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Land Use and Land Use Change for LULUCF reporting under the Convention on Climate Change and the Kyoto protocol

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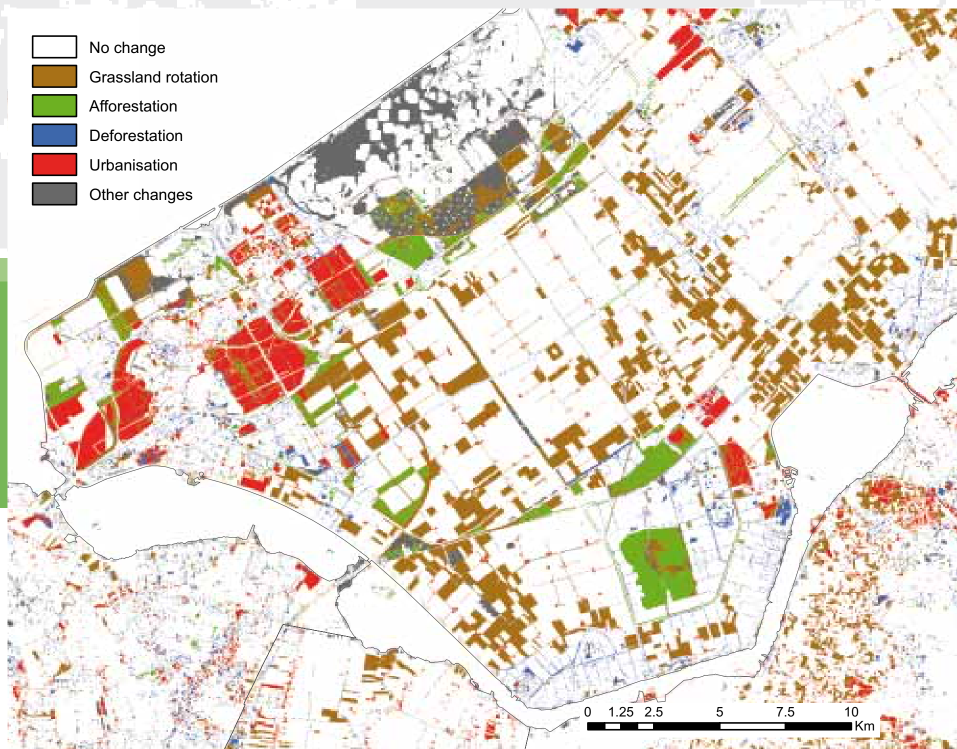

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ABSTRACT

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This report aims to give a complete and transparent overview and motivation of all steps involved in the construction of the land use and land use change matrix used for the UNFCCC submission 2009 for LULUCF and onwards. For the 2009 submission to the UNFCCC the land use change matrix was updated and based on an improved wall-to-wall approach derived from topographical maps. Updates in methodology and data sets were included in order to present the best estimate of land use and land use change in The Netherlands that is currently possible. In this report all steps involved in the calculation of the land use and land use change matrix used from 2009 on are described. Also a motivation is given why The Netherlands considers the approach taken as the best possible in their specific situation. The results of the calculations are reported and the final matrix is discussed in view of developments in Dutch land use related policies. Transitions that appear counterintuitive are explained and motivated using examples from the maps.

Keywords: land use, land use change, LULUCF, The Netherlands

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Preface

This report aims to give a complete and transparent overview and motivation of all steps involved in the construction of the land use and land use change matrix used for the UNFCCC submission 2009 for LULUCF and onwards. For the 2009 submission to the UNFCCC the land use change matrix was updated and based on an improved wall-to-wall approach derived from topographical maps. Updates in methodology and data sets were included in order to present the best estimate of land use and land use change in The Netherlands that is currently possible. In this report all steps involved in the calculation of the land use and land use change matrix used from 2009 on are described. Also a motivation is given why The Netherlands considers the approach taken as the best possible in their specific situation. The results of the calculations are reported and the final matrix is discussed in view of developments in Dutch land use related policies. Transitions that appear counterintuitive are explained and motivated using examples from the maps.

Summary

The Netherlands has developed an overall approach within the National System since 2003, which has been deployed for the National Inventory Reports since 2005. It was taken into account to provide a full recalculation of the period 1990 – 2003. The previous submissions for the LULUCF sector were based on a land use change matrix that was derived from two maps representing the land use in 1990 and 2000. During the in-country review in April 2007, the Expert Review Team (ERT) was critical about the methodology to derive the land use matrix and experienced a limited transparency on the procedures and values used for land use and land use change. For the 2009 submission to the UNFCCC the land use change matrix was updated and based on an improved wall-to-wall approach derived from topographical maps. Updates in methodology and data sets were included in order to present the best estimate of land use and land use change in The Netherlands that is currently possible. In this report all steps involved in the calculation of the land use and land use change matrix used from 2009 on are described. Also a motivation is given why The Netherlands considers the approach taken as the best possible in their specific situation.

The new land use maps are based on two maps for monitoring nature development in The Netherlands, "Basiskaart Natuur" (BN) for 1990 and 2004. The maps were created to monitor changes in nature areas, but because of its national coverage and inclusion of other land use types it is also very suitable as land use data set for the reporting of the LULUCF sector. The source material for BN1990 consists of the topographic map 1:25,000 (Top25) and digital topographical map 1:10,000 (Top10Vector). Map sheets with exploration years in the period 1986-1994 were used. The source material for BN2004 consists of the digital topographic map 1:10,000 (Top10Vector). All topographic maps have been explored in the period 1999-2003. For the BN2004, information from the Top10Vector map was combined with four other sources, i.e. information from two subsidy regulations, a map with the geophysical regions of the Netherlands and a map with the land use in 2000.

Though based on the same data sets, the methodology for digitalisation, classification and aggregation was improved and for 1990 in correspondence with the map for 2004. One of the main improvements for the 1990 map is a much better distinction between built-up areas and agricultural lands. This was based on manually checking of all areas. If the source information was a paper map, it was converted to a digital high resolution raster map. Then both Top10Vector files and digitised Top25 maps were (re)classified to match the requirements set by nature monitoring and UNFCCC reporting. In this process additional data sets were used. Simultaneously, harmonisation between the different source materials was applied to allow a sufficiently reliable overlay. The final step in the creation of the land use maps was the aggregation to 25 m × 25 m raster maps. For the 1990 map, which had a large part of the information derived from paper maps, an additional validation step was applied to check on the digitising and classifying processes.

The land use change matrix is the result of an overlay between the 25 m × 25 m land use maps of 1990 and 2004. The total area of land use change in the period 1990 to 2004 is about 6700 km^2, which is around 16% of the total area. The largest changes in land use are the conversion of cropland to grassland and vice versa. Other important land use changes are the conversions of cropland and grassland to settlement (urbanisation), which is occurring at the rate of 114 km^2 per year.

The "Basiskaart Natuur" matches the requirements for a primary land use dataset for carbon reporting in a small, intensively managed country as The Netherlands. It is spatially explicit, covers the entire country and the spatial resolution allows sufficiently detailed representation of the fine-grained land use mosaic in The Netherlands. It is the basis for the monitoring of nature in The Netherlands, and as such it has a legal status. It is based on the digital topographical maps (Top10Vector) which had an update frequency of 4 years, which will even increase in the future. The spatially explicit land use map allows overlays with other maps to fulfil additional needs like reporting the areas on peat soils.

The land use change matrix was derived by overlaying the 1990 and 2004 land use maps. The results were compared with expectations from policies and other sources. Taking into account all uncertainties, the trends and results from the land use matrix matched other sources remarkably well and could be explained from the specific land use policies in The Netherlands. It is therefore concluded that the approach taken is in compliance with GPG-LULUCF and gives the best estimate currently possible for land use and land use change for The Netherlands. Inconsistencies that were suspected by the Expert Review Team based on counterintuitive land use change results were either solved as good as possible using auxiliary data sets or - if they were genuine results - explained by examples and land use policies specific to The Netherlands.

1 Introduction

1.1 Background

As a Party to the United Nations Framework Convention on Climate Change the Netherlands has the obligation to report their greenhouse gas (GHG) emissions annually (Article 4 of the UNFCCC). One of the sectors for which to report is Land Use, Land Use Change and Forestry (LULUCF). Official guidance on what is good practice for the LULUCF sector was formalized in 2003, with the publication of the Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF; IPCC, 2003).

The Netherlands has developed an overall approach within the National System since 2003, which has been deployed for the National Inventory Reports (NIR's) since 2005. It was taken into account to provide a full recalculation of the period 1990 – 2003. After an extensive inventory of available land use datasets in The Netherlands (Nabuurs et al., 2003), information on the surface of the different land use categories and conversions between categories was based on a wall-to-wall map overlay, resulting in a national scale land use and land use change matrix (Nabuurs et al., 2005).

As part of the annual review of the National System for GHG reporting for the UNFCCC as well as the initial review for the Kyoto Protocol the Expert Review Team (ERT) visited the Netherlands on 16-21 April 2007. The review expert was very critical with regard to the current methodology for land use change area estimates. In particular the comment was:

"The ERT noted that the data in the land-use change matrix reported by the Party are inconsistent since the methodologies of classification applied to the two maps (1990 and 2000) differ. This inconsistency is clearly shown by the area (9.7 per cent in 10 years) which, according to the matrix reported by the Netherlands, has been converted from settlements to all the other uses (mainly grassland – 6.3 per cent); in practice, this would imply that the country's cities and infrastructure are being abandoned or disrupted by the inhabitants. The ERT recommends that the Party apply the same methodology of classification to each set of land-referred data in order to make it possible to compare them in a consistent manner and thus estimate land-use changes accurately."

In addition, a limited transparency was experienced by the ERT, as many aspects of the land use and land use change matrix were published in different reports or were unpublished at that time (e.g. Nabuurs et al., 2003, 2005; de Groot et al., 2005; Van den Wyngaert et al., 2008). The ERT asked the Dutch Party to improve the methodology and advised to consider a sampling approach, or the use of CORINE.

1.2 Objective

In the 2009 submission to the UNFCCC, land use category data were based on an improved wall-to-wall approach of the land use and land use change matrix (van den Wyngaert et al., 2009). In this report, the improved methodology is described and motivated. Throughout the document, the requirements from GPG-LULUCF are guiding for the choices made and options considered. Critical comments of the ERT (initial review 2007) with respect to unexpected or counterintuitive outcomes are addressed. The objective of this report is to make transparent all steps involved in the calculation of the land use and land use change matrix used from 2009 on, and motivate why The Netherlands considers the approach taken as the best possible in their specific situation.

1.3 Former methodology and steps for improvement

The previous submissions for the LULUCF sector were based on a land use change matrix that was derived from two maps representing the land use in 1990 and 2000 (Van den Wyngaert et al., 2008). These two maps are geographically explicit land use maps, which were based on detailed topographical maps (Top10 Vector). The Netherlands used a wall-to-wall approach to create the land use change matrix.

The Top 10 Vector (1:10,000) is a very detailed topographical vector based geographical information system of The Netherlands. Its envisaged update cycle is 4 years. However for 1990, digital Top 10 Vector files were not available for large parts of The Netherlands. Instead, hardcopy topographical maps at a scale of 1:25,000 (Top25) from the period 1986-1994 were digitised. This was in compliance with the methods used to construct the maps on historical land use (Historisch Grondgebruik Nederland, i.e. HGN) between 1900 and now for The Netherlands. During this process, a distinction had to be made between cropland and built-up areas, both of which were white on the map. In view of the low importance of buildings for carbon reporting, this was done on a rather coarse level.

For 2000 the land use map was completely derived from the Top 10 Vector files. Both maps were classified to one of the ten distinguished HGN classes. Afterwards the maps were aggregated to 25 m grid cells for the overlay procedure. Since the source data for both land use maps were not exactly the same, the digitalisation of the topographical maps, the classification and the aggregation to 25 meter grid cells induced artefacts in the maps. In the overlay procedure these artefacts lead to an overestimate of some land use changes, especially the rates of deforestation and afforestation seemed too high. This overestimation was confirmed by a field validation of land use change to and from forest for two small study areas in Eastern Netherlands (Van den Wyngaert et al., 2008). Correction factors were applied on the land use change matrix, but these factors influenced the total area reported. Furthermore a series of counterintuitive land use transitions occurred, which decreased credibility of the land use change matrix to international experts.

In response, a combined update and improvement of the land use change matrix was planned. After thorough consideration, The Netherlands decided to continue with the wall-to-wall approach based on the topographical maps, as these are the most detailed and validated land use information available (par. 2.2). Synergy was sought with land use maps to monitor nature and nature development ('Basiskaart Natuur' 1990 and 2004) based on the same system of Top 10 Vector maps and added Top 25 maps for 1990. This meant changing the map years to 1990 and 2004. The methodology to include built-up areas was improved, and other, auxiliary information was used (Chapter 3). It was decided that the maps should be adapted using the best (auxiliary) information available, but the matrix would be the direct result of a map overlay. There would be no correction factors or other processing other than on the maps. After generation of the land use change matrix, the result would be discussed in the framework of Dutch land use policies, identifying and explaining counterintuitive land use transitions.

1.4 Content of the report

This report aims to give a complete and transparent overview and motivation of all steps involved in the construction of the land use and land use change matrix used for the UNFCCC submission 2009 for LULUCF and onwards.

In Chapter 1 the need for an update of the land use and land use change matrix as was used between 2005 and 2008 is identified. The former methodology is discussed with respect to the IPCC guidelines and the comments of the 2007 ERT.

In Chapter 2 the basis for land use and land use change reporting in The Netherlands is presented. The availability of information sources to base land use calculation on is discussed. Choice of the topographic maps as a basis for land use reporting is motivated and a clear overview of the characteristics of the topographic maps in relation to UNFCCC requirements is given.

Chapter 3 contains a description of the steps taken to extract the required information from the selected maps to construct the land use and land use change matrix used for UNFCCC LULUCF reporting. For reasons of readability and concise reporting, the more technical details are provides in the annexes.

In Chapter 4 the results of the calculations are reported and the final matrix is discussed in view of developments in Dutch land use related policies. Transitions that appear counterintuitive are explained and motivated using examples from the maps. This chapter also includes all relevant tables and maps to show the land use in 1990 and 2004, as well as the transitions in between. The values and maps presented here are the basis for reporting of land use and land use change values for the LULUCF sector for the UNFCCC Convention on Climate Change as well as for the Kyoto Protocol.

Chapter 5 compares the results with the requirements in the guidelines and the review comments. Future developments of land use and land use change reporting are discussed.

2 General overview of the steps in the improvement

2.1 Availability of digital land use and land cover data in the Netherlands

Topographic maps for the Netherlands are produced by the Kadaster, formerly the Topographic Service. The first topographic map series to cover the whole of The Netherlands is the Topographic Military Map from 1850 with a scale of 1:50,000. The second series are the Bonnemaps with a scale 1:25,000. These have been produced form 1874 until 1940. The third series are the Topographic maps 1:25,000 which were produced from 1950 until 1995. This is the first series that uses the Rijskdriekhoeksstelsel (RD-system) as the map coordinate system which is still is use today. The most recent series are the digital topographic maps 1:10,000 for which production started in 1991. In 2000 the Kadaster launched, as one of the first in the world, the Top10vector. This is a nationwide and highly detailed topographical base with a update frequency of four years. In 2007 the Kadaster launched Top10NL. This is an improved topographical base with advanced GIS features which makes it possible to combine the topographical data (from the top10vector) with other data sources. In 2008 the Top10NL was assigned as the official base map for topography. This dataset will be updated frequently.

A topographic map cannot be used as a land use database straightaway. The information from the map has to be adapted to the specific needs of the purpose for which the land use information is needed. In the preparatory phase of the LULUCF emission inventory Nabuurs et al. (2003) reported the available monitoring systems and databases. They concluded that the available systems in the Netherlands are well developed and that only problems that may arise from lack of consistency in time and from differences in classification of land use types. In the last 5-10 years the attention in the Netherlands for accurate land use information, for many different purposes, has increased strongly. The development of the Top10vector and Top10NL, the coordination in the use of the topographical base and further harmonization are a good illustration of this increased attention, but also reflects the attention for accuracy and consistency. The interest in accurate land use maps is reflected in the development of the 'Basiskaart Natuur' 2004 (Kramer et al., 2007). and 2007 (currently in process). These maps are based on the topographical base and addresses in detail the land use, with extra emphasis on nature.

The availability of these accurate and detailed topographical base maps and land use maps makes it possible to supply the land use data that is needed for a wall-to-wall land use and land use change inventory. The planned update frequency of both the topographical maps and 'Basiskaart Natuur' means that also in the future the required land use information will be available.

2.2 Continuing the wall-to-wall approach

In the IPCC Good Practice Guidance (IPCC, 2003) three approaches for representing land areas are described: 1) basic land use data, 2) survey of land use and land-use change and 3) geographically explicit land use data. In the first approach statistical data sets of land use areas are used, e.g. agricultural statistics. In this approach the total land use areas can be estimated accurately, but the transition between the land use categories is unknown. The second approach is based on a survey, which gives information about the specific changes in land use, i.e., changes from and to a land use category, but is not spatially explicit. In the third approach geographically explicit land use data of the reference year and the reporting year is used. The data may be obtained either by sampling of geographically located points, a complete tally (wall-to-wall mapping), or a combination of the two. For a sampling approach the sampling density needs to be sufficient to allow spatial interpolation for the production of a land use map. Although the approaches are not presented as hierarchical tiers, the third approach can be considered to be the most elaborated method.

The Netherlands decided to continue to use a wall-to-wall approach based on spatially explicit land use maps that are derived from topographical maps for the following reasons:

- In the Netherlands high quality spatial data sets with high resolution (1:10,000) are available. Land use changes can therefore be monitored very accurately and with low uncertainty. The topographical maps were created based on detailed aerial photographs. The uncertainty related to the classification is therefore much lower compared to satellite remote sensing images. In addition to the aerial photographs detailed field surveys are used to improve the topographical map.
- Wall-to-wall is a common approach that is appropriate for national circumstances, in particular when a benchmark land cover map is needed. A sampling approach is less suitable for small countries.
- The European Environment Agency has developed harmonised pan-European land cover maps for 1990 and 2000. The CORINE land cover maps are based on classifications of Landsat satellite images (30 m resolution). The minimum mapping unit was set at 25 hectares and the thematic accuracy was set at 85% (Achard et al., 2008). According to Hazeu and de Wit (2004) the overall accuracy of the CORINE land cover and change databases for the Netherlands have high thematic accuracy. Despite the high accuracy, the dataset was not used for LULUCF, especially because the land cover category 'agriculture' addresses insufficiently the different uses in the Netherlands. Besides, infrastructures and inland water are underestimated due to difficulties in recognition respectively the used definitions of water bodies. In the detailed maps and datasets used in the Netherlands for the wall-to-wall approach these shortcomings do not occur.
- Other countries (UK, Germany) successfully implemented a wall-to-wall approach as well. Denmark is in process of implementing this approach. They all report a high accuracy of the land use data and accurate land use change data.

A drawback of a wall-to-wall approach is that the temporal extent will be less, due to the extensive data needs, since a sampling approach is not limited to every location and can therefore be updated more easily. However, the topographical maps in The Netherlands are continuously updated with currently an average update frequency of about 4 years.

2.3 Description of the selected land use data sets

Since the start of the National System, two maps for monitoring nature development in The Netherlands, “Basiskaart Natuur” (BN), were developed based on the Top10Vector maps for 2004 (BN2004) and on a combination of Top10Vector and Top25 maps for 1990 (BN1990). The maps were created to monitor changes in nature areas, but because of its national coverage and inclusion of other land use types it is also very suitable as land use data set for the reporting of the LULUCF sector.
Though based on the same data sets, the methodology for digitalisation, classification and aggregation is improved and for 1990 in correspondence with the map for 2004. One of the main improvements for the 1990 map is a much better distinction between built-up areas and agricultural lands. This was based on manually checking of all areas.

For the BN2004, information from the Top 10 vector is combined with four other sources, i.e. information from two subsidy regulations (information from 2004), a map with the geophysical regions of the Netherlands (Fysisch Geografische Regio’s) and a map with the land use in 2000 (Bestand BodemGebruik 2000) (Kramer et al., 2007). The topographical maps are based on aerial photographs and field surveys from the period 1999-2003. The characteristics of both land use maps are presented in Table 1.

Table 1. Comparison of BN1990 and BN2004

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

3 Methodology for the land use maps and land use change matrix

In this Chapter all steps are described that lead from the raw information in the topographic vector maps as well as on the paper topographic maps, to the digital raster maps and finally the land use change matrix.

The land use change matrix is the result of an overlay between the 25 m × 25 m land use maps of 1990 and 2004. For both years, the land use maps were based on topographic maps, either digital (Top10Vector) or paper (Top25). The Top10Vector has an update frequency of 4 years, now decreasing to between 2 and 4 years. The Top25 had an update frequency of between 4 to 10 years. Higher update frequencies occur in urban areas, lower in rural areas.

For both years map sheets were selected to constitute the source information of the land use maps as described in par 3.1. If the source information was a paper map, it was converted to a digital high resolution raster map as described in par.3.2. Then both Top10Vector files and digitised Top25 maps were (re)classified to match the requirements set by nature monitoring and UNFCCC reporting. In this process additional data sets were used and this is described in par 3.3. Simultaneously, harmonisation between the different source material was applied to allow a sufficiently reliable overlay.

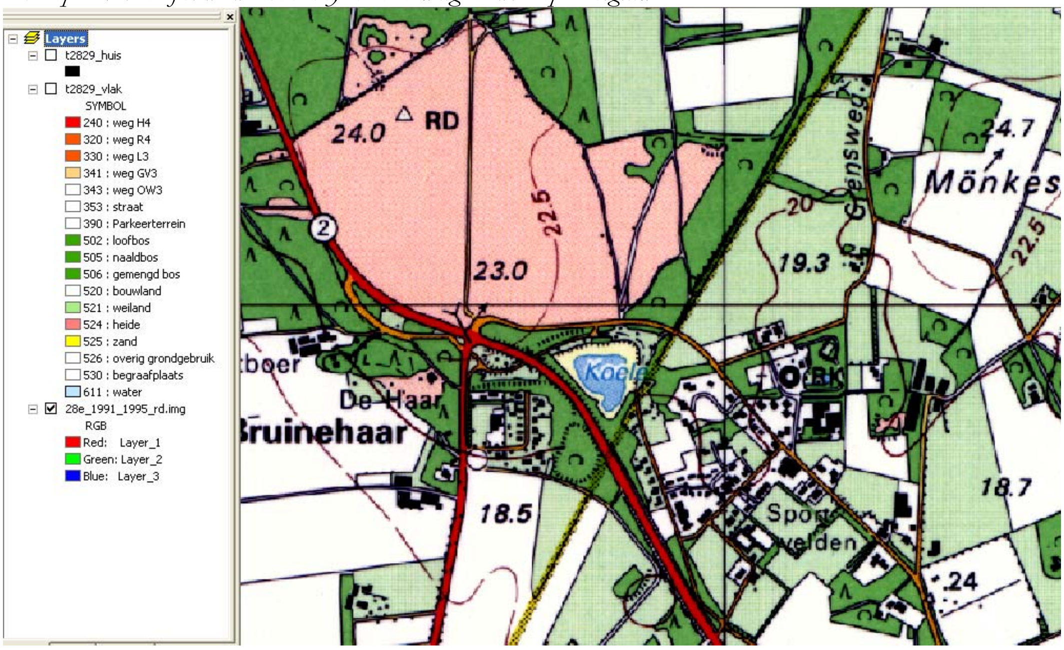
The final step in the creation of the land use maps was the aggregation to 25 m × 25 m raster maps as described in par. 3.5. For the 1990 map, which had a large part of the information derived from paper maps, an additional validation step was applied to check on the digitising and classifying processes (par. 3.7). Overlaying these two land use maps using standard procedures yielded the final land use and land use change matrix.

3.1 Selection of source material

The source material for BN1990 consists from the topographic map 1:25,000 (Top25) and digital topographical map 1:10,000 (Top10Vector). Both have the same underlying information, only the form (paper versus digital) and scale are different, as illustrated in Figure 1. To cover the entire Netherlands, map sheets with exploration years in the period 1986-1994 were used, see Annex 1. For most of the maps the only available exploration was selected. For a number of maps several revisions had appeared during this period and the revision which connects best with the exploration year of neighbouring maps was chosen. For some years and map sheets, the digital version of the Top 10 Vector was available instead of scanned Top25 maps and these were used.

The source material for BN2004 consists of the digital topographic map 1:10,000 (Top10Vector). All topographic maps have been explored in the period 1999-2003, see Annex 2. This was the only available exploration year for all maps. Auxiliary information on areas managed for nature purposes was dated on 2004.

A. Top10Vector file with colour layout according to the Top25 legend



B. Top25 scanned topographic map 1:25,000

Figure 1. Comparison of the two types of source material. (A) shows a reproduction of a Top10vector file and (B) the Top25 map of the same location and exploration year 1991.

3.2 Digitising paper maps (Top25)(1990)

The topographic maps 1:25,000 (Top25) which were produced between 1986 and 1994 are the source for the 1990 land use database. Figure 1 shows an example of the land use information that is available in this map. Land use information is included in the map using colour codes and symbols. Figures and names are written on the map, covering part of the coloured areas. The delineation of roads, ditches, etc. follows mapping rules, designed to allow visual interpretation rather than GIS type of processing. Built-up area, arable land and local roads are all represented by the colour white. The actual land use class can only be established from it's shape or geographical connection.

Colour scans (geometrical detail of 2.5 m × 2.5m) of these maps were georeferenced to the reference coordinate system, the RD-system for The Netherlands. Based on colour reflection values, colour codes were translated into land use classes (see Annex 3 for technical details). For information that was represented in another way (e.g. symbols indicating reed marsh) or involved non-unique colours (e.g. white for built-up areas and arable land), additional steps were taken, most of which involved manual steps in the digitising process (see also Annex 3 for details). This resulted in a 2,5 m × 2,5 m grid map with incomplete classification of the grids. Grid cells that were clogged by text and hatching, but also grid cells with non-decisive colours due to map discolouration, were not classified. These incomplete classified maps were input to the aggregation procedure as described in par. 3.5, which dealt with unclassified pixels.

3.3 (Re)classifying the digital maps

The classes distinguished in the Top10Vector and the Top25 did not match one-to-one with the classes needed for the land use maps and land use change matrix. For the Top25 maps this was partly dealt with in the procedure to go from paper map to digitised information source with 2.5 m × 2.5 m grid cells. For the Top10Vector a similar procedure was followed for reasons of comparability. First the Top10Vector codes were recoded to the BN classes (see Table 1). This corresponded to the colour based classification in the procedure for paper maps (par. 3.2). After recoding the vector file a raster file was created with a 2.5 meter cell size. The resulting map was in principle identical to the 2.5 m × 2.5m raster files from the scanned paper maps.
Then some additional classes were distinguished in both files. Inland sands (shifting sand) are distinguished from coastal sands (dunes, beaches and sand plates) using a map with the geophysical regions of the Netherlands (Fysisch Geografische Regio's). Nature grasslands were distinguished based on information from the Ministry of Agriculture, the State Forestry and the Dutch NGO Natuurmonumenten. However, the nature grasslands are still underestimated, especially on the BN 1990 map, due to incomplete registrations.

3.4 Harmonizing Top10Vector and digitised Top25

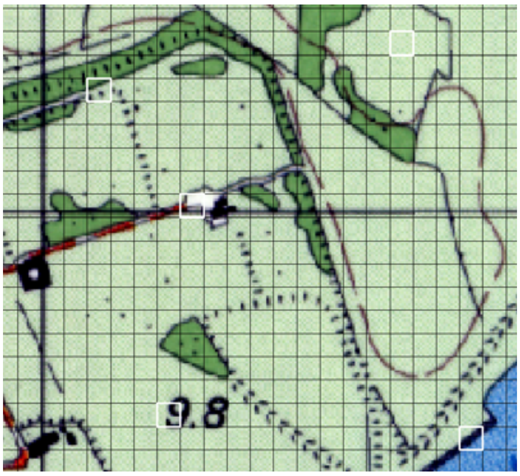
Although the underlying information of both maps is identical, the differences in form and scale make it necessary to actively harmonize the land use maps derived from the Top25 scanned maps and from the Top10Vector. This has been done by systematic adaptations to either the 1990 or 2004 map as well as by using additional data sets. The following issues were identified and dealt with:

1) Text, figures and symbols covered part of the colour codes in the paper maps. This resulted in a number of pixels which could not be classified at the pixel level for the Top25 material. This was settled in a correct manner during the aggregation step.
2) The paper maps have some features which are directed by the limits of visualization. The roads are drawn with a black line edge. The coloured part of the roads in Top10Vector are broader. Some narrow (white) roads are omitted on the Top25 map whereas these roads are visible on the Top10Vector map. To enhance comparability between the maps, the roads from the rasterized Top10Vector file were shrunk with one grid cell to create a narrower road.
3) On the reverse, the houses are generally drawn broader in Top25 than in Top10Vector. This was also caused by a black line around the houses. Since the houses are drawn in black they become a bit broader. To make the two sources similar, the raster houses on the Top10Vector map were expanded with one grid cell.
4) The scale difference between 1990 (1:25,000) and 2004 (1:10,000) and the small geometric imprecisely of the paper maps caused problems for the exact representation of linear features, in particularly roads. The artefact movement of roads causes an exaggeration in transitions to and from built-up areas. This was solved by using existing road databases from the ministry of public works. Data was available both for 1990 and 2004, and were used to determine whether changes in the aggregated maps (see par. 3.5) were actually correct. The 1990 map, being the more uncertain of the two for roads, was then corrected. The road maps also showed that part of the transitions away from built up areas were actually roads that had disappeared, e.g. a reconstruction of a highway intersection from a cloverleaf to a different type of intersection.

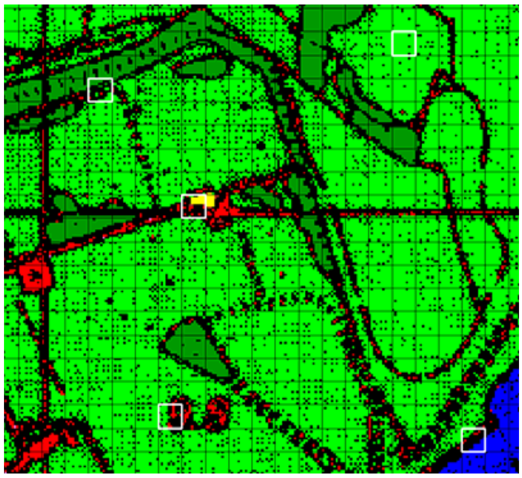
3.5 Aggregation

The input to the aggregation procedure are 2.5 m × 2.5 m raster files with complete (Top10Vector) or incomplete (Top25) classification of the grid cells to the BN classes. Incomplete means that there are still cells (pixels) that are not classified due to lack of information. These may be cartographic elements such as text and hatchings, but also pixels with colours that could not be classified from the scanned map.

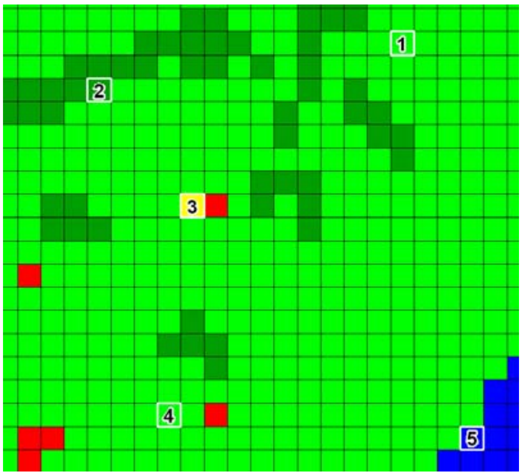
The final grid size for the land use maps was 25 m × 25 m. At this resolution, the effect of missing information and clogging almost disappears and the impact of geometrical inaccuracy has been limited (see also Nabuurs et al., 2005). The aggregation procedure applies a majority rule at the 25 m × 25 m grid cell level: the grid cell is attributed the class of the majority of all underlying 2.5 m × 2.5 m grid cells, excluding all non-classified cells. Small features like buildings but also linear features like roads thus disappear in many cells. Therefore roads and buildings were combined with built-up area to make sure that these features are still represented in the final land use database. An example of the steps in the procedure is shown in Figure 2. This example is discussed in detail in Annex 4.



A. Scan with 25 by 25 meter grid border overlay



B. preliminary classification with 25 by 25 meter grid border overlay



C. Aggregation of the preliminary classification with numbers of the example locations

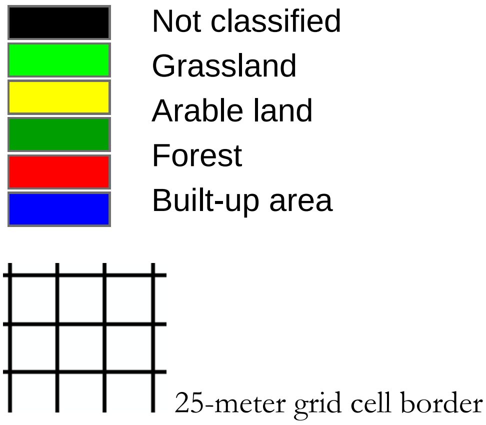


Figure 2. Example of the steps towards the land use maps form the Top 25: from scanned paper (A) over the 2.5 m × 2.5 m incompletely classified raster files (B) to the final product of a 25 m × 25 m land use map (C).

3.6 Distinguishing Kyoto Forest

For reporting to the Kyoto Protocol, the forest definition includes a minimum size of the area that is used as forest. In the land use maps that result after the aggregation, all wooded land is classified as forest, no matter the size. To distinguish forests that comply to the definition chosen by The Netherlands for the Kyoto Protocol, wooded areas of 0.5 ha (i.e. 8 grid cells) or larger, and at least 2 grid cells wide, are classified as Forests (according to the Kyoto definition), while all other wooded areas are classified as "Trees outside Forest".

3.7 Validation

The procedure from paper topographic maps to digital land use information was validated for 1990. The scanned maps were taken as the truth as no comparable independent source for land use from the 1990's is available. This validation is thus basically a check on the classification procedure. A random set of in total 6700 points were drawn. For each point the classification result was compared with the original topographic map. The overall classification accuracy is almost 94% (Table 2).

Table 2. Validation of the classification procedure from paper to digital land use information.

land use class	ref totals	class totals	number of cells classified correctly	product accuracy	user accuracy
Grassland	1912	1885	1820	95.2%	96.6%
arable	1379	1413	1338	97.0%	94.7%
heath land	277	277	265	95.7%	95.7%
forest	714	708	663	92.9%	93.6%
buildings and infrastructure	562	549	463	82.4%	84.3%
water	489	475	454	92.8%	95.6%
reed swamp	278	301	275	98.9%	91.4%
dunes and drifting sands	313	339	309	98.7%	91.2%
built-up area	487	444	393	80.7%	88.5%
greenhouses	289	309	288	99.7%	93.2%
Total	6700	6700	6268		
Overall Classification Accuracy				*93.6%*	

4 Land use and Land Use Change in The Netherlands

Developments in demography, economy, society and technology have impact on the use and cover of the available land. These developments are partly autonomous and partly induced by policies. This Chapter addresses the results of the land use change matrix for the period 1990 and 2004 and highlights the main drivers, both the autonomous and policy driven. The target is to show the major trends using statistical information (land use change statistics based on spatial information and statistics on demographical and socio-economic developments) and to discuss the reasoning behind the observed changes. To some extent this is a kind of verification and contributes to the answer on the question whether the land use change matrix is plausible.

4.1 Land use map and statistics for 1990

The final land use map for 1990 is presented in Figure 3 and the land use statistics are shown in Table 3. Agricultural land use (other grassland and arable land) is the major land use with more than 2.4 million hectares, which is about 58% of the total land. Forests and built-up and transport areas cover both almost 10% of the total area.

Table 3. Land use statistics for 1990

Code	Land use	Area (ha)	Percentage of total
10	other grassland	1 405 136	33.8
11	nature grassland	52 979	1.3
14	small forest	20 806	0.5
20	arable land	1 019 353	24.6
30	heath land	49 567	1.2
40	forest	362 100	8.7
70	water	771 696	18.6
80	reed swamp	20 843	0.5
90	shifting sands	3 584	0.1
91	dunes, beaches and sand plates	35 979	0.9
101	built-up area	188 529	4.5
102	railroads	5 205	0.1
103	roads	215 723	5.2
	total	4 151 500	

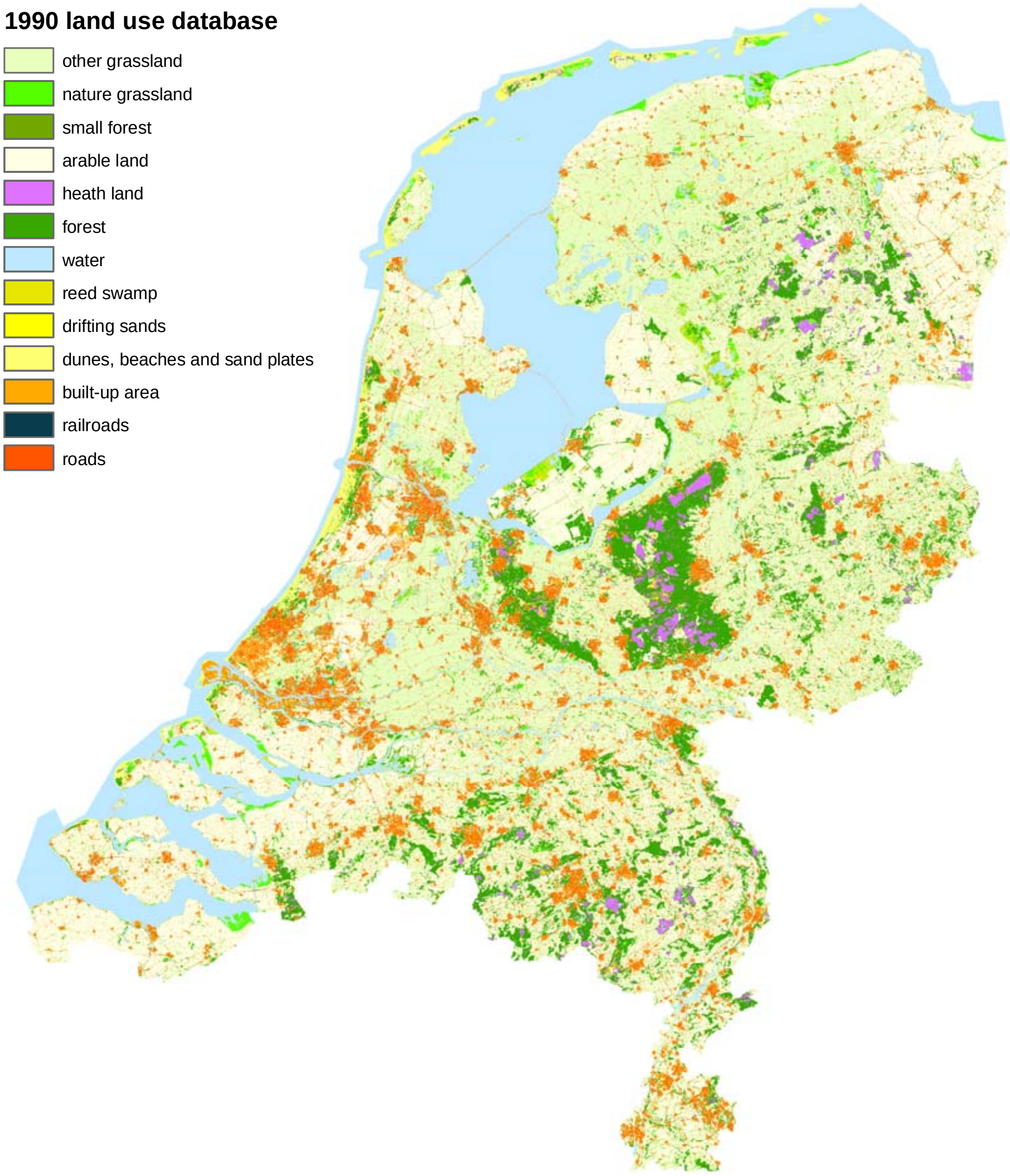


Figure 3. Land use map of 1990

4.2 Land use map and statistics for 2004

In The final land use map for 2004 is presented in Figure 4 and the land use statistics are shown in Table 4. The main land use pattern did not change a lot, but it is clearly visible that the built-up and transport areas increased to 13.5% of the total land area. This is mainly at the expense of agriculture, which decreased to 52.3%.

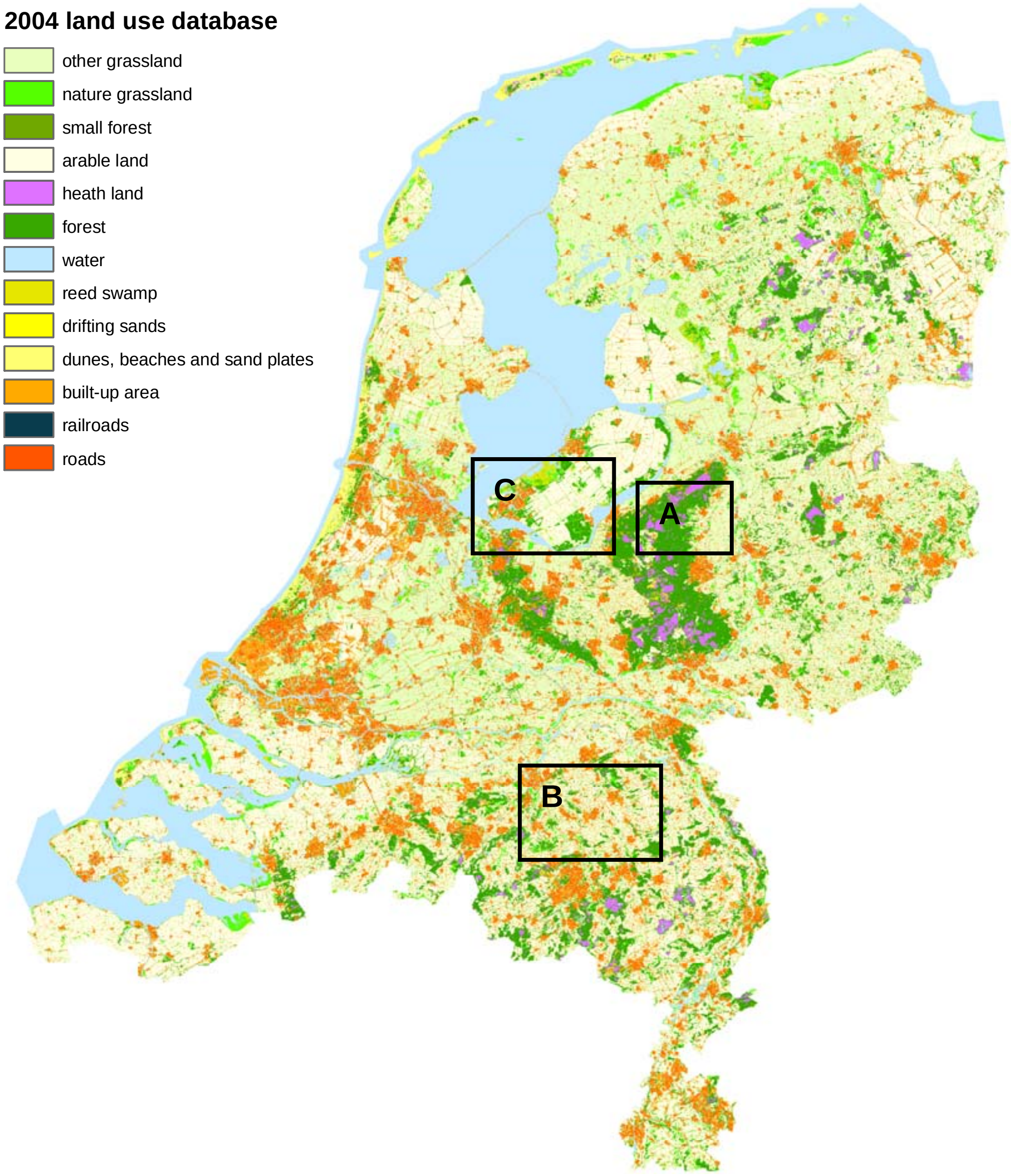


Figure 4. Land use map of 2004. The boxes indicate the locations of the land use change maps of Figures 5-7.

Table 4. Land use statistics for 2004

Code	Land use	Area (ha)	Percentage of total
10	other grassland	1 233 176	29.7
11	nature grassland	126 973	3.1
14	small forest	22 207	0.5
20	arable land	939 617	22.6
30	heath land	47 915	1.2
40	forest	370 041	8.9
70	water	780 139	18.8
80	reed swamp	27 126	0.7
90	drifting sands	2 971	0.1
91	dunes, beaches and sand plates	35 002	0.8
101	built-up area	326 353	7.9
102	railroads	6 195	0.1
103	roads	233 784	5.6
	total	4 151 500	

4.3 The Land Use and Land Use Change matrix

An overlay was produced of the land use maps of 1990 and 2004, which resulted in a land use and land use change matrix over 14 years (1 January 1990 – 1 January 2004). The matrix shows the changes for thirteen land use categories (Table 5). The land use matrix represents the national level, but the system can also support analysis at regional scale. In the context of this chapter the most relevant changes in land use are explained in more detail. The analysis is based on the thirteen land use categories and not on the six UNFCCC land use classes. This is primarily done because these thirteen categories better reflect the changes in land use compared to the six classes.

For the purpose of the CRF and NIR, the thirteen land use categories are aggregated into the six land use classes that are defined in the LULUCF guidelines. The definition of the UNFCCC land use categories is given in Annex 5. In Table 6 the resulting land use change matrix is given for the six UNFCCC land use categories and in Table 7 the matrix is presented on an annual basis. The total area of land use change in the period 1990 to 2004 is about 6700 km^2, which is around 16% of the total area. The largest changes in land use are the conversion of cropland to grassland and vice versa. Other important land use changes are the conversions of cropland and grassland to settlement (urbanisation), which is occurring at the rate of 114 km^2 per year.

Table 5. Land Use and Land Use Change Matrix based on the classification in 13 classes (in ha).

	BK_1990													
BK_2004	10	11	14	20	30	40	70	80	90	91	101	102	103	Grand Total
10 Grassland	1047889		2781	159806	255	6388	3924	1196	130	216	9505	134	953	1233176
11 Nature grassland	58206	40878	380	16350	759	4918	1679	1958	74	1438	275	8	51	126973
14 Trees outside Forest	3949	306	11336	2039	220	2852	274	54	15	83	979	13	85	22207
20 Arable land	195545	1002	386	739190	48	1218	523	73	4	5	1456	9	158	939617
30 Heather	332	338	155	641	42083	3280	291	44	437	252	52	5	5	47915
40 Forest (Kyoto)	10194	3065	2352	12520	4806	334211	569	319	205	348	1198	24	230	370041
70 Open water	8019	1763	247	5042	739	1197	757870	1419	171	2332	1248	5	86	780139
80 Reed marsh	3813	4274	71	1780	33	306	1141	15577	1	78	44	3	3	27126
90 Shifting sands	94	21	9	88	147	197	103	1	2303		8		1	2971
91 Coastal dunes	139	381	101	113	124	502	2663	24	3	30838	103	0	10	35002
101 Built-up area	67151	889	2768	71942	334	6344	2398	158	235	345	163204		10587	326353
102 Railways	372	2	29	590	7	103	20	4	0	1		4885	183	6195
103 Roads	9434	60	192	9252	11	583	240	17	6	43	10456	119	203371	233784
Grand Total	1405136	52979	20806	1019353	49567	362100	771696	20843	3584	35979	188529	5205	215723	4151500

Table 6. Land Use and Land Use Change Matrix aggregated to the six UNFCCC land use categories (in ha)

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

Table 7. Land use change matrix (in ha/year)

	BN 1990						
BN 2004	**Forest land**	**Cropland**	**Grassland**	**Wetland**	**Settlement**	**Other land**	***Total***
Forest land		1040	1 610	87	181	46	*2 964*
Cropland	115		14 042	43	116	1	*14 316*
Grassland	1 279	12 628		649	785	182	*15 523*
Wetland	130	487	1 332		99	184	*2 233*
Settlement	716	5 842	5 590	203		45	*12 395*
Other land	58	14	65	199	9		*345*
Total	*2 297*	*20 012*	*22 639*	*1 181*	*1 189*	*459*	*47 776*

The overlay of both land use maps that indicates the land use changes in The Netherlands for the period 1990 to 2004 was made. However, the changes in land use are generally small, and although they occur at many locations (16% of the total area changed land use), it is not possible to correctly visualise the land use change map for The Netherlands within this report. Instead we zoomed in on three locations (see Figure 4) to illustrate the land use changes.

In Figure 5 the main land use changes are indicated for the northern part of the Veluwe, an area which is largely forest land on a Pleistocene moraine complex with poor sandy soils. The map clearly shows that both afforestation and deforestation occur, generally on small scale. However, also more large scale afforestations occur. Outside the forest area rotational grassland and urbanisation are the main land use changes.

Figure 6 shows the main land use changes for an area of the province of Noord-Brabant. This area is typical for a small-scale Holocene landscape with sandy soils with a mosaic of cropland, grassland, settlements and forests. The map indicates that a large part of the area has changed land use, which is mainly the conversion of grassland to cropland and cropland to grassland. In this part of the Netherlands with sandy soils rotational grasslands are very common nowadays. Near the cities the urbanisation is clearly visible. Deforestation and afforestation only occur at very small scale in this part of the Netherlands.

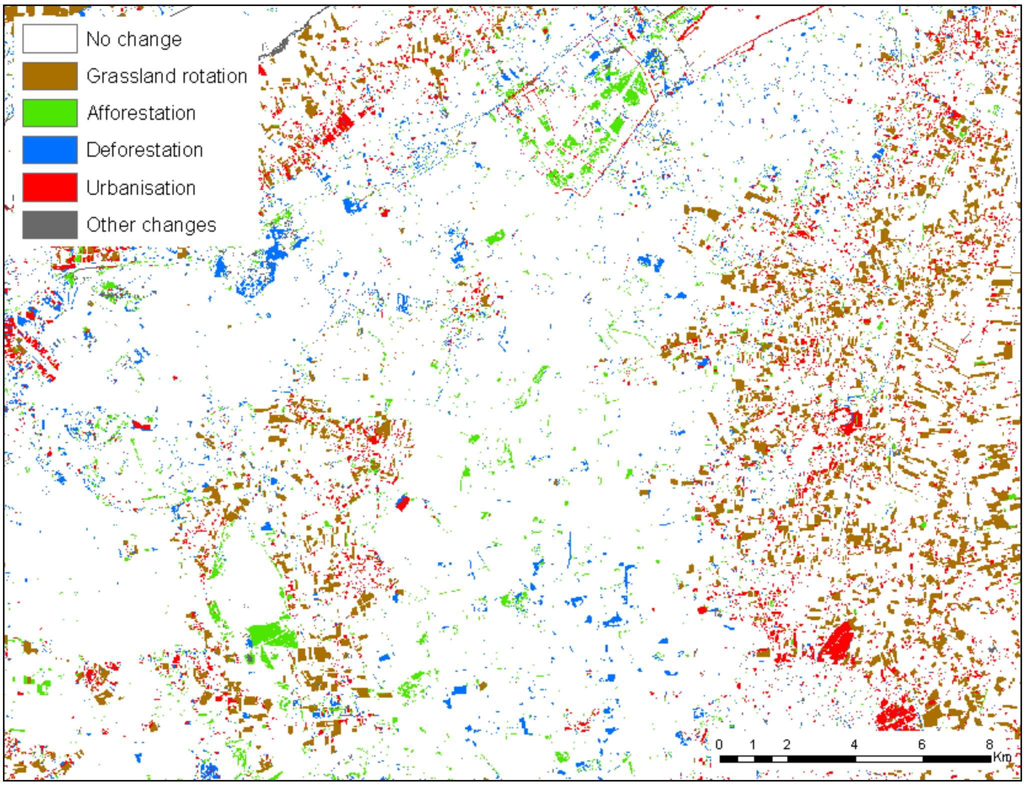


Figure 5. The main land use change processes for the northern part of the Veluwe (location A in Figure 4)

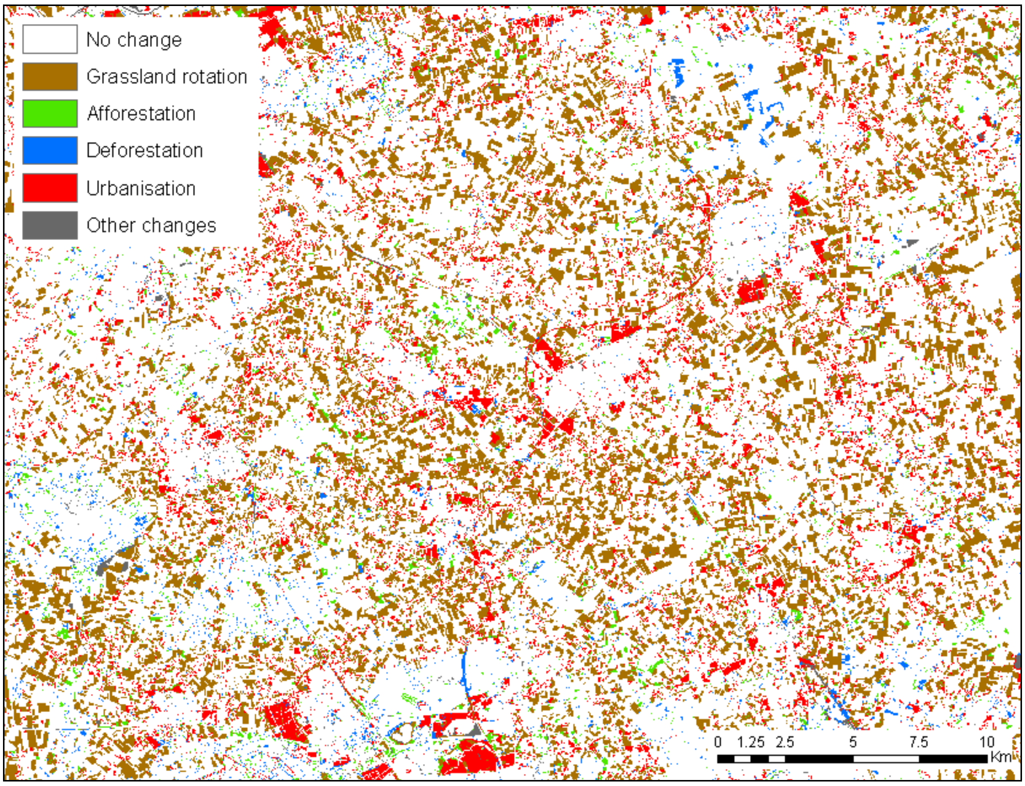


Figure 6. The main land use change processes for province of Noord-Brabant (location B in Figure 4)

The last example is the southern part of the province of Flevoland, a polder with clay soils which is reclaimed from the sea in 1968 (Figure 7). In this part of the Netherlands many different types of land use change processes occurred. First of all the large scale urbanisation of Almere and Lelystad is a major land use change. Also large parts have been afforested during recent years. In this area the 'other changes' cover a significant area, which is mainly the nature reserve Oostvaardersplassen. In this nature area land use changed from grassland and forest to wetland due to decreased drainage for nature development.

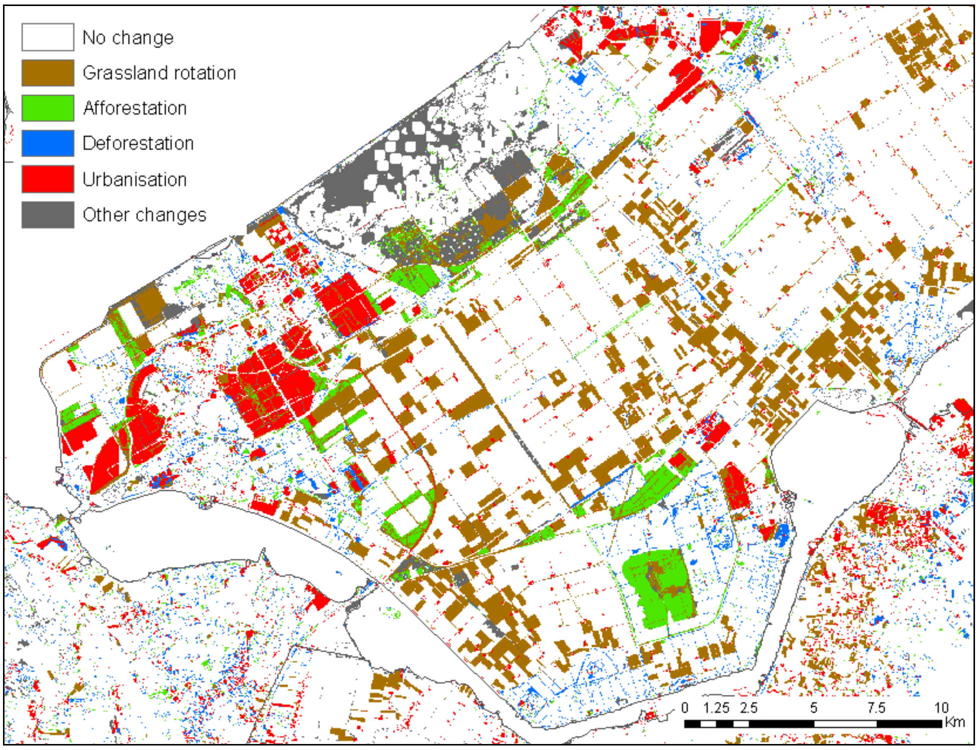


Figure 7. The main land use change processes for the southern part of Flevoland (location C in Figure 4)

In Table 8 the main land use change processes for the period 1990-2004 are summarised. As said before about 16% of the total area changed land use during this period. Most of the land use change is related to the conversion of grassland to cropland and vice versa (9%), which is mainly related to the system of rotational grasslands, which is nowadays a standard management in large parts of The Netherlands. Also urbanisation is with almost 4% an important driver of land use change. Afforestation is about 1.0% and deforestation about 0.8%, which means a net increase in Forest land.

Table 8. Occurrence of the main land use changes in the period 1990-2004

Land use change process	Area (km^2)	Percentage of total
No Change	34826	83.9
Grassland rotation	3734	9.0
Afforestation	415	1.0
Deforestation	322	0.8
Urbanisation	1635	3.9
Other changes	583	1.4

4.4 Comparing LUC matrix and statistical data on land use change

Statistics Netherlands (CBS) regularly updates its statistics on land use ('bodemgebruik'). The legend shows eighteen classes. In Figure 8 the results for both the land use matrix and the CBS statistics are presented. Both legends are aggregated at a comparable level of six main land use classes.

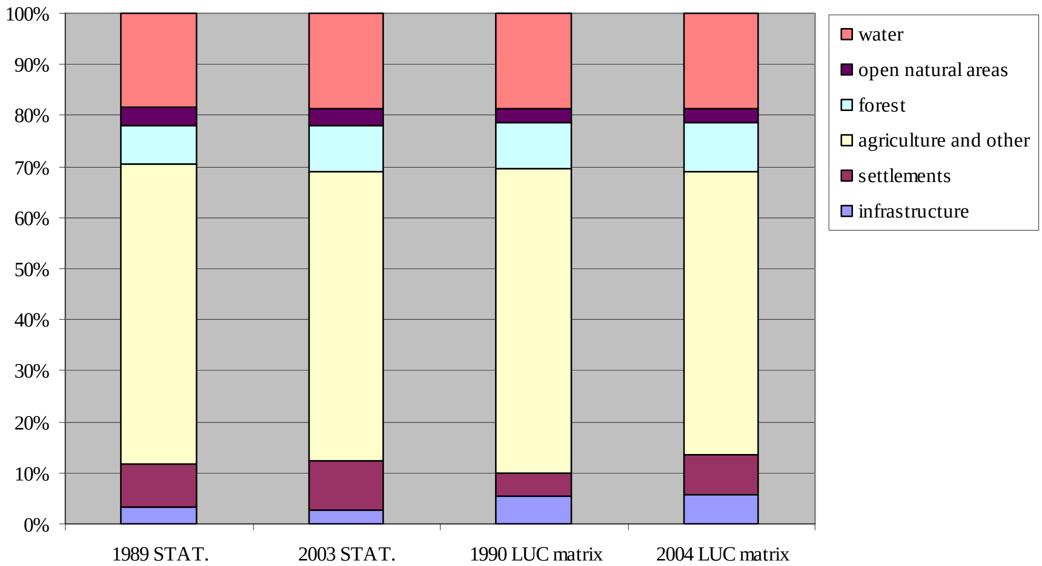


Figure 8. Land use in/around 1990 and 2004 according to the Dutch Bureau for Statistics and according to the land use and land use change matrix presented in this report

The Figure shows that the subdivision between infrastructure and settlements differs between the LUC matrix and statistics. If these two classes are combined the difference is reduced. The main reason for this significant difference is the use of a datasets on road and railway infrastructure in the LUC matrix. In the statistics the roads are often included in the settlements and therefore underestimated. A second difference is the somewhat lower area 'open natural terrain'. In the LUC matrix this category reflects the area with heather, reed swamp, dunes and beaches. In the statistics this class is just one category. It is assumed that the 'Basiskaart natuur' better reflects the areas compared to the statistics. If the area 'open natural terrain' is added to the area forests both approach are very comparable in area. The conclusion is that the LUC matrix and the Statistical information show results that, although the difference in source, are rather comparable.

From both the land use change matrix and the statistics we learn that there are several significant changes in the period 1990-2004. The first one is the increased area of settlements and infrastructure and the second one is the decrease in agriculture in favour of urban developments and natural land use.

4.4.1 Trends in settlements and forest

Settlements: According to the land use matrix the major development in land use since 1990 up to 2004 is the change from arable and grassland areas to settlements and infrastructure. This change is both in area and in rate the most significant. Of the total area of settlements in 1990 93% is also settlement in 2004 and 5% is converted to grasslands ('other grassland') and the remaining is converted to forest, small forests and water. The category 'other grasslands' covers both agricultural grassland (about 70%) and grassland used otherwise (about 30% and are mainly parks, playing ground, roadsides, sporting facilities, recreational areas). It is likely that the conversion from settlements to grasslands is mainly to the grasslands that are linked with the urban environment. The yearly conversion from settlement and infrastructure to grassland is about 750 ha. In 2004 about 70% of the settlements and infrastructure had the same land use in 1990. The increase in settlements and infrastructure was mainly on land formerly used for agriculture. According to the matrix 14% was from grasslands, 14% was from arable land and 2% from forests (Figure 9). These conversions are very likely because the extension of urban areas, but also the extension of smaller cities in rural areas, are surrounded by agriculture land. A conversion from natural grasslands and forested areas to settlements is less obvious, mainly because of policy to protect land with natural grassland and forest ecosystems. The 2% from forests is caused by a complex set of reasons. According Dutch law cuttings of trees or a forest should always be compensated (nearby or elsewhere), and it is likely that the decrease due to settlement development is fully compensated in conversions to forests.

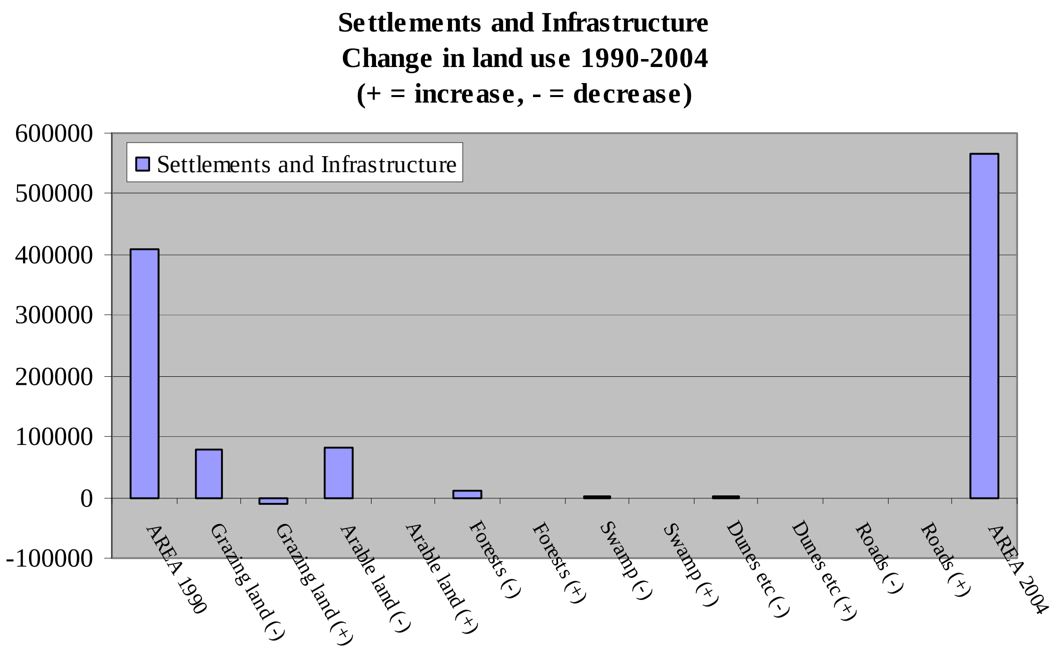


Figure 9. Change in land use categories Settlements and Infrastructure between 1990 and 2004

Forests: the development in forested area is especially considered because of the strong linkage with the carbon balance. Of the total area forest in 1990 92% is also forest in 2004. 2% is converted to grasslands ('other grasslands') and 2% is converted to settlements. In 2004 about 90% of the forests were also forests in 1990. The increase in forests was mainly on land formerly used for agriculture. According to the matrix 3% was from grasslands and 3% was from arable land.

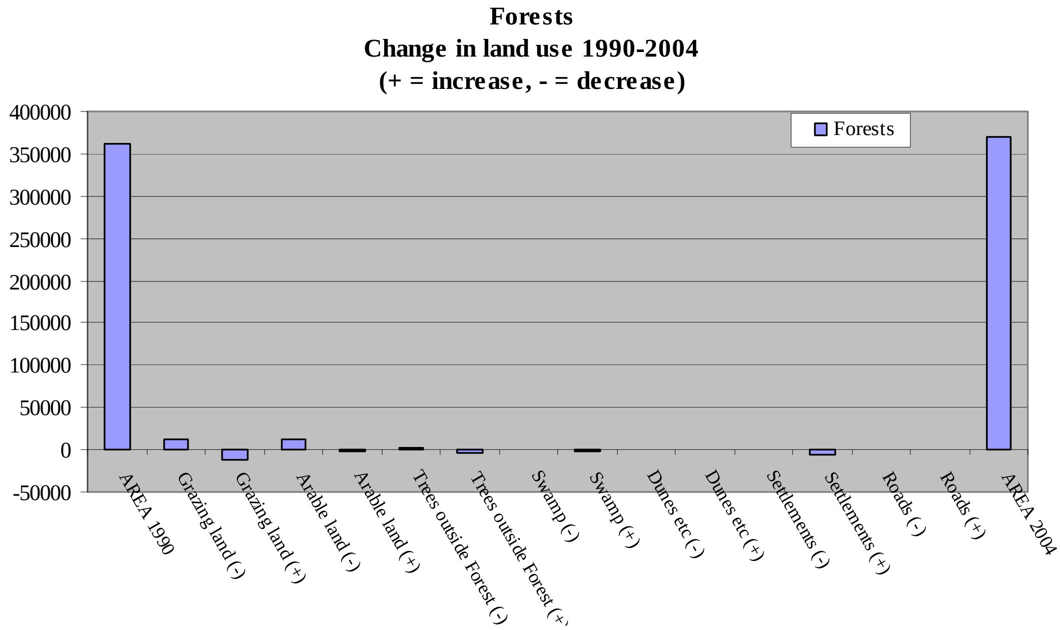


Figure 10. Change in land use category forests between 1990 and 2004

4.4.2 Autonomous and policy driven developments

For a better understanding of the changes in land use and to check whether the results of the matrix are plausible various sources of information are available. In the former paragraph the spatial statistics on land use where discussed. In this context we have distinguished two major sources: the more general statistics and policy information.

The first source includes national statistics on demography, building and housing, infrastructure, and agriculture etc.. Such statistical datasets do reflects trends at regional and national level in land use, but lack the ability to show the processes behind and only present net result of a development instead of presenting the increases and decreases. Especially in land use analysis such information is relevant.
The second source is information on national or sub-national policies, especially those that have a direct impact on land use are relevant in this context. Some examples of such policies are policies directed towards urban extension (e.g. so called 'VINEX' locations), long-term planning of infrastructural developments (e.g. extension of roads, new roads, harbour extensions, airport extension), new locations for businesses and industry outside residential areas and nearby main infrastructure, development of the main ecological structure ('EHS'), policies in agriculture ("Reconstructiewet concentratiegebieden", "Ruimte voor Ruimte" directive), policies

in rural areas that lead to new functions of former terrains and buildings (e.g. re-use military terrains, integration of 'care centre' in urban regions).

4.4.3 Major developments

From the land use change matrix and statistical information was learned that major changes in land use are the growth of the area with settlements and infrastructure and the extension of the area for nature, both at the cost of the agricultural area. In the middle and at the end of the 90's the Dutch economy was booming. Over the period 1990-2004 the population increased with 9% and in the same time the number of households increased with 16% and the number of houses increased with about one million. The economic growth also contributed to an increase in recreational houses (almost 40%), golf courts (80%) and horse stables (50%).

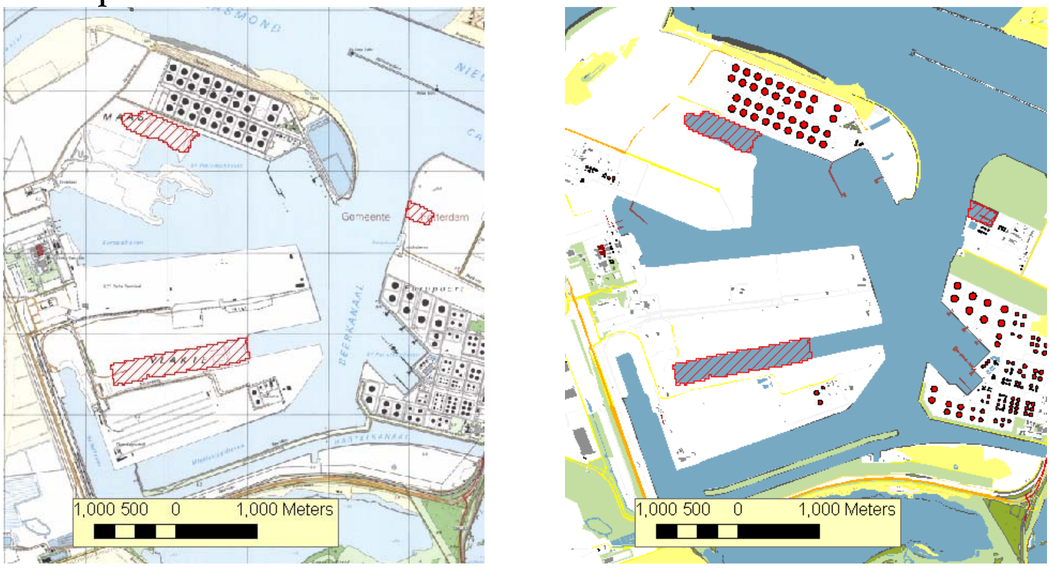
According to CBS statistics the growth in settlements (categories 'built-up land' and 'semi-built-up land') was 12% of which 40% was due to extension of the area for enterprises. In a comparable period the amount of km's highway increased with about 15% (period 1990-2005). In the period 1990-2004 not only autonomous demographical and economic development effected land use but also policies with a direct impact in land use were valid. The most outspoken policies are directed towards the development of a national ecological network (NEN, Nature 2000). This has stimulated the change in land use from agriculture, and to less extend from settlements and infrastructure. In the period 1990 to 2004 about 50,000 ha land was acquired for this purpose.

Most of the changes in land use where on the account of agricultural land. In the period 1990-2004 the total land area used for agriculture decreased with 51,000 ha to 1,955,000 ha in 2004. These figures are according to the Netherlands agricultural Statistics and only reflect those activities on farms that exceed a certain minimal economic size (e.g. minimum of 2 cows or 200 m^2 paprika's). Of the agricultural area about 50% is grassland. The remaining area is mainly arable land, maize land, vegetables, horticulture, bulbs and flowers (including greenhouses). Since 1990 the area of grassland, sugar beet and potatoes decreased and the area maize, seed onions and fallow land increased. The area grassland is not a fixed area. Part of it permanent, but a growing area is temporary grassland (often in combination with the production of silage maize). Besides the shifts in cultivation and the small decrease in area the most significant change is the drop in the number of farmers. Since 1990 the number of farmers decreased with about one third. Especially the number of small farmers dropped significantly and the number of large farmers doubled. This development clearly reflects the increase in scale since the land area only decreased a few percent. The CBS land use statistics and the land use matrix both present figures that do not match with the agricultural statistics. Partly, it is due to the above discussed minimal economic size (agricultural statistics) and partly because of the definitions. In the land use matrix and the CBS land use statistics the category 'agricultural land' is wider defined and does includes grasslands outside the main agricultural function (e.g. road banks, parks). The large decrease in number of farmers has also consequences for the farmhouses and stables. The farmhouses often get a new housing function, whereas the unused stables are demolish, or demolished in combination with the permission to build a few new houses (‘ruimte voor ruimte regeling’). This development, together with an increase in economic activities which are not related to agriculture, caused a continuous increase in built-up land in the rural areas. This, but also the attractiveness of the rural areas for urban citizens has contributed to in increase of area of settlements in rural areas. Figures from 1996-2004 show an increase of about 20%.

4.5 Counterintuitive land use changes: examples and explanations

4.5.1 Disappearance of built-up area between 1990 and 2004

Built-up area in 1990 and water in 2004



Top25 1990 Top10 2004

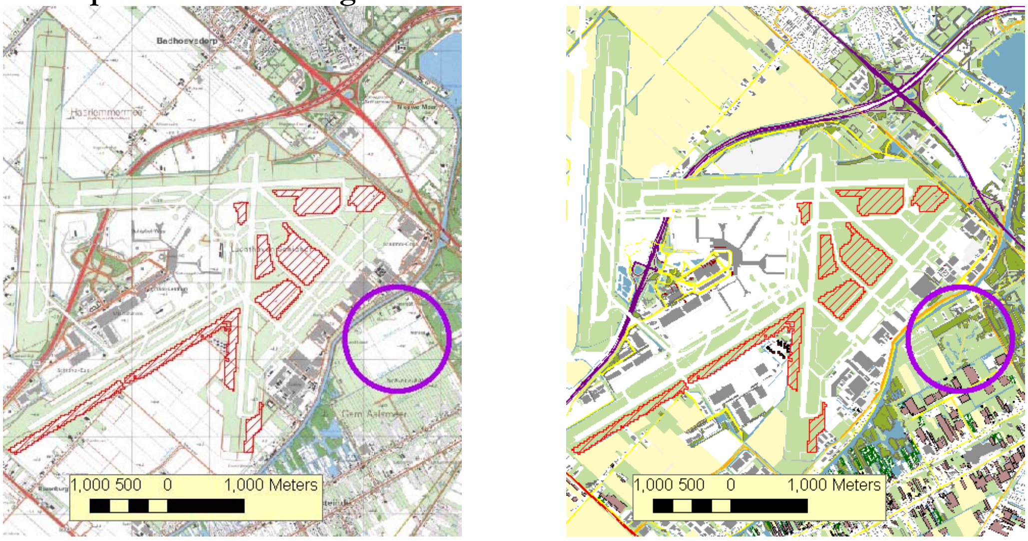
Figure 11. Industrial harbour 'Maasvlakte' (west of Rotterdam)

The three red shaded area’s in Figure 11 are an example of newly created water in area’s that were classified as built-up area in 1990. This is a part of the development of the harbour. The white areas in this figure are classified as built-up area in 1990 and 2004 because they are a part of the industrial complex of the harbour.
This figure also shows examples of the transition from:

- built-up area to grassland (white in 1990 and green in 2004)
- built-up area to sand plates (white in 1990 and yellow in 2004)
- water to built-up area (blue in 1990 and white in 2004)
- sand plates to built-up area (yellow in 1990 and white in 2004)

All these transition are due to planned activities, both industrial and nature development. They can occur through the whole of the Netherlands.

Built-up area in 1990 and grassland in 2004

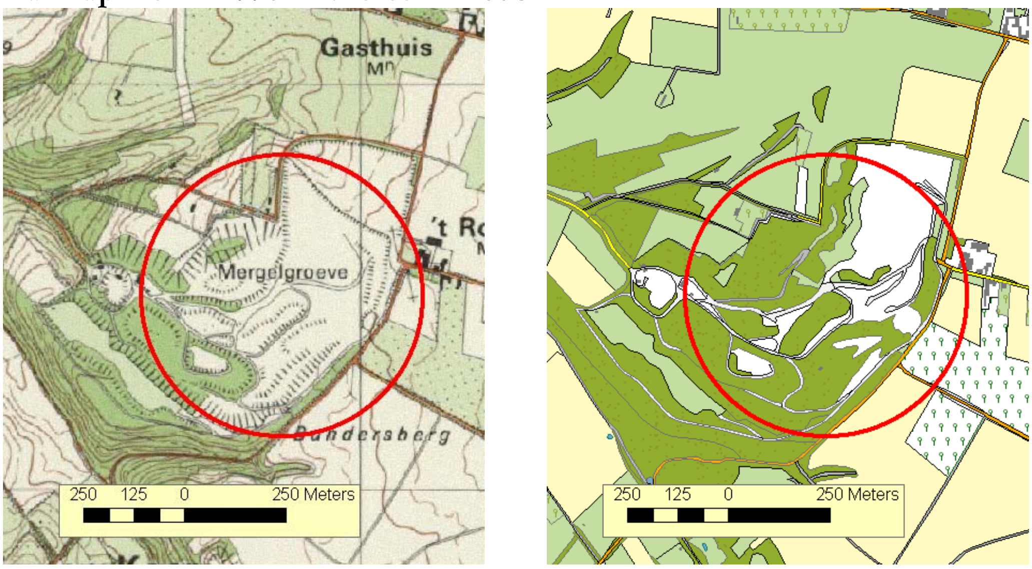


Top25 1990 Top10 2004

Figure 12. Schiphol airport

The nine red shaded area's in Figure 12 are an example of the transition from built-up area to grassland. These areas belong in both years to the domain of the airport but land cover has changed. The topographic map from 1990 (Top25) does not indicate whether these areas are bare soil or do contain some kind of pavement. These areas are classified as built-up because they are white on the map and are within the domain of the airport. The area indicated by the purple circle shows the transition from arable land in 1990 to forest, water and grassland in 2004. This is a part of the Schinkelpolder where the zoning plan indicates the development of a new recreation/nature area with forest, water and grassland. This kind of transition can be found through the whole of the Netherlands.

Built-up area in 1990 and forest in 2004



Top25 1990 Top10 2004

Figure 13. Marl quarry Het Rooth in Limburg

In Figure 13 the area inside the red circle shows marl quarry that was still in use in 1990 but has been abandoned in 2004. For a part of the marl quarry new forest has been planted.

4.5.2 Disappearance of forest between 1990 and 2004

Forest in 1990 and grassland in 2004

Top25 1990 Top10 2004

Figure 14. Conversion of forest to grassland for a golf course

In Figure 14 the area inside the red circle shows the expansion of a golf course into the forest. Parts of the forest have been replaced by grassland but also part of the grassland has been replaced by water.

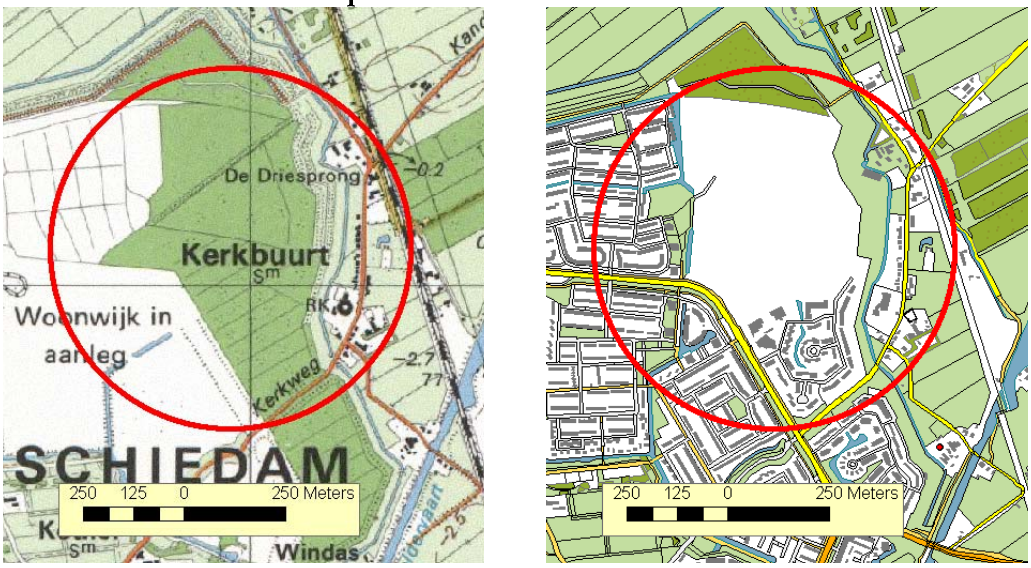
Forest in 1990 and heath land in 2004

Top25 1990 Top10 2004

Figure 15. Nature development in the Slabroeksche Bergen near Uden (Noord-Brabant)

In Figure 15 the area inside the red circle shows an example of nature development. Two plots with forest have been replaced by heath land.

Forest in 1990 and built-up area in 2004

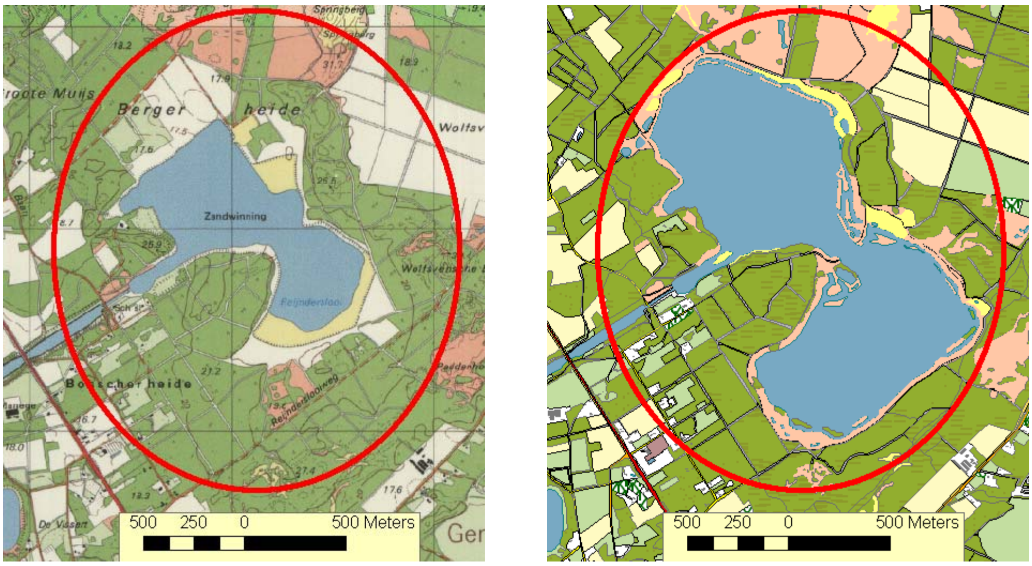


Top25 1990 Top10 2004

Figure 16. Urbanisation in Schiedam (Zuid-Holland)

In Figure 16 the area inside and below the red circle shows an example of urban expansion. The urban expansion is still in motion but the forest area has already been cleared.

Forest in 1990 and water in 2004



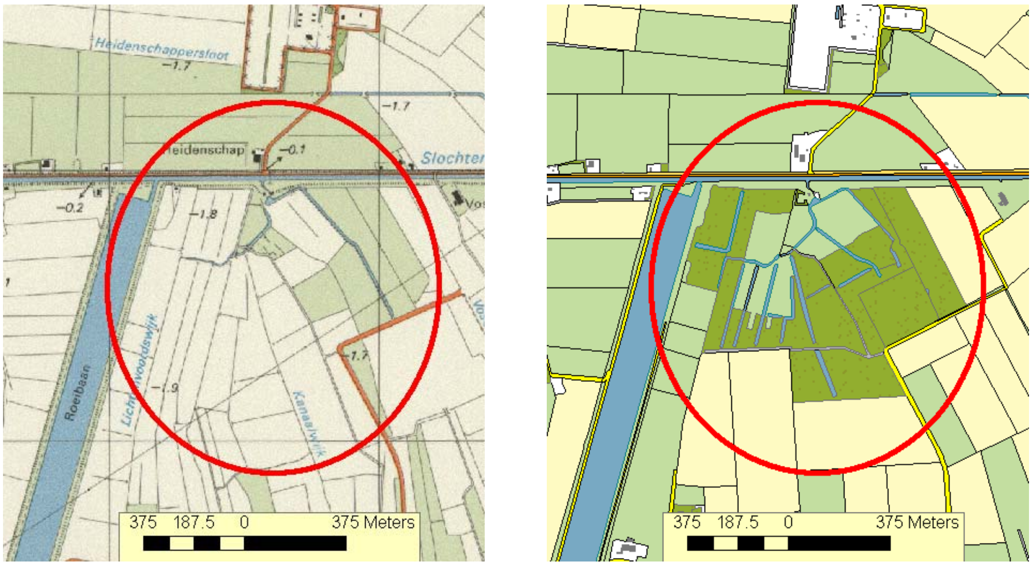
Top25 1990 Top10 2004

Figure 17. Expansion of water due to sand extraction near Well (Limburg)

In Figure 17 the area inside the red circle show an example of the expansion of water due to sand extraction. The extraction area grows into its surroundings, replacing forest, sand, grassland and arable land with water.

4.5.3 New forest in 2004

Arable in 1990 and forest in 2004



Top25 1990 Top10 2004

Figure 18. Conversion of arable land to forest near Groningen

In Figure 18 the area inside the red circle shows another example of nature development. In this location, agriculture land has been converted to a nature area with forest.

Grassland in 1990 and forest in 2004

Top25 1990 Top10 2004

Figure 19. Conversion of grassland to forest north of Leeuwarden

In Figure 19 the area inside the red circle shows an example of nature development. In this location, agriculture grassland has been converted to a nature area with forest and water.

5 Conclusions

During the in-country review in April 2007, the Expert Review Team (ERT) experienced a limited transparency on the procedure and values used for land use and land use change. The information on the land use change matrix was either unpublished or scattered over several reports. This report aims to fill this gap. Simultaneously, updates in methodology and data sets were included to present the best estimate of land use and land use change in The Netherlands that is currently possible. The - sometimes counterintuitive - results were discussed in view of the land use policies in the Netherlands.

The "Basiskaart Natuur" matches the requirements for a primary land use dataset for carbon reporting in a small, intensively managed country as The Netherlands. It is spatially explicit, covers the entire country and the spatial resolution allows sufficiently detailed representation of the fine-grained land use mosaic in The Netherlands. It is the basis for the monitoring of nature in The Netherlands, and as such it has a legal status. It is based on the digital topographical maps (Top10Vector) which had an update frequency of 4 years and will now have an update frequency of 2-4 years. The "Basiskaart Natuur" itself will be updated regularly. The spatially explicit land use map allows overlays with other maps to fulfil additional needs like reporting of areas on peat soils.

The main limitation of the use of the digital topographic maps is that digital maps started only in 1991. For construction of the "Basiskaart Natuur 1990" the gaps have been filled with a secondary data set in compliance with GPG-LULUCF scheme 2.3.2 (p. 2.15). This secondary data set, the scanned paper maps of the Top25, consisted of the same raw information but was available in a different form. Therefore additional steps were taken and auxiliary information was used to assure consistency between the land use maps, as outlined in Chapters 2 and 5.6 (Time series consistency) of GPG-LULUCF.

The land use change matrix was derived by overlaying the 1990 and 2004 land use maps. These results were compared with expectations from policies and other sources. Taking into account all uncertainties, the trends and results from the land use matrix matched other sources remarkably well and could be explained from the specific land use policies in The Netherlands. Validation of the 1990 digitalised raster map against the original sources (paper maps) showed an accuracy of almost 94%. This is within the range given in Table 2.3.6 (p. 2.17) of GPG-LULUCF for the land areas. As mentioned in the table, uncertainty in land use change rates may be much higher due to multiplication of errors.

It is therefore concluded that the approach taken here is in compliance with GPG-LULUCF and gives the best estimate currently possible for land use and land use change for The Netherlands. Inconsistencies that were suspected by the Expert Review Team based on counterintuitive land use change results were either solved as good as possible using auxiliary data sets or - if they were genuine results - explained by examples and land use policies specific to The Netherlands. The approach taken will allow frequent updates of land use maps in the future, consistent with land use maps used for national purposes.

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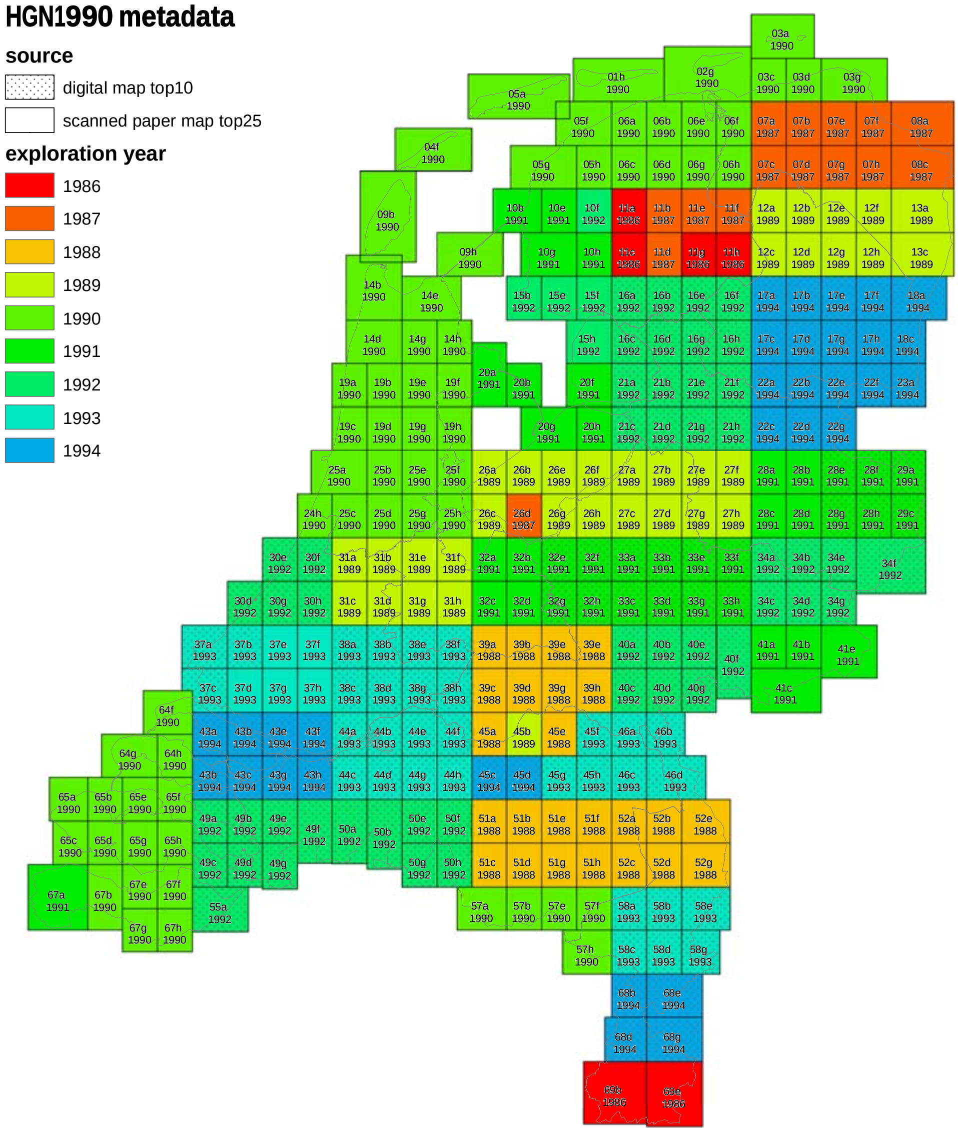
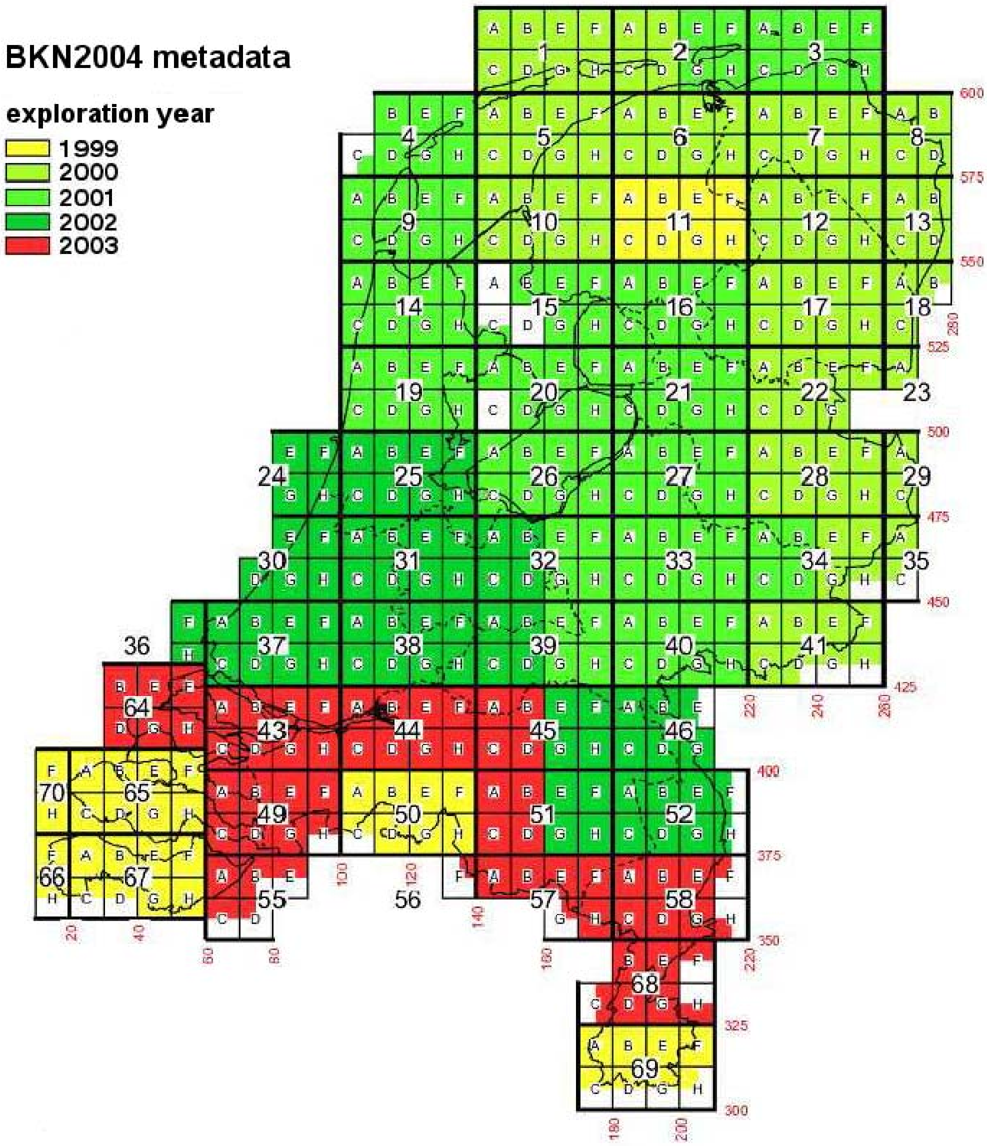
Annex 1 Source map and exploration year by map sheet used for BN1990



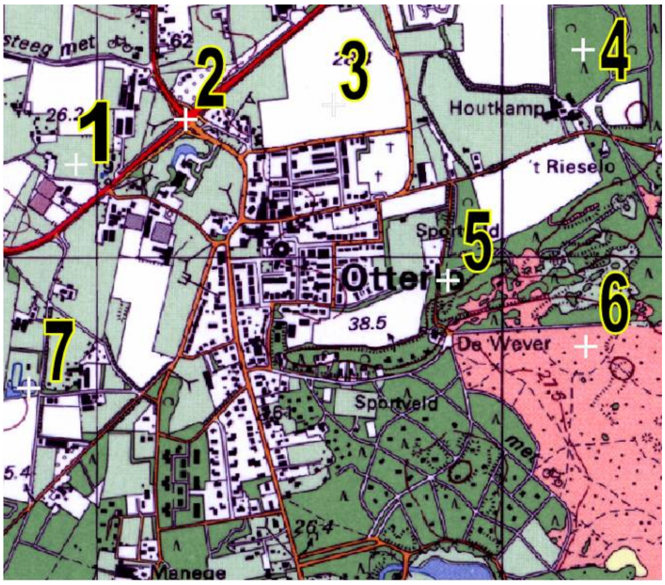
Annex 2 Exploration year by map sheet used for BN2004



Annex 3 Procedure to go from paper to digital map

Paper topographic maps with information on historical land use

The topographic maps 1:25,000 (Top25) which were produced around 1990 are the main source for the 1990 land use database. Figure 20 shows an example of the land use information that is available in this map.



Land use :
1 : grassland
2 : main road
3 : arable land
4 and 5 : forest
6 : heath land
7 : water

buildings are drawn in black and grey but annotation is also drawn in black.

Figure 20. Topographic map from 1990 with land use examples

Different land use classes can have the same colour in the topographic map. Built-up area, arable land and local roads are all represented by the colour white. The actual land use class can only be established from its shape or geographical connection. All forest is printed with a dark green colour. The difference between coniferous and deciduous forest is indicated with symbols.

From paper topographic map to georeferenced digital map

A land use database can be create from paper maps by scanning the maps and georeferencing the scanned maps to the reference coordinate system, the RD-system for The Netherlands. This way, a digital topographic map for the whole of The Netherland was created. This digital map does not contain any thematic information yet, it's only available as a picture. These pictures can be processed to create the land use database.

Digitising the information in the map: colours on paper represent land use classes

In a scanned topographic map, all colours are stored as a reflection value for the three primary colours: red, green and blue. Figure 21 shows these reflection values for seven locations.

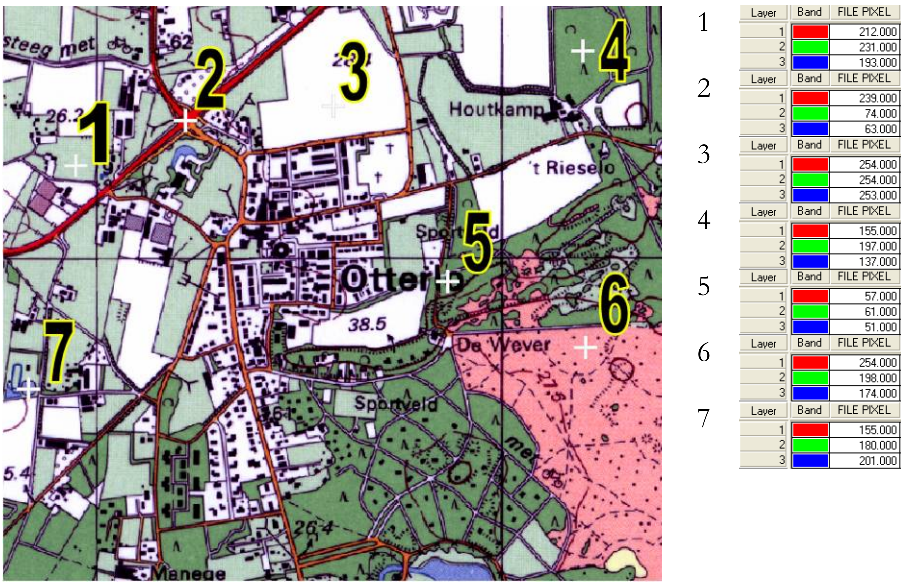


Figure 21: Scanned map with seven locations (1-7) for which the reflection values of the pixels are shown

Using image processing techniques that are commonly used for the classification of satellite images, the scanned maps are converted to digital databases that contain information about land cover. Only land cover classes which can be derived from the maps based on a distinctive colour are a part of the database at this point.

Table 9. Land cover classes derived from scanned paper maps

grassland	roads
Agricultural land, bare soil and built-up area	water
Heath land	dunes and sand plates
forest	buildings

Digitising the information in the map: using additional information to create land use classes

Classes where the reproduction colour is not unique for concerning classes must be classified in a derogatory manner. This also applies to classes which are reflected with a symbol or hatching. Additional actions are necessary in the following cases:

1. The classes 'agriculture and bare soil' and 'built-up area' both have been reflected in white on the maps and are assigned to the same preliminary class during the preliminary classification process. For subdividing this preliminary class in the two HGN classes a manual post processing procedure is required. The border of the built-up area is digitized for this purpose and is used to recode the preliminary class to the HGN class 'built-up area'. Digitizing is done by visual interpretation, the border of the built-up area is stipulated by means of the existence of houses.
2. The class 'reed marsh' is reflected on the topographical map with a black point symbol and can only be classified by manual interpretation. This also means a visual interpretation of the area is which is commented as a marsh. A marsh area

is represented on the map with a number of spread symbols. An area with several marsh symbols is digitized as marsh.
3. The class 'greenhouses' is reflected on a part of the used maps with a black line hatching and on another one part with grey/brown colour. This depends on the year on expenditure on the map sheet. For the map sheets where the greenhouses are reflected with a hatching these are digitised manually.
4. The railroads are a part of the class 'built-up area and infrastructure', these are reflected with a black/white block hatching crammed on the maps. These railroads have been digitized as a line where an attribute for the width of the railroad has been taken along. The railroad has been converted on the basis of this width into an area and then incorporated in the preliminary classification result.

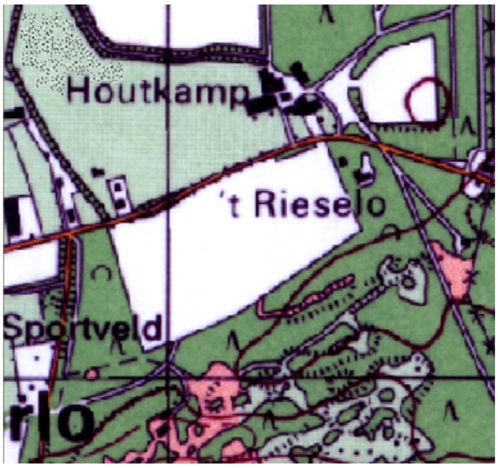
Table 10. Land use classes created after applying additional actions

grassland	water
Agricultural land and bare soil	reed marsh
heath land	dunes and sand plates
forest	green houses
Built-up area, buildings and infrastructure	

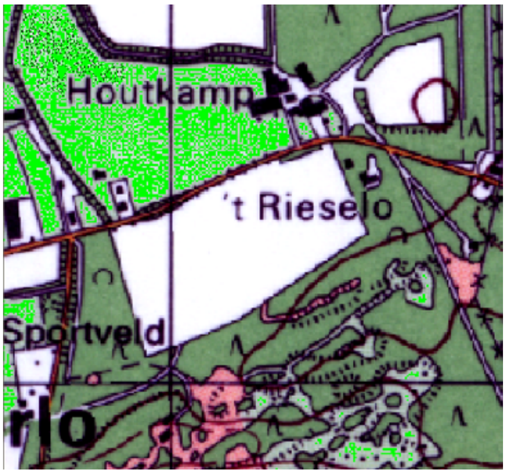
Preliminary classification of the scanned maps: an example

As first step in the classification process the classes have been defined on the basis of different map colours in the legend of the map. The map thereby is considered as reality. The land cover classes mentioned in Table 10 have been distinguished at this point. Figure 21 shows an example of how this process takes place. First, a representative area for the desired land cover class is indicated in the scanned map (Figure 21a). This way, a profile for this class is created. Next, the computer assigns all parts of the scanned map that correspond with this selection to this land cover class (Figure 21b). This was done for all desired land cover classes (Figure 21c).

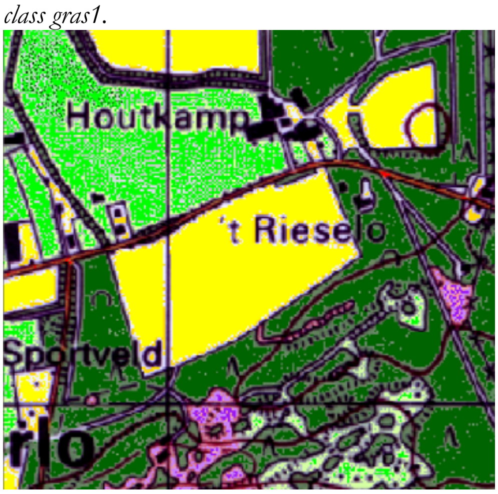
The result at this point is called the preliminary classification. It still contains parts that have not been assigned a value, e.g. all text and symbols in the map.



a: The black/blank dotted line above Houtkamp reflects the area of which the reflection values from the scan are used for the drawing up of the profile for the class gras1.



b: The classification result on the basis of the profile of the class grass 1. In the background the scan is still visible and it also shows grass areas that are not assigned to the class gras1 (in the lower-right part)



c: Classification result with the profiles of all classes. In the background still some parts off the scan remain visible, these are non-classified areas (e.g. black colour, the text)

Class #	>	Signature Name	Color
1	>	gras1	
2		gras2	
3		kaal1	
4		bos1	
5		heide1	
6		heide2	
7		kaal2	
8		weg1	
9		weg2	

d: Overview of all produced classes. A class can be represented by several profiles.

Figure 21. Creation of profiles for several classes

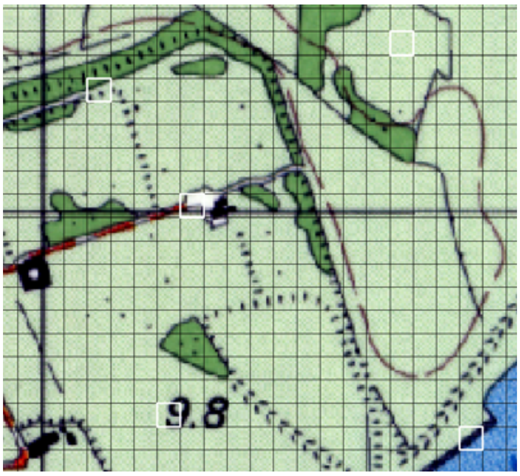
Annex 4 Thematic aggregation towards a 25 m × 25 m raster file

The procedure of classifying scanned topographical maps assumes an incomplete preliminary classification with a detail 2.5 meters grids, the geometrical detail on which the maps are scanned. Incomplete means that there are still many not-classified pixels present. These are for example the cartographic elements as text and hatchings, but also not decisively colours in the scan. Such cloggings disappear mainly at aggregation. The final detail for the land use database is 25 meters. During the aggregation process to 25 meters grids nearly all not-classified pixels are assigned to the dominant land use class. Also at this grid size the impact of geometrical inaccuracy has been limited. For each 25 meter grid cell, a majority rule is applied. The majority of all underlying 2.5 meter grids is calculated with exclusion of the not-classified cells. During this process, linear features like roads and others small features like buildings that are smaller than 12.5 meters disappear, these form almost never a majority. Roads and buildings were combined with built-up area to make sure that these features a still represented in the final land use database.

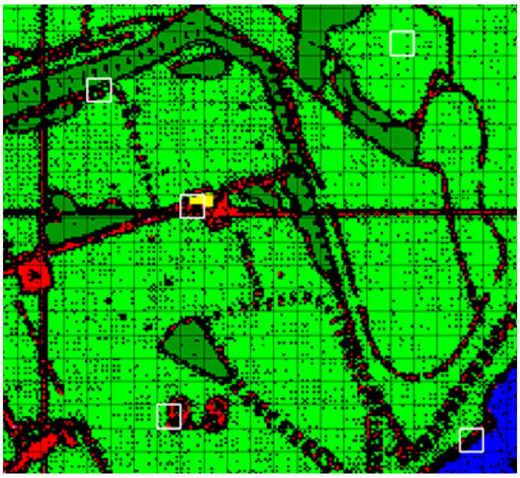
An example of the thematic aggregation process is shown in Figure 22. Five example locations (1-5) are shown to comment the functioning of the majority rule. For a large number of grid cells the assignment of the majority is univocal.

On location 1 only 2.5 meters grid cells from the preliminary classification of the class grassland and not-classified are contained within 25-meter the grid cell. The majority thus is grassland.

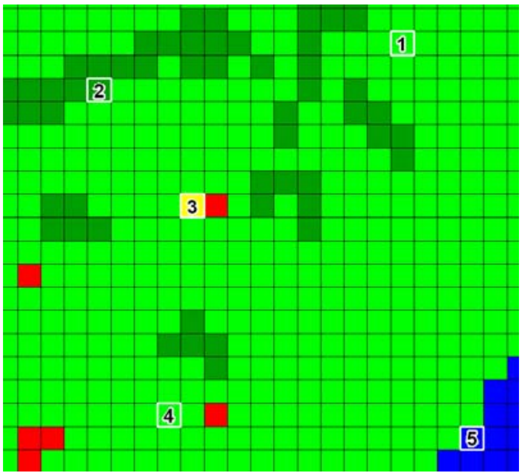
Location 2 concerns a 25-meter grid cell with forest, grassland and cartographic symbols for relief. The border between forest and grassland and the symbols has been incorporated in preliminary classification as not-classified. Within the 25 meter grid cell it is notable that not all the light green colour has been assigned to grassland in the preliminary classification. The colours on the black border and symbols deviate too much from the established profile for the class grassland and are assigned to the preliminary class not-classified. At grid cells which lie on the border of two land use classes this can cause the majority rule not to calculate the desired class for 25-meter grid cell. On this location the calculated majority from the preliminary classification is forest whereas on the scan it is clear to see that this should be grassland.



a. Scan with 25 by 25 meter grid border overlay



b. preliminary classification with 25 by 25 meter grid border overlay



c. Aggregation of the preliminary classification with numbers of the example locations

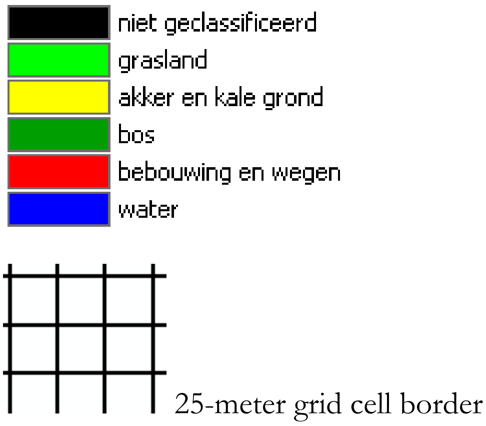


Figure 22. Example of the thematic aggregation process

On location 3 occurs a mix of red (roads), white (agriculture) and black (map lines). The colour white has been well incorporated in the preliminary classification as the class agriculture, the rood as roads and built-up area and the black has been taken as roads and built-up area or as not-classified. The black buildings in the scan can be classified on the basis of its colour profile. The majority of the black in the scan (text, hatchings) deviates with regard to colour assignment enough from black buildings and as far as it is classified as the class buildings this is generally a small number of grid cells in the preliminary classification which within a 25-meter grid cell will not be the majority. On this location the correct majority is calculated, the class agriculture / bare soil.

Location 4 concerns a mix of grassland, black text classified as preliminary class 'buildings' and the class not-classified. For this location, the majority rule calculates the correct class value, the majority of the 25-meter grid cell is grassland. Two grid cells to the right an example of an incorrect majority calculation is shown. Here the calculated class is built-up area and roads. Seen from the basis material, this is correct, the majority within the 25-meter grid cell is black text. A visual interpretation of this area this would however result in the class grassland. The cartographic symbols cover here the actual land use. In figure 2.7b and c it is clear to see that in general this goes well. The largest part of text and hatchings that is incorporated as a built-up area in the preliminary classification disappears after aggregation with the majority rule. In the 25-meter grid file, the concerning locations do have the correct HGN class value.

Location 5 gives another example of a 25-meter grid cell on the border between water and grassland. Within this 25-meter grid cell there is almost as much grassland as water. The majority in this case is water.

Annex 5. Definition of land use categories

The IPCC GPG distinguishes six main groups of land use categories: Forest Land, Cropland, Grassland, Wetland, Settlements and Other Land. Countries are encouraged to stratify these main groups further e.g. by climate or ecological zones, or special circumstances (e.g. separate forest types in Forest Land) that affect emissions. In the Netherlands, stratification has been used for Forest Land, Grassland and Wetlands.

The natural climax vegetation in the Netherlands is forest. Thus, except for natural water bodies and coastal sands, without human intervention all land would be covered by forests. Though different degrees of management may be applied in forests, all forests are relatively close to the natural climate vegetation. Extensive human intervention creates vegetation types that differ more from the natural climax vegetation like heathers and natural grasslands. More intensive human intervention results in agricultural grasslands. In general, an increasing degree of human intervention is needed for croplands and systems in the category Settlements are entirely created by humans. This logic is followed in the allocation of land to land use categories. In addition, lands are allocated to wetlands when they conform to neither of the former land use categories and do conform to the IPCC GPG definition of wetlands. This includes open water bodies, which are typically not defined as wetlands in the scientific literature. Until the 2008 submission, open water bodies were included in the Other Land category for that reason. However, from the 2009 submission on they form a separate subcategory of wetlands. The remaining lands in The Netherlands, belonging to neither of the former categories, are sandy areas with extremely little carbon in the soil. These were and are again included in Other Land. See for more information about the definition of the land use categories also Van den Wyngaert et al. (2009).

Forest Land

The land use category "**Forest Land**" is defined as all land with woody vegetation consistent with thresholds used to defined forest land in the national GHG inventory, sub divided into managed and unmanaged units and also by ecosystem type as specified in IPCC Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed the threshold of the forest land category (IPCC, 2003, 2006).

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

- "Forest" or "Forest according to the Kyoto definition" (FAD), i.e. all forest land which complies to the following (more strict than IPCC) definition chosen by the Netherlands for the Kyoto protocol: forests are patches of land exceeding 0.5 ha with a minimum width of 30 m, with tree crown cover at least 20% and tree height at least 5 meters, or, if this is not the case, these thresholds are likely to be achieved at the particular site. Roads in the forest less than 6 meters wide are also considered to be forest. This definition conforms to the FAO reporting and was chosen within the ranges set by the Kyoto protocol.

- "Trees outside Forests" (TOF), i.e. wooded areas that comply with the previous forest definition except for their surface (=< 0.5 ha or less than 30 m width). These represent fragmented forest plots as well as groups of trees in parks and nature terrains and most woody vegetation lining roads, fields etc. These areas comply to the GPG-LULUCF definition of Forest Land (i.e. they have woody vegetation) but not to the strict forest definition that The Netherlands applies.

The TOP10Vector map classes that are reported under FAD and TOF are deciduous forest, coniferous forest, mixed forest, poplar plantations and willow coppice. A patch of a certain forest class is allocated to FAD if it exceeds the minimum requirements and to TOF otherwise. Groups of trees are mapped as forest only if they have a minimum surface of 50 m^2, or of 1000m^2 in built-up areas or parks.

Cropland

The land use category "**Cropland**" is defined as all arable and tillage land, including rice-fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category (IPCC, 2003).
The Netherlands has chosen to define croplands as arable lands and nurseries (including tree nurseries). Intensive grasslands are not included in this category and are reported under Grasslands. For part of the agricultural land, rotation between 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 land under agricultural crops and classified as arable land at the time of recording reported under Cropland and land with grass vegetation at the time of recording classified as Grassland.
The TOP10Vector class arable land is reported under Cropland, as well as the class Tree nurseries. The latter does not conform to the forest definition, and the agricultural type of farming system justifies the inclusion in Cropland. Greenhouses are not included in Cropland, but instead they are considered as Settlement.

Grassland

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

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

The Netherlands currently reports under grassland any type of terrain which is predominantly covered by grass vegetation (equivalent to one general class of grasslands on the TOP10Vector maps). No distinction is made between agricultural intensively and extensively managed grasslands and natural grasslands. However, the potential and the need for this is currently under discussion.
Apart from pure grasslands, all orchards (with standard fruit trees, dwarf varieties or shrubs) are included in the category grasslands. They do not conform to the forest definition, and while agro-forestry systems are mentioned in the definition of Croplands, this is motivated by the cultivation of soil under trees. However, in The Netherlands the main undergrowth of orchards is grass. We therefore chose to report them as grasslands. As for grasslands no change in above-ground biomass is reported, the carbon stored in these trees is not reported.
The TOP10Vector map class heath land, reported as "Nature", includes all land that is covered (mostly) with heather vegetation or rough grass species. Most of these were created in The Netherlands as a consequence of ancient grazing and sod cutting on sandy soils. As these practices are not part of the current agricultural system anymore, conservation management is applied to halt the succession to forest and conserve the high landscape and biodiversity values associated it.

Wetland

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

Though The Netherlands is a country with many wet areas by nature, many of these are covered by a grassy vegetation and those are included under grasslands. Some wetlands are covered by a more rough vegetation of wild grasses or shrubby vegetation, which is reported in the subcategory "Nature" of Grassland. Forested wetlands like willow coppice are reported in the subcategories FAD or TOF of Forest Land, depending on their surface.
In The Netherlands, only reed marshes and open water bodies are included in the Wetland land use category. Reed marshes are areas where the presence of Common Reed (*Phragmites australis*) is indicated separately on the TOP10Vector maps. These may vary from wet areas in natural grasslands to extensive marshes. The presence of reed is marked with individual symbols which are translated to surfaces (Kramer et al., 2008) and conform to neither of the previous categories.

Open water bodies are all areas which are indicated as water on the TOP10Vector maps (water is only mapped if the surface exceeds 50 m^2). This includes natural open water in rivers, but also man-made open water in channels, ditches and artificial lakes. It includes bare areas which are under water only part of the time as a result of tidal influences, and very wet areas without vegetation. It also includes "wet" infrastructure for boats, i.e. waterways but also the water in harbours and docks.

Settlements

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

In The Netherlands, the main TOP10Vector classes included in Settlements are urban areas and transportation infrastructure, and built-up areas. Built-up areas include any constructed item, independent of the type of construction material, which is (expected to be) permanent, fixed to the soil surface (i.e. to distinguish from caravans,…) and serves as place for residence, trade, traffic and/or labour. Thus it includes houses, blocks of houses and apartments, office buildings, shops and warehouses but also fuel stations and greenhouses.
Urban areas and transportation infrastructure include all roads, whether paved or not, are included in the land use category Settlements with exception of forest roads less than 6 m wide, which are included in the official forest definition. It also includes train tracks, (paved) open spaces in urban areas, parking lots and graveyards. Though some of the last class are actually covered by grass, the distinction cannot be made based on maps. As even the grass graveyards are not managed as grasslands, inclusion in the land use category "Settlements" conforms better to the rationale of the land use classification.

Other Land

The land use category "**Other Land**" was included to allow the total of identified land to match the national area where data are available. It includes bare soil, rock, ice and all unmanaged land area that do not fall in any of the other five categories (IPCC, 2003).

In general, Other Land does not have a substantial amount of carbon. The Netherlands uses this land use category to report the surfaces of bare soil which are not included in any other category. It does not include bare areas that emerge from shrinking and expanding water surfaces (these "emerging surfaces" are included in wetlands).
The TOP10Vector class "Sand" is completely included in it. It includes all terrains which do not have vegetation on them by nature. The last part of the phrase "by nature" is used to distinguish this class from settlements and fallow croplands. "Sand" includes e.g. beaches and coastal dunes with little to 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 wind). Inland bare sand dunes developed in The Netherlands as a result of heavy overgrazing and were combated by planting forests for a long time. These areas were, however, the habitat to some species which have become extremely rare nowadays. Inland sand dunes can be created as vegetation and top soil is again removed as a conservation measure in certain nature areas.