

## Protocol

### 5B-G: CO<sub>2</sub> emissions for total land-use categories

|                |   |
|----------------|---|
| GPG 2003       | Category 5B-G: Land use and land-use change |
| NFR Code:      | n.a.  |
| NOSE Code      | n.a.  |
| NACE code 2008 | n.a.  |

#### 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 GPG 2003 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, (GPG 2003) – further referred to as GPG 2003 – and concerns the emissions and stocks of soil carbon in all the aforementioned six groups for the following two categories:

- 5.A.1 - 5.F.1: Land use remaining as such.
- 5.A.2 - 5.F.2: Land converted to a specific land use.

Within these categories special attention is given to the cultivation of organic soils. The protocols contain 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 and 2004.

This protocol also contains information for estimating data for CRF Tables 5(I)-5(IV), from which the aggregated data are summarised in category 5G.

The following emissions must be reported in Gg:

- CO<sub>2</sub> (net)
- CH<sub>4</sub>
- N<sub>2</sub>O
- NO<sub>x</sub>
- CO

This protocol provides for a method for calculating carbon stock levels in soils for the various types of land use. In principle, the CO<sub>2</sub> 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<sub>2</sub> emissions or sources) or gains (CO<sub>2</sub> sinks) for each land-use category. Concerning the **CO<sub>2</sub> emissions**, the carbon stock levels in soil were recalculated for the 2009 submissions due to the improvement in the allocation of land areas to the specific and relevant land-use (sub)categories.

Determining CO<sub>2</sub> in forest land (category 5A) is specified into living biomass, dead organic matter and soil organic matter, and the methods are described in a separate protocol 5A CO<sub>2</sub> Forest land (protocol 9082).

Emissions of NO<sub>x</sub>, CH<sub>4</sub> and CO are not estimated (NE) because these emissions are negligible in these particular soils. Emissions of N<sub>2</sub>O and CH<sub>4</sub> 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.

N<sub>2</sub>O emissions from disturbance associated with land-use conversion to cropland are not estimated and are reported as NE in Table 5(III)

CO<sub>2</sub> emissions from land use as a result of liming the agricultural land with limestone and dolomite are reported in Table 5(IV) CO<sub>2</sub> emissions from agricultural lime application

CH<sub>4</sub> emissions resulting from forest fires are considered to be negligible because fires seldom occur and are therefore reported in Table 5(V) as NE.

CH<sub>4</sub> emissions from wetlands are not estimated due to the lack of data.

N<sub>2</sub>O (and CH<sub>4</sub>) emissions from land use as a result of the application of manure and fertilisers or due to cultivation of organic soils and wetlands are reported under *Category 4, Agriculture*.

### *1.1.1 Classifying land use*

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, in conformity with the GPG 2003.

CO<sub>2</sub> emissions resulting from soil subsidence of peat areas (cultivation of organic soil) are reported under Grassland as the majority of organic soils are used as grasslands. For information only, an indication of the area of organic soils for each land-use category is available and reported in the NIR.

A separate calculation is made for CO<sub>2</sub> emissions from land use as a result of liming agricultural land with limestone and dolomite.

This protocol follows the GPG 2003 Good Practice Guidance for defining and allocating land into specific categories (GPG 2003, Chapter 2, pages 2.5 – 2.7). The categories are differentiated according to Chapters 3 and 4 of the GPG 2003. The GPG 2003 distinguishes six main groups of land-use categories: Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land. Countries are encouraged to stratify these main groups further e.g. by climate or ecological zones, or special circumstances (e.g. separate forest types in Forest Land) that affect emissions. In the Netherlands, stratification has been used for Forest Land, Grassland and Wetlands.

Without human intervention most land would be covered by forests. Extensive human intervention creates vegetation types that differ more from the natural climax vegetation and other land uses. 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 when allocating land to land-use categories. In addition, lands are allocated to wetlands when they conform to neither of the former land-use categories and do conform to the GPG 2003 definition of wetlands. This includes open water bodies. Until the 2008 submission, open water bodies were included in the Other Land category, as open waters 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.

The main categories are defined as follows.

#### *5A Forest land*

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

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 afforestations). This is explained further as:

- 'Forest' or 'Forest according to the Kyoto definition' (FAD), i.e. all forest land which complies with the following (stricter than GPG 2003) definition chosen by the Netherlands for the Kyoto protocol: forests are patches of land exceeding 0.5 ha with a

minimum width of 30 m, with tree crown cover at least 20% and tree height of at least 5 metres, or, if this is not the case, these thresholds are likely to be achieved at the particular site. Roads in the forest less than 6 metres wide are also considered to be forest. This definition conforms to the FAO reporting and was chosen within the ranges set by the Kyoto protocol.

- 'Trees outside Forests' (TOF), i.e. wooded areas that comply with the previous forest definition except for their surface ( $\leq 0.5$  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 applied by the Netherlands.

*5B Cropland:* all land used as building land or where crops are usually grown.

The landuse category 'Cropland' is defined as all arable and tillage land, including rice-fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category (GPG 2003).

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

#### *5C Grassland*

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

- 'Grasslands', i.e. all areas predominantly covered by grass vegetation (whether natural, recreational or cultivated)
- 'Nature', i.e. all natural areas excluding grassland (natural grasslands and grasslands used for recreation purposes). It mainly consists of heathland, peat moors and other nature areas. Many have the occasional tree as part of the typical vegetation structure. In the previous submissions (2008 and before) this category was a subcategory within Forest Land

Grassland is currently reported as any type of terrain which is predominantly covered by grass vegetation. No distinction is made between agricultural intensively and extensively managed grasslands and natural grasslands. However, the potential and the need for this is currently under discussion. Apart from pure grasslands, all orchards (with standard fruit trees, dwarf varieties or shrubs) are included in the category grasslands. They are not in conformity with the forest definition, and while agro-forestry systems are mentioned in the definition of Croplands, this is motivated by the cultivation of soil under trees. However, in the Netherlands, the main undergrowth in orchards is grass. We therefore chose to report them as

grasslands. With respect to grasslands, no change in above-ground biomass is reported, as the carbon stored in these trees is not reported.

Heathland is reported as Nature, and 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 no longer part of the current agricultural system, conservation management is applied to halt the succession to forest and conserve the high landscape and biodiversity values associated with heathland.

#### *5D Wetlands*

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

Although the Netherlands is a country with many wet areas by nature, many of these are covered by a grassy vegetation and are therefore 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, such as willow coppice, are reported in the subcategories FAD or TOF of Forest Land, depending on their surface.

In the Netherlands, only reed marshes and open water bodies are included in the Wetland land-use category. Reed marshes are areas where the presence of Common Reed (*Phragmites australis*) is indicated separately on maps. These may vary from wet areas in natural grasslands to extensive marshes. The presence of reed is marked with individual symbols that are translated to surfaces (Kramer *et al.*, 2008) and conform to neither of the previous categories.

Open water bodies are all areas that are indicated as water if the surface exceeds 50 m<sup>2</sup>. This includes natural open water in rivers, but also man-made open water in channels, ditches and artificial lakes. It includes bare areas that 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.

#### *5E Settlements*

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

In the Netherlands, Settlements are urban areas and transportation infrastructure, as well as 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 them from caravans, tents etc.) and serves as a place for residence, trade, traffic and/or labour. This therefore includes houses, blocks of houses and apartments, office buildings, shops and warehouses, but also filling stations and greenhouses.

Urban areas and transportation infrastructure include all roads, whether paved or not, are included in the land-use category Settlements, with the exception of forest roads less than 6 metres wide, which are included in Forest (see Forest land definition). It also includes train tracks, (paved) open spaces in urban areas, carparks and graveyards. Though some of the last

class are actually covered by grass, the distinction cannot be made based on maps. As even the grass graveyards are not managed as grasslands, inclusion in the land-use category 'Settlements' conforms better to the rationale of the land-use classification.

#### *5F 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. (GPG 2003)

In general, Other Land does not have a substantial amount of carbon. The Netherlands uses this land-use category to report the surfaces of bare soils that are not included in any other 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).

#### *1.1.2 Allocation of areas to land use*

All land in the Netherlands is allocated to one of the aforementioned categories, thus creating consistency for the entire area over a period of time. Land-use changes can be calculated by comparing the digitally available digitised map files for 1990 and the digital map files for 2004. The basis of allocation for GPG 2003 land-use (sub)categories is the TOP10 land-use/cover classification. For most of the TOP10 classes, there was one GPG 2003 land-use (sub)category where it could be unambiguously included, and some for which additional judgement was needed. Appendix 1 provides an overview of the TOP10 Vector classes and GPG categories.

In the future, updates of the digital land-use map will become available regularly (2-4 years) and these will assist the future LULUCF process in its aim to present accurate information on land-use changes. However, at the moment, changes after 2004 are obtained by linear extrapolation.

#### Allocation of areas to land use 2004

The 2004 dataset on land use was especially developed to support the temporal and spatial development in land use, and was especially designed to support policy in the field of nature conservation. As this dataset is incorporated into a broader project that also uses other sources for validation (Kramer, 2007) a quality improvement compared to the 2000 map was realised. This 2004 dataset is completely based on the **digital** topographic map 1:10,000 (TOP10Vector). All topographical maps were explored during the period 1999-2003.

For most of the TOP10Vector classes, there was one GPG 2003 land-use (sub)category where it might be included unambiguously (Kramer 2009). For other TOP10Vector classes, there were some reasons for including it in one, and other reasons for including it in another GPG 2003 land-use (sub)category. In these cases, areas were allocated to the land-use category where (in sequential order):

- 1) the majority of systems (based on surface) in the TOP10Vector class would fit best based on the degree of human impact on the system;
- 2) or, if this did not give an unambiguous solution, we allocated it where the different types of carbon emission considered/reported best represented the situation in the TOP10Vector class.

#### Allocation of areas to land use 1990

The source material for the 1990 map consists of three sources:

- digital topographical maps 1: 10,000 (Top10Vector);
- topographical maps 1: 10,000 (Top10);
- topographical maps 1: 25,000 (Top25).

All topographical maps were explored during the period 1986-1995. The Top10 and Top25 maps were digitised and were allocated to land uses based on coloured areas. The general procedure of the overall working method at the development of HGN-1990 is presented in Figure 1.

In the foregoing inventory the calculation was based on the maps 1990 (and 2000), while for some areas correction factors had to be used (Van den Wyngaert *et al.*, 2007 and 2008). For the 2009 submission, the new map 2004 was used as a starting point for allocation rules for 2004 as well as for 1990, and changes in land use over the period 1990–2004 were also checked in detail (Kramer *et al.*, 2009). Omissions due to methodological reasons (e.g. legend, classification, and gridding) were manually adjusted in favour of a correct presentation of the changes in land use over the period 1990–2004. This approach meant that correction factors were no longer required.

#### Organic soils

This year the area of organic soil is reported (for the first time) specified for the land-use category Forest Land, Cropland and Grassland. For this, an overlay was made between the land-use maps and a map showing organic soils in the Netherlands (Kuikman *et al.*, 2005).

All net carbon stock change in organic soils and all CO<sub>2</sub> emissions from organic soils are reported in the CRF Table 5C under Grassland.

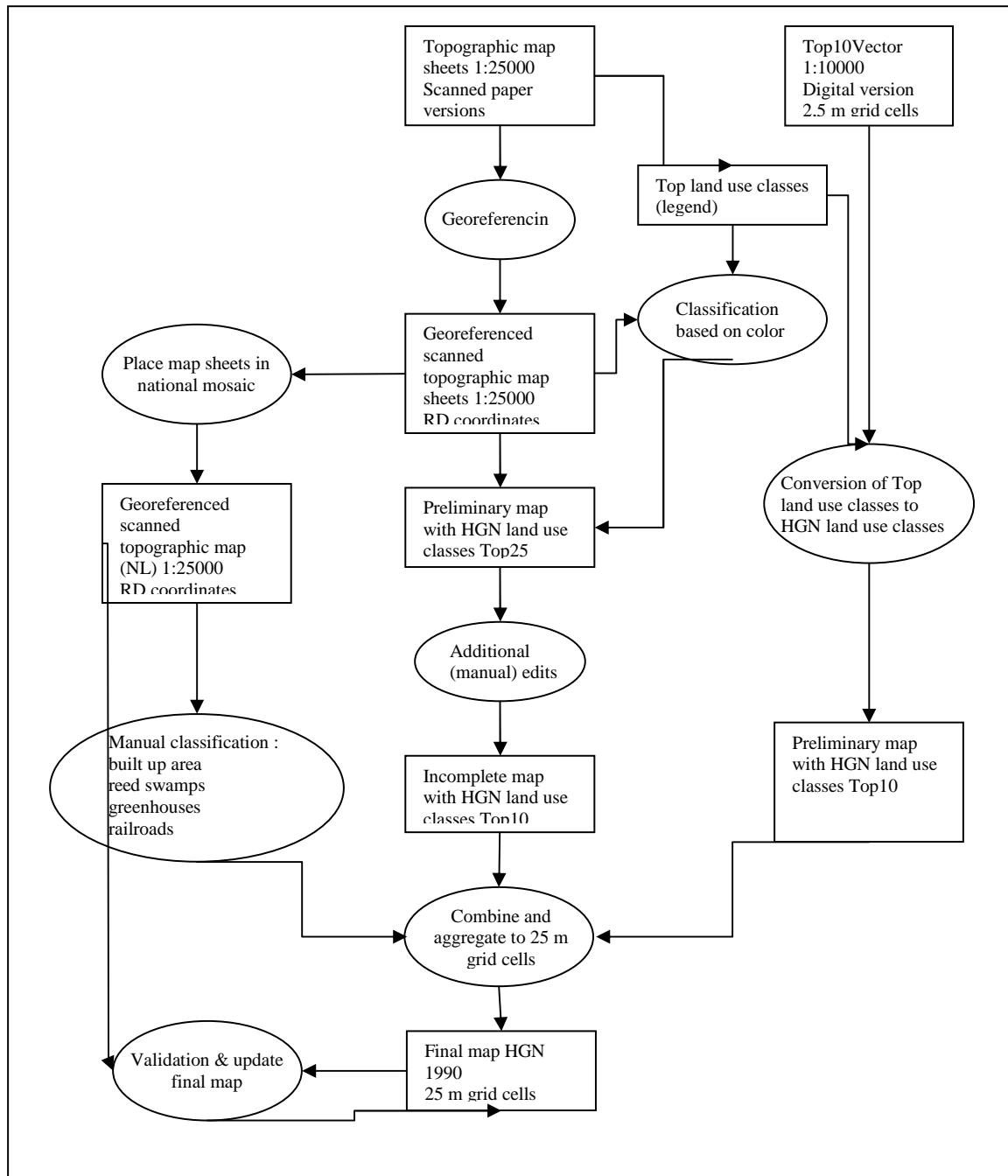
#### ***1.1.3 Soil carbon content in the Netherlands, per soil type***

The Netherlands has detailed information on its entire land area. The carbon content in the soil can therefore be expressed with a relatively high degree of accuracy. Kuikman *et al.* (2002) made a start on this topic using descriptions of profile details in the so-called LSK (a national random check of map units, Finke *et al.*, 2001). A limited number of definitions are used for this map set, including the organic substance levels. This random check was meant to provide further quantitative information for the existing soil maps.

The random check was implemented on a nationwide and stratified scale, where main categories and/or symbol units were combined in order to produce a more homogeneous grouping with respect to landscaping, soil formation or parent material. Based on the ALBOS file, the land use for 'nature' has been separated (see Nabuurs *et al.*, 2005). Each point can be

coupled to symbol units via the wrong route, thus also to the soil map of the Netherlands, scale 1: 50,000.

Figure 1: Overall working method for the development of HGN-1990



In 2006 (Wyngaert *et al.*, 2006) the method was improved as the calculation of the average carbon sink, per soil stratum, is now based on 70 categories (previously only eight categories);

## 1.2 Significance and influences

### 1.2.1 Contribution to total national emissions

CO<sub>2</sub> emissions from soil (reported under GPG 2003 category 5B-G) contribute several megatons to the total annual greenhouse gas emissions in the Netherlands. This is entirely due to the contribution of carbon emitted from drained peat soils (cultivation of organic soils).

### 1.2.2 Developments that influence emissions

Not applicable

## 2 Method, emission factors and activity data

### 2.1 Calculation method

The country-specific method for the Netherlands for the period 1990-2000 and following years is described in the Alterra Report 1035-3 by De Groot *et al.* (2005), and is summarised in the following three steps.

- Step 1: allocation of areas

Land use is determined using the digital and digitised topographical TOP10 map and Top 25 maps, 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.

- Step 2: calculation of C stock

The map is coupled to the soil map of the Netherlands showing carbon content for soil types from the national sample of map units (Landelijke Steekproef Kaarteenheden; LSK) (Finke *et al.*, 2003; Kuikman *et al.*, 2002). Based on the soil map of the Netherlands (scale 1: 50,000) in combination with results of the LSK, it is possible to produce a map and achieve a spatially explicit picture of the carbon stocks in the topsoil, using the following formula (de Groot, 2005):

C – stocks for an individual soil type

$$SOC_{(1990-2000),s1} = \sum_1^n (os \times \text{bulk density} \times \text{average C-content} \times \text{topsoil}) / n$$

$SOC_{(1990-2000),s1}$  = soil organic carbon in the period 1990-2000 for soil unit S1 in tons C.ha<sup>-1</sup>

os = organic substance level in dry ground (%)

Bulk density = kg. m<sup>-3</sup> dry ground (calculated using a pedotransfer function, which defines a relationship between soil characteristics and bulk density).

Average C content = kg C. kg<sup>-1</sup> os (default 0.5)

Topsoil = the thickness of the topsoil, in metres (default is 0.3 m)

N = number of soil samples in soil unit S1

Total carbon content of the Netherlands:

$$\Delta C_{(c, \text{ mineral})} = \sum_s [(SOC_{(1990-2000)} \cdot A)]$$

Where:

|                       |   |
|-----------------------|---|
| $\Delta C_{(c)}$ =    | annual change in carbon content in mineral soils (ton C per year)               |
| $SOC_{(1990-2000)}$ = | stock of soil organic carbon in the relevant year (ton C per ha)                |
| $SOC_{(0-T)}$ =       | soil organic carbon stocks in T years for the relevant inventory (ton C per ha) |
| T =                   | inventory period in years   |
| A =                   | land area of a specific land use (ha)   |
| S =                   | varying and differentiated soil types   |

### - Step 3: Calculation of C-stock changes

Soils - other than cultivated organic soils - in the Netherlands are not a net source of carbon. Results from several studies that report evaluation of changes in organic matter in mineral soils in the Netherlands are summarised in Chardon *et al.* (2009). This assessment shows that the total of mineral soils in the Netherlands is a sink and soil organic matter - on average - increases but with uncertainties as to the sinks strength. Based on this conclusion that the mineral soils are not a source of carbon dioxide, we have decided to follow a conservative principle and report 'not estimated' (NE) rather than to report a quantification of the C-stock change for C stock changes in mineral soils.

### Calculation method for organic soils

When peat soils settle this creates additional CO<sub>2</sub> emissions compared to the normal assumption that there is no loss of carbon in the soil

For carbon emissions from cultivated organic soils the methodology is described in (Kuikman *et al.*, 2005; Alterra report 1035–2). This method is based on subsidence as a consequence of oxidation of organic matter. Oxidation is typically 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). Based on many series of long-term measurements, a relationship was established between subsidence and either ditch-water level or mean lowest groundwater level (Kuikman *et al.*, 2005; van den Akker *et al.*, 2008). For all peat soils in the Netherlands, the estimated subsidence could thus be predicted from GIS information. The occurrence of peat soils was based on the application of the GPG 2003 definition to the (updated) Dutch soil map (de Vries, 2003, 2004). This yielded 223 kha of relevant peat soils in the Netherlands in a matrix defined by upper soil type and drainage.

The carbon emissions per ha are calculated from the mean ground surface lowering using the following general equation (Kuikman *et al.*, 2005):

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

With

|               |  |
|---------------|--|
| $C_{em}$      | Carbon emission from oxidation of peat (Gg C ha <sup>-1</sup> year <sup>-1</sup> ) |
| $R_{GSL}$     | Rate of ground surface lowering (mm year <sup>-1</sup> )                           |
| $\rho_{peat}$ | Bulk density of lowest peat layer (kg soil m <sup>-3</sup> )                       |
| $f_{ox}$      | Oxidation status of the peat (-)   |
| $[OM]$        | Organic matter content of peat (kg OM kg <sup>-1</sup> soil)                       |

$[C_{OM}]$  Carbon content of organic matter (0.55 kg C kg<sup>-1</sup> OM)  
 $f_{conv}$  Conversion from kg m<sup>-2</sup> year<sup>-1</sup> to Gg C ha<sup>-1</sup> year<sup>-1</sup> (10<sup>4</sup>)

For deep peats (> 120 cm), the calculation is based on the of raw peat (bulk density of 140 kg soil m<sup>-3</sup>, oxidation status of 1, and organic matter content of 0.80 kg OM kg<sup>-1</sup> soil), which results in an emission of 616 Gg C ha<sup>-1</sup> year<sup>-1</sup> 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 peat oxidation process 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 around 80 cm, all values in equation (1) can be the same as for a deep peat soil, because the change in subsidence and bulk density of the raw peat below 60 cm depth is negligible. Also for peat soils thinner than 80 cm all values in equation (1) were used. This estimation is made because there are no data on subsidence of such shallow peat soils and because this is just cause a small error, because the fast majority of the Dutch peat soils are thicker than 80 cm. Moreover the underestimation of the bulk density will be compensated (more or less) by the overestimation of the subsidence.

### **Calculation method for agricultural lime application**

CO<sub>2</sub> emissions as a result of using calcium on agricultural soils are determined for reporting in Table 5(IV). Limestone ('calcareous marl') and dolomite ('calcium magnesium carbonate') are used in the agricultural sector to add calcium to the soil. The amounts used are reported in the Agricultural Statistics for the total of calcium manure products (LEI/CBS, for various years). The available figures are totals and do not specify the application on grassland and cropland separately. Since these figures are reported in CO<sub>2</sub>-eq. there is no need to correct for inaccuracy and the CO<sub>2</sub> emissions can be calculated as follows:

$$CO_2 = \text{limestone use} * EF1 + \text{dolomite use} * EF2$$

with EF1 = 440 kg CO<sub>2</sub>/ton pure limestone  
 and EF2 = 477 kg CO<sub>2</sub>/ton pure dolomite

## **2.2 Emission factors**

In 2005 De Groot (*et al.*) set the CO<sub>2</sub> emissions for unchanging land use in the Netherlands at zero, because there had been no change in soil carbon and, in any case, no loss of soil carbon was expected for the period 1990-2000 (Velthof, 2004; BLGG, Reijneveld, 2005). In addition, within the LSK random tests, no difference was found for building land and grassland as the dominant land-use form in the Dutch agricultural sector (De Groot *et al.*, 2005). Results from several studies that report evaluation of changes in organic matter in mineral soils in the Netherlands are summarised in Chardon *et al.* (2009). This assessment shows that the total of mineral soils in the Netherlands is a sink and soil organic matter - on average - which increases, but with uncertainties as to the sinks strength. Based on this conclusion that mineral soils are not a source of carbon dioxide, we have decided to follow a conservative principle and report 'not estimated' (NE) rather than to report a quantification of the C-stock change for C stock changes in mineral soils.

However, organic soils (cultivation of histosols) do produce CO<sub>2</sub> emissions. A country-specific method is used to calculate these emissions as a result of peat soils settling, based on the recommendations given in the GPG 2003. A carbon loss averaging 5.2 ton/ha is used for the total area of organic soils (223k ha in 2003) and the associated water management. This corresponds to a calculated emission factor of 19.04 CO<sub>2</sub>/ha (Kuikman *et al.*, 2005). This factor was improved in 2006 (Van den Wyngaert *et al.*, 2006),

The GPG 2003 default values are used for lime use in agricultural soils, i.e.

- 440 kg CO<sub>2</sub>/ton pure limestone and
- 477 kg CO<sub>2</sub>/ton pure dolomite

### 2.3 Activity data

The following statistical information is required for the calculations mentioned in this protocol:

Topographical maps (from the Topographical Service). These have been digitised as TOP10 files for the years 1990 and digital TOP10Vector for 2004. In future the digital maps will become available as part of the project 'Basiskaart Natuur' ('Base map Nature').

Soil map of the Netherlands, with soil carbon estimates and calculations from LSK. Implemented once only by Alterra Wageningen, and documented in its report (Finke *et al.*, 2001).

LEI: Agricultural and horticultural figures for lime usage in agricultural soils.

## 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 & environment, [www.kennisonline.wur.nl](http://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).

The data on the TOP10 maps are available from the Topographical Service. The digitised information from the TOP10 maps, representative for 1990 and 2004, is available from Alterra (Wyngaert *et al.*, 2008, Kramer *et al.*, 2009). The soil maps of the Netherlands and the LSK random test, plus information on carbon content, are all available from Alterra (Finke *et al.*, 2001; Kuikman *et al.*, 2002).

## 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 GPG 2003. 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<sub>total</sub> 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.

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

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 <sub>onz.</sub> | EF <sub>onz.</sub> | Uncertainty estimates <sub>tot</sub> |
|------|------------------------------------|-----------------|--------------------|--------------------|--------------------------------------|
| 5B2  | 5B2. Land converted to Cropland    | CO <sub>2</sub> | 25                 | 50                 | 56                                   |
| 5C1  | 5C1. Grassland remaining Grassland | CO <sub>2</sub> | 25                 | 50                 | 56                                   |
| 5C2  | 5C2. Land converted to Grassland   | CO <sub>2</sub> | 25                 | 61.2               | 66                                   |
| 5E2  | 5E2. Land converted to Settlements | CO <sub>2</sub> | 25                 | 50                 | 56                                   |
| 5F2  | 5F2. Land converted to Other Land  | CO <sub>2</sub> | 25                 | 50                 | 56                                   |
| 5G   | 5G. Other (liming of soils)        | CO <sub>2</sub> | 25                 | 1                  | 25                                   |

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].

#### Cropland [5B]

The uncertainties in the Dutch analysis of carbon levels depended on the collective factors with which the calculations were implemented (calculation of the organic substances in the soil profile and the conversion to a national level) and data on land use and land-use change

(topographical data). The uncertainty in the CO<sub>2</sub> emissions from 5B2 *Land converted to Cropland* was calculated at 56%.

*Uncertainty in the implied emission factor for 5B2 Land converted to Cropland*

The uncertainty in the implied emission factor for 5B2 *Land converted to Cropland* referred to the change in carbon content of mineral soils. The uncertainty in the change in carbon content of mineral soils was calculated at 38% (rounded to 50% in the Tier 1 calculation spreadsheet, since it is the order of magnitude that is important) [Olivier et al, 2009].

**Grassland [5C]**

The uncertainty in CO<sub>2</sub> emissions in the categories 5C1 *Grassland remaining Grassland* and 5C2 *Land converted to Grassland* was calculated at 56%.

*Uncertainty in the implied emission factor for 5C1 Grassland remaining Grassland*

The uncertainty in the oxidation of organic soils,(category 5C1) was calculated at 55%. Combined with the 38% uncertainty in the change in carbon content of mineral soils, the overall uncertainty in the implied emission factor for category 5C1 lies in the 50% range (50% used in the Tier 1 calculation spreadsheet).

*Uncertainty in the implied emission factor for 5C2 Land converted to grassland*

For the uncertainty in 5C *Land converted to Grassland*, reference was made to the description of 5B2 *Land converted to Cropland* (Section 2.5.2). The calculation for *land converted to Grassland* was based on the same assumptions as those made for 5B2 *Land converted to Cropland*, and the uncertainties, therefore, are identical (38%, rounded to 50% in table) [Olivier et al, 2009].

**Wetland [5D], Settlement [5E] en Other Land [5F]**

For information on the uncertainty estimates, the reader is referred to PBL-Report 500080013, Section 2.5.1 [Oliver et al 2009] which discusses the uncertainty in soil carbon and changes in land use.

**4.2 Quality assurance and quality control (QA/QC)**

The ER work package leader 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 leader 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*

The reporting information for the NIRs 2005-2009 was compiled by Alterra and substantiated in a number of reports: series 1035-1 through 1035-3 (Nabuurs *et al.*, 2005; Kuikman *et al.*, 2005 and de Groot *et al.*, 2005). Since then a number of studies and improvements have been conducted, documented in Updates to the Dutch National System of the LULUCF sector (Wyngaert, several years). As a result of the initial review, the composition of the 1990 map has been improved for the allocation of land use and calculations for C-changes have improved (Van den Wyngaert *et al.*, 2009).

#### *4.4.2 Future*

No improvements are planned. Resources have been allocated for Kyoto reporting under Article 3.3.

## **5 Remaining aspects**

### **5.1 Point source criteria**

Not applicable

### **5.2 Substance profiles**

Not applicable

### **5.3 Regionalisation**

The LSK random checks were implemented at plot level, and lead to estimates of carbon content in the soil that are relevant for groundwater categories, and thereafter for various forms of land use, plus various soil types that are shown on the soil map of the Netherlands.

### **5.4 Time-based variations in source strength**

Not applicable

## 6 References and additional information

### 6.1 References

- CBS/LEI, Landbouwstatistiek voor totaal kalkmeststoffen 1990-2003 (Agricultural statistics for total lime fertilisers) (various years).
- Akker, van den, J.J.H., P.J. Kuikman, F. de Vries, I. Hoving, M. Pleijter, R.F.A. Hendriks, R.J. Wolleswinkel, R.T.L. Simões and C. Kwakernaak, 2008. Emission of CO<sub>2</sub> from agricultural peat soils in the Netherlands and ways to limit this emission. In: Farrell, C and J. Feehan (eds.), 2008. Proceedings of the 13th International Peat Congress After Wise Use – The Future of Peatlands, Vol. 1 Oral Presentations, Tullamore, Ireland, 8 – 13 june 2008. International Peat Society, Jyväskylä, Finland. ISBN 0951489046. pp 645-648
- Chardon, W.J., H. Heesmans, and P.J. Kuikman (2009) Trends in carbon stocks in Dutch soils: datasets and modeling results. Alterra report 1869
- Finke, P.A, Gruijter de J.J. and Visschers R., 2001. Status 2001 Landelijke steekproef Kaartenheden en toepassingen; Gestructureerde bemonstering en karakterisering Nederlandse bodems.(Status 2001 National random check of map units and applications; structured sampling and characterisation of Dutch soils). Alterra, Wageningen UR, rapport 389, Wageningen
- Groot, W.J.M.de, R. Visschers, E. Kiestra, P.J. Kuikman and G.J. Nabuurs, 2005: National system to report to the UNFCCC on carbon stock and change of carbon stock related to land use and changes in land use in the Netherlands (in Dutch). Alterra, Alterra - rapport 1035 - 3.r, Wageningen.
- IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories, Three volumes: Reference Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK
- IPCC, 2001: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan
- Kramer, H. & W. Knol (2005) Historisch grondgebruik in Nederland: een landelijk reconstructie van het grondgebruik 1990. Alterra, Wageningen Alterra report 1035-4 (in Dutch)
- Kramer, H., Hazeu, G.W. & Clement, J., 2007. Basiskaart Natuur 2004, Werkdocument 40, Wettelijke Onderzoekstaken Natuur & Milieu, Wageningen UR
- Kramer, H., Born, G.J. van den, Lesschen, J.P. Oldengarm, J., and Wyngaert, I.J.J. van den, 2009. Land Use and Land Use Change for LULUCF reporting under the Convention on Climate Change and the Kyoto Protocol. Alterra. Wageningen UR. Alterra Report 1916. ISSN 1566-7197.
- Kuikman, P.J., De Groot W., Henriks, R., Verhagen J. and De Vries. J., 2002. Stocks of C in soils and emissions of CO<sub>2</sub> from agricultural soils in the Netherlands. Alterra. Wageningen UR. Alterra report 561
- Kuikman, P.J., Van den Akker J.J.H and F. De Vries, 2005. Lachgasemissie uit organische landbouwbodems (Laughing gas emissions from organic agricultural soils), Alterra, Wageningen UR. Alterra report 1035-2
- Nabuurs, G.J., I.J. Van den Wyngaert, W.D. Daamen, A.T.F. Helmink, W. De Groot, W.C. Knol, H. Kramer, P.J. Kuikman, 2005. National System of Greenhouse Gas Reporting for Forest and Nature Areas under UNFCCC in The Netherlands - version 1.0 for 1990 – 2002. Alterra, Wageningen UR. Alterra report 1035-1
- Olivier J.G.J., L.J. Brandes and R.A.B. te Molder, 2009 (in print) Uncertainty in the Netherlands' greenhouse gas emissions inventory: Estimate of annual and trend

uncertainty for Dutch sources of greenhouse gas emissions using the IPCC Tier 1 approach, PBL-Report 500080013, Bilthoven

- Reijneveld, A., J. Van Wensem and O. Oenema (2005). Regional trends in soil organic matter level of agricultural land in the Netherlands in past decades. Report Soil Protection Technical Committee TCB R19, The Hague (in English, with Dutch database)
- Velthof, G.L., Beek, C.L. van, Brouwer F. et al., 2004. Denitrificatie in de zone tussen bouwvoor en het bovenste grondwater in zandgronden (Denitrification in the zone between the building base and the top groundwater in sandy soils). Report 730.1, Alterra, WageningenGroenigen, J.W. van, Gebauer, G., P
- Vries, F. de, 2003. Bodemkundige basisinformatie provincies Groningen, Drenthe en Overijssel (Soil scientific information for the provinces Groningen, Drenthe and Overijssel). Alterra Wageningen UR. Alterra report 696.
- Wyngaert, I.J.J. van den, W. de Groot, P. Kuikman, G.J. Nabuurs, Updates of the Dutch National System for greenhouse gas reporting of the LULUCF sector. Alterra, Wageningen, Alterra report 1035-5, 2007
- Wyngaert, I.J.J. van den, Kramer, H., Kuikman, P., Nabuurs, G.J. & Vreuls, H., Greenhouse gas reporting of the LULUCF sector, revisions and updates related to the Dutch NIR 2008, Alterra, Wageningen, Alterra report 1035-6, 2008
- Wyngaert, I.J.J. van den, Kramer, H., Kuikman, P., Lesschen, J.P., (2009) Greenhouse gas reporting of the LULUCF sector , revisions and updates related to the Dutch NIR 2009. Alterra, Wageningen. Alterra - rapport 1035 . 7 ISSN 1566 - 7197

## **6.2 Additional information**

Not applicable

**APPENDIX 1****Netherlands TOP10 Vector classes and corresponding GPG (sub)categories**

| <b>TOP10Vector</b>                    | <b>Dutch TOP10Vector name</b>          | <b>GPG classes</b> |             |
|---------------------------------------|--|--------------------|-------------|
| 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  |