoretically, was 5×5=25%. This was without doubt an overestimation, as not all land use would have changed over this decade [Olivier et al, 2009].

The uncertainty in the CO_2 emissions from 5A1 Forest Land remaining Forest Land was calculated at 67%. For 5A2 Land converted to Forest Land this was 63% [Olivier et al, 2009].

Uncertainty in the implied emission factor of 5A1 Forest Land remaining Forest Land
CO_2 capture and CO_2 emissions as a result of changes in forestry and woody biomass stocks were estimated based on country-specific Tier 2 approaches. The approach chosen followed the IPCC 1996 Revised Guidelines and its updates in the Good Practice guidance on Land Use, Land Use Change and Forestry (IPCC, 2003). The basic assumption was that the net flux could be derived from converting the change in growing stock volumes in the forest into carbon [Olivier et al, 2009].

The Dutch method was based on the carbon cycle of managed forests. Distinguished are: above-ground biomass, below-ground biomass, litter, dead wood, and soil organic carbon. Carbon stock changes were calculated for above-ground biomass, below-ground biomass, and dead wood. For litter and soil organic carbon, and for biomass in other natural terrains, the stock was assumed to remain unchanged, during the period of 1990 to 2000. Calculations for the living biomass carbon balance were carried out at plot level.
In the Tier 1 uncertainty calculation sheet, the uncertainty in the implied CO_2 emission factor was derived from the calculated total uncertainty for this category (67%), and in activity data (25%).The uncertainty in implied emission factors of 5A1 Forest Land remaining Forest Land concerned forest, and trees outside the forest. As the approach and data sets used were the same for both sources, the uncertainty calculation was performed for forests. The results were considered to be representative of trees outside forests, as well [Olivier et al, 2009].

The uncertainty in the implied emission factor of living biomass increment was calculated at 13% (rounded at 15% in the calculation LULUCF spreadsheet). The uncertainty in the implied emission factor of decreased living biomass was calculated at 30%. The uncertainty in the net carbon flux from dead wood was calculated at 30% (rounded at 50% in the LULUCF calculation spreadsheet) [Olivier et al, 2009].

Uncertainty in implied emission factor of 5A2 ‘Land converted to Forest Land’
In the Tier 1 uncertainty calculation sheet, the uncertainty in the implied CO_2 emission factor was derived from the calculated total uncertainty for this category (5A2) (63%) and the uncertainty in activity data (25%). For the increment in living biomass, the same data and calculations were used as for 5A1 Forest Land remaining Forest Land and, thus, the same uncertainties were used in the Tier 1 calculation spreadsheet (15%). The uncertainty for the other parameter in the calculation, change in carbon content in mineral soil, was estimated at 50%, see the discussion below [Olivier et al, 2009].

4.2 Quality assurance and quality control (QA/QC)

The ER work package leader responsible checks that:

1. the basic data are well documented and adopted (check for typing errors, use of the correct unit sizes and correct conversion);

2. the calculations have been implemented correctly;
3. assumptions are consistent, also whether specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

Any actions that result from these checks are noted on an ‘action list’. Before defining the data, supervisors check whether the relevant actions on this list, plus the QC checks, have all been completed. Defining the data is carried out by the WEM (working group on emissions monitoring), and confirmed in writing via an e-mail from the institute representatives to the ER project leader at PBL.

The work package leaderresponsible fills out a new documentation sheet when adding new data. For reasons of efficiency a minimum level has been set for obligatory documentation, i.e. 5% changes at target group level, and 0.5% at levels concerning the national total. These documentation sheets form part of the trend analysis, as well as the eventual definition of the data set.

The ER work package leaders communicate by e-mail regarding these QC checks, results and actions. They send a printed copy to the ER secretary, who keeps a logbook and compiles these e-mails into an ‘action list’. This shows explicitly that the required checks and corrections have been carried out.

4.3 Verification

In order to check the quality of the emission figures for the sources in this protocol, general QA/QC procedures have been followed that are in line with the IPCC guidelines. These are described further in the QAQC programme used by the National System, and the annual working plans published by the ER.

- Sector-specific QC

No additional specific verification procedures are implemented for the sources defined in this protocol.

4.4 Possibilities for improvement compared to the current calculation method

4.4.1 History

Up until 2002 only the CO_2 emissions for category 5A ‘Changes in forest biomass stocks’ were reported. The last changes reported were for the year 2000, and the years after this were assumed to be constant. When generating these reports the Netherlands used a simple method where the average growth was converted into carbon on the basis of IPCC defaults (Daamen 1, 2, 3). When calculating the CO_2 amounts for 1990-2000 for Table 5A (Daamen (3), 2001) the definition of forest land is the same as that used in the current, new method.

From the NIR 2005 onwards, a complete re-evaluation was carried out for the years 1990-2003. This new method is based on detailed forest inventory data, together with new biomass expansion factors and detailed land-use changes (Nabuurs *et al*., 2005).

In the NIR 2009 the improved allocation of land use is reported, and emissions from litter are estimated. This resulted in recalculation of the entire time series from 1990 onwards. This is documented in Wyngaert *et al*. (2009) and Kramer (2009).

4.4.2 Future

Possible improvements for the future include:

- Soil C changes under remaining forests (including data);
- Soil organic matter, litter and dead wood should be dynamic (including data);
- Biomass change after 2005 of existing forest, based on a newly started MFV (National Forest Inventory) cycle.

5 Remaining aspects

5.1 Point source criteria

Not applicable

5.2 Substance profiles

Not applicable

5.3 Regionalisation

Most calculations are carried out at inventory plot level. In theory, very detailed flux maps can be produced. In addition, the land-use changes are also specified geographically.

5.4 Time-based variations in source strength

Forest growth varies per tree type, per week, month and year. However, it is assumed that the MFV monitoring ranges sufficiently cover the variations in time and area. This is why the sampling design was set out with over 3000 plots. The time variation in soil C is much less, so that a far less-intensive sampling is required.

6 References and additional information

6.1 References

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6.2 Additional information

Not applicable

Appendix 1

Netherlands TOP10 Vector classes and corresponding GPG (sub)categories

TOP10Vector	Dutch TOP10Vector name	GPG classes	
Deciduous forest	Loofbos	5A	Forest Land
Coniferous forest	Naaldbos	5A	Forest Land
Mixed forest	Gemengd bos	5A	Forest Land
Poplar plantation	Populierenopstand	5A	Forest Land
Willow coppice	Griend	5A	Forest Land
Arable land	Bouwland	5B	Cropland
Tree nursery	Boomkwekerij	5B	Cropland
Pasture & meadow	Weiland	5C	Grassland
Orchard (high standards)	Boomgaard	5C	Grassland
Orchard (low standards & shrubs)	Fruitkwekerij	5C	Grassland
Heathland & peat moors	Heide & hoogveen	5C	Grassland
Houses / blocks of houses / buildings	Huizen/ huizenrijen/ gebouwen	5D	Settlement
Greenhouses	(Tuinbouw)kassen	5D	Settlement
Fuel station	Tankstation	5D	Settlement
Main roads	Hoofdwegen	5D	Settlement
Local roads	Lokale wegen	5D	Settlement
Unpaved roads	Onverharde wegen	5D	Settlement
Train tracks	Spoorlijnen	5D	Settlement
Pedestrian area	Voetgangersgebied	5D	Settlement
Bicycle roads	Fietspaden	5D	Settlement
Spur / groyne	Steenglooiing / krib	5D	Settlement
Landing stage	Aanlegsteiger	5D	Settlement
Graveyard	Begraafplaats	5D	Settlement
Other	Overig bodemgebruik	5D	Settlement
Reed marsh	Rietmoeras	5E	Wetland
Water (large open water bodies)	Water (grote oppervlakte)	5E	Wetland
Water (small open water bodies)	Oeverlijn / Water (kleine oppervlakte)	5E	Wetland
Ditch	Sloten	5E	Wetland
Low water line / emerging surfaces	Laagwaterlijn / droogvallende gronden	5E	Wetland
Dockyard	Dok	5E	Wetland
Unvegetated coastal dunes		5F	Other land
Sandy areas and beaches		5F	Other land
Inlands and dunes		5F	Other land