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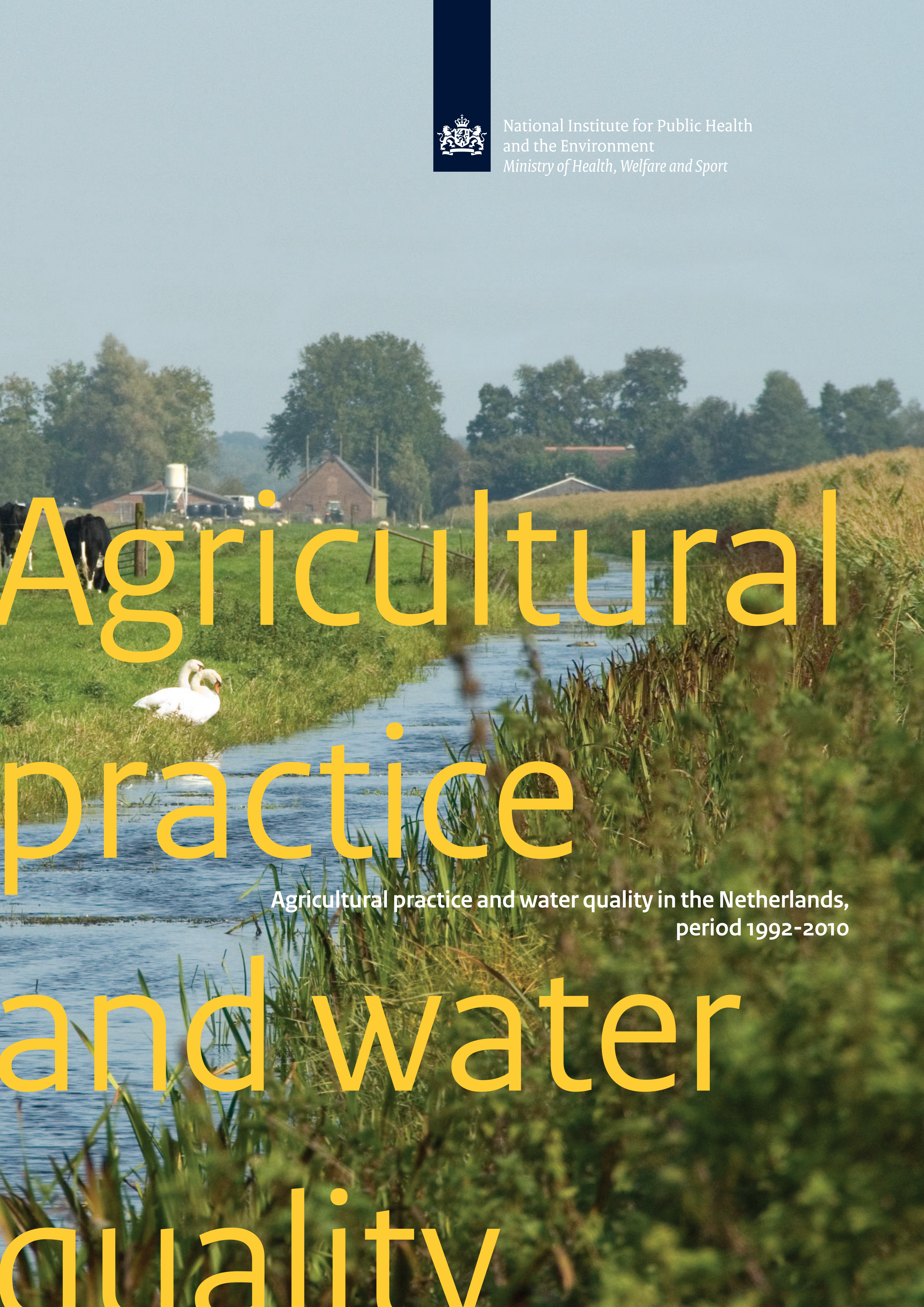

# Agricultural practice and water quality

## Agricultural practice and water quality in the Netherlands, period 1992-2010

National Institute for Public Health
and the Environment
*Ministry of Health, Welfare and Sport*

# Agricultural practice and water quality in the Netherlands in the period 1992-2010

RIVM Report 680716008/2012

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# Abstract


**Agricultural practice and water quality in the Netherlands in the period 1992-2010**

The nitrogen surplus in Dutch agriculture decreased by almost 50% between 1992 and 2010. This decrease is the result of measures applied to Dutch agriculture pursuant to the EU Nitrates Directive, such as using less manure during a shorter period of the year. This improvement is evident from an inventory of changes in groundwater and surface water quality and in agricultural practice. The report on the developments is a four-yearly EU obligation. RIVM (National Institute for Public Health and the Environment) carried out this inventory in cooperation with Statistics Netherlands, the Water Department of the Directorate-General for Public Works and Water Management (RWS), the Agricultural Economics Research Institute (LEI, part of Wageningen University and Research Centre, UR) and Dienst Regelingen (Regulatory Service) of the Ministry of Economic Affairs, Agriculture and Innovation.

**Decreasing nitrate content**
As a result of the implementation of the EU Nitrates Directive, the nitrate concentration in water that leaches from root zones in agricultural land to groundwater and surface water declined steeply between 1992 and 2010. This is especially true of in sandy areas, where the average concentration decreased from 140 mg/l to 60 mg/l. In areas containing clay, the average nitrate concentrations in leaching water also decreased, falling to 29 mg/l. Regarding peat regions, the leaching water there never contains much nitrate (less than 10 mg/l), as nitrate decomposes rapidly in such regions.

**Fresh surface water**
Since 2002, the average nitrate concentration in fresh surface waters has hovered around the same level (15 mg/l from 2008 to 2010). Despite this, between 2004 and 2010 the chlorophyll-a concentration in the summer (an indicator for eutrophication) in regional fresh surface waters affected by agriculture increased slightly.

**Water quality continues improving**
The quality of water in the Netherlands is expected to improve further over the next few years. To be precise, it will actually take some years before the measures implemented under the current action programme (2010-2013), such as more stringent application standards for manure, expressed as nitrogen content, lead to better water quality.


Keywords: nitrates directive, agricultural practice, groundwater and surface water quality

# Rapport in het kort

**Landbouwpraktijk en waterkwaliteit in Nederland, periode 1992-2010**

Het stikstofoverschot in de Nederlandse landbouw is tussen 1992 en 2010 met bijna 50% afgenomen. Dit is een gevolg van maatregelen die vanwege de Europese Nitraatrichtlijn in de Nederlandse landbouw zijn genomen, zoals minder mest gebruiken gedurende een kortere tijd van het jaar. Dit blijkt uit een inventarisatie van de ontwikkelingen in de grond- en oppervlaktewaterkwaliteit en de landbouwpraktijk. De rapportage hiervan is een vierjaarlijkse Europese verplichting. Het RIVM heeft de inventarisatie uitgevoerd met het Centraal Bureau voor de Statistiek, de Waterdienst, LEI (onderdeel van Wageningen UR) en Dienst Regelingen van het ministerie van Economische Zaken, Landbouw en Innovatie.

**Nitraatconcentratie daalt**
Dankzij de uitvoering van de Europese Nitraatrichtlijn is ook de nitraatconcentratie in het water dat uitspoelt uit de ‘wortelzone’ van landbouwpercelen naar het grond- en oppervlaktewater sterk gedaald tussen 1992 en 2010. Vooral in de zandgebieden is dat het geval: in deze gebieden daalde de gemiddelde concentratie van 140 naar 60 milligram per liter. In de gebieden met kleigrond zijn de gemiddelde nitraatconcentraties in het uitspoelende water eveneens gedaald, naar 29 milligram per liter. In veengrond is altijd weinig nitraat in het uitspoelende water aanwezig (minder dan 10 milligram per liter). Dat komt doordat nitraat in veengronden snel afbreekt.

**Zoet oppervlaktewater**
In zoet oppervlaktewater schommelt de gemiddelde nitraatconcentratie sinds 2002 rond hetzelfde niveau (15 milligram per liter in 2008-2010). Desondanks is tussen 2004 en 2010 de chlorofyl-a-concentratie in de zomerperiode (een indicator voor eutrofiëring) in regionale zoete oppervlaktewateren die door de landbouw worden beïnvloed licht toegenomen.

**Waterkwaliteit blijft zich verbeteren**
Het is te verwachten dat de waterkwaliteit in Nederland in de komende jaren verder verbetert. Het duurt namelijk enkele jaren voordat de maatregelen uit het huidige actieprogramma (2010-2013), zoals aangescherpte gebruiksnormen voor mest, uitgedrukt in de hoeveelheid stikstof, zich vertalen naar een betere waterkwaliteit.

Trefwoorden: nitraatrichtlijn, landbouwpraktijk, grondwater- en oppervlaktewaterkwaliteit

# Preface

This report was prepared by order and for the account of the Ministry of Infrastructure and the Environment (IenM) and the Ministry of Economic Affairs, Agriculture and Innovation (EL&I). Kaj Locher as project supervisor represented the Ministry of IenM, and Martin van Rietschoten represented the Ministry of EL&I. The authors of this report would like to thank both gentlemen for their discerning questions and comments. Our thanks also go to Jaap Willems of the Netherlands Environmental Assessment Agency and Gerard Velthof of Alterra, part of Wageningen UR, who checked the final draft of the report and helped improve the consistency of the conclusions presented here with those presented in other reports being prepared for the Evaluation of the Fertilisers Act 2012.

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# Contents

# Summary and conclusions


**Introduction**
This report provides the background information for the Netherlands Member State report that is obligatory under the EU Nitrates Directive. It has to be submitted to the European Commission in mid-2012. The contents of this Member State report conform to the guidelines published in November 2011. The report covers the period 1992-2010, with data for 2011 also presented if available.

The report provides an overview of current agricultural practices, and groundwater and surface water quality in the Netherlands, outlines the trends in these waters and assesses the time scale for change in water quality due to changes in agricultural practice. The implementation and impact of the measures taken as part of the action programmes are described, including a forecast of the future evolution of water body quality.
The data presented in this background document are for the period preceding the First Action Programme (before December 1995) as well as the period of the First (1995-1999), Second (1999-2003), Third (2004-2009), and partly the Fourth Action Programme (2010-2013).

**Agricultural policy measures and practice**
*Policy measures*
The system of manure bookkeeping (introduced in 1987) was replaced in 1998 by a system of minerals accounting, known as MINAS. It was based on the mineral balance of nitrogen (N) and phosphorus (P) (farm gate balance). Under this system, limits were set for the permitted levels of the N and P surpluses on farms (MINAS loss standards). These loss standards have gradually been tightened. On 1 January 2002, the Manure Transfer Contracts (MAO) system came into force to ensure compliance with the application limits under the Nitrates Directive. Livestock farmers who produced too much manure were obliged to enter into manure transfer contracts with arable farmers, other less intensive livestock farmers or manure processors. The MAO system was abolished in early 2005. In January 2006, the Netherlands adopted a new manure policy based on application limits instead of loss standards. This manure policy, including application limits for nitrogen in manure and fertilisers as stipulated by the Nitrates Directive, also means a further tightening of the regulations governing the use of nitrogen and phosphorus.

*Agriculture in the period 2008-2011*
In the period 2008-2011, the area under cultivation in the Netherlands totalled 1.85 million ha, corresponding to 54.7% of the country’s land surface. Of this area, 52% comprised grassland (81% permanent), 13% silage maize and 29% other arable crops. The rest (6.4%) was used for horticulture. There were about 72,700 farms, of which 52% represented farms for grazing animals, 17% arable farms, 17% horticultural farms, and 14% factory and mixed farms.

Livestock comprised 3.9 million head of cattle, 12.2 million pigs, 98 million head of poultry, and 1.5 million sheep and goats. The livestock produced manure containing about 487 million kg of nitrogen (N) and 77 million kg of phosphorus (P). Cattle manure was responsible for some 58% of the nitrogen and 51% of the phosphorus. Of the phosphorus in the manure, around 22% was exported or used for non-agricultural purposes; for nitrogen, the amount was about 11%. Nitrogen (N) input to agricultural soils was on average 354 kg/ha, of which

186 kg/ha was via manure, 120 kg/ha via artificial fertiliser and 47 kg/ha via atmospheric deposition and other sources. The nitrogen surplus on the soil surface balance was on average about 145 kg/ha. Phosphorus (P) input to agricultural soils was on average 38 kg/ha, of which 33 kg/ha was via manure, 4 kg/ha via artificial fertiliser, and 2 kg/ha via other sources. The phosphorus surplus on the soil surface balance was 9 kg/ha on average.

*Trends in agricultural practice in the period 1992-2011*
The land area used for agriculture in the period 1992-2011 shrank by 6.2% and the number of farms by 38%. The number of cattle decreased by 18% and the number of pigs by 16%. By contrast, the number of poultry increased by 4%.

Nitrogen and phosphorus in manure from livestock decreased by 30% and 23% respectively, due to the combined effect of a reduction in the number of livestock and in the amount of mineral excretion per animal. The latter was a consequence of lower nitrogen and phosphorus content in fodder and improved fodder conversion. As a result of this, as well as from a steep decline in the use of artificial fertiliser, the nitrogen and phosphorus surpluses in Dutch agriculture decreased by 48% and 75% respectively (Figure S1).

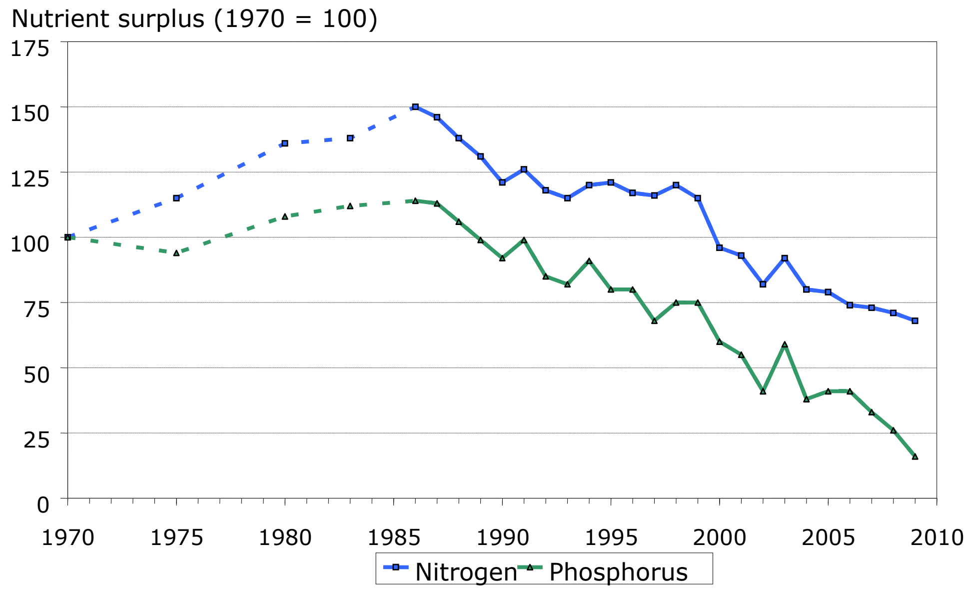


*Figure S1. Trends in the nitrogen and phosphorus surpluses in Dutch agriculture in the period 1970-2009, with 1970 values defined as 100.*

Compared with the previous reporting period (2004-2007), the net manure transport (difference between input and output) increased significantly in a number of areas. Exports (to other countries) increased threefold.

Ammonia emissions from agricultural sources into the atmosphere continue to decrease, for the latest reporting period (2008-2010) being 55% below the level for the period 1992-1995.

By comparison with the previous reporting period, the storage capacity for manure has expanded substantially. In 2010, 96% of dairy farms, 95% of pig farms and 87% of intensive veal calf farms had storage facilities sufficient for at least six months of manure production.

**Quality of groundwater and surface waters**
*Nitrate concentrations in the period 2008-2010*
Since changes in agricultural practice affect water leaching from the root zone (leach water) first, it was decided to monitor the effects of the action programmes in the top metre of the groundwater, in tile drain water or in the moisture of soil layers just beneath the root zone. This report also includes the data from nitrate measurements in deeper groundwater and surface waters.

Nitrate concentration decreases the further it is measured from the source, i.e. agricultural activities (see Table S1). This applies to groundwater as regards depth (of measurement) and to surface waters as regards distance. The nitrate concentration in groundwater decreases with respect to depth, which can clearly be seen in Table S1. In surface waters, the nitrate concentration is lower the further away the nitrogen source is. The overview below shows the different types of surface water according to nitrate concentration, from the highest to the lowest: regional waters strongly affected by agriculture > other regional waters > fresh national waters > coastal waters > open sea.

Two factors influence this falling concentration. The first is the conversion of nitrate into nitrogen molecules (denitrification) during transport; the second is the mixing with water originating from non-agricultural areas (dilution). In the case of groundwater, two additional factors play a role: time and the hydrological conditions. Water leaching from a root zone is young water (1 to 5 years old). In the Sand region, groundwater at a depth of 5 to 15 metres has a travel time of approximately 10 years, and groundwater at a depth of 15 to 30 metres, a travel time of approximately 40 years. Hence, groundwater at a depth of 15 to 30 metres reflects agricultural practice of at least 40 years ago. The groundwater at the above-mentioned depths in Clay and Peat regions is generally even older. Hydrological factors (channels) play a key role here, as the groundwater in aquifers in clay and peat areas to a depth of 5 to 15 metres, as well as 15 to 30 metres, is often wholly or partly confined by a weakly permeable clay aquifer. In such regions, the precipitation surplus drains away through the soil surface to the surface water. Wholly and partly confined aquifers also occur locally in the Sand region.

In the Peat region, nitrate concentrations in leach water and groundwater are lower than in the Clay region, the concentrations here being in their turn lower than in the Sand region (Table S1). This is caused by differences in denitrification rates. Soils in the Sand region have the lowest denitrification capacity, soils in the Clay region come next, and soil in the Peat region have the highest.

*Table S1. Average nitrate concentrations measured (in mg/l) and exceedance of the EU standard of 50 mg/l (as a percentage of the number of monitoring wells) in groundwater and surface waters for the period 2008-2010[1].*

| Water type | Sand | Clay | Peat | Loess | All types |
|---|---|---|---|---|---|
| Leaching from root zone (agriculture) | 60 (53%) | 29 (21%) | 7.5 (2%) | 78 (66%) | 48 (38 %) |
| Groundwater at a depth of 5-15 metres (agriculture) | 32 (19%) | <1 (0%) | <1 (0%) | - | - |
| Groundwater at a depth of 15-30 metres (agriculture) | 8 (4%) | < 1 (0%) | < 1 (0%) | | - |
| Groundwater at a depth exceeding 30 metres (phreatic extraction) | 7 (0%) | - | - | | - |
| Fresh surface waters[2] | | | | | |
| Affected by agriculture | | | | | 15 (3%) |
| Other regional water | | | | | 14 (1%) |
| Marine surface waters[2] | | | | | |
| Coastal water | | | | | 4 (0%) |
| Open sea | | | | | < 1 (0%) |

[1] The percentages between brackets are the relative numbers of exceedances of the EU standard of 50 mg/l in the period 2008-2010. For water leaching from a root zone (under 5 metres in depth), the percentage is the relative number of farms with exceedance of the standard. For groundwater at a depth exceeding 5 metres, the percentage is the relative number of wells, and for surface water, the relative number of monitoring locations.

[2] Average nitrate concentrations in the winter, the season when the leaching has a substantial effect on the quality of the surface water.

Around 65% of the total amount of nitrogen found in the Netherlands' fresh surface waters originates from other countries. The remainder found in the Dutch water system originates from various other sources, with leaching and run-off from agriculture as the main sources of nitrogen in the Netherlands. The remainder originates from various other sources.

_Eutrophication state of surface waters in the period 2008-2010_

The eutrophication of surface waters can be assessed from the chlorophyll-a concentration, with the total nitrogen and phosphorus concentrations as state indicators. Just as for nitrates, eutrophication indicators have lower concentrations the further the nitrogen and phosphorus sources are (see Table S2). The overview below shows the different types of surface water according to concentration of eutrophication indicators, from the highest to the lowest: regional waters strongly affected by agriculture > other regional waters > fresh national waters > coastal waters > open sea. At 21% of the regional monitoring locations in waters strongly affected by agriculture and at 13% in other regional waters, the chlorophyll-a concentrations exceed 75 µg/l.

*Table S2. Eutrophication parameters (chlorophyll-a in µg/l and total nitrogen and phosphorus in mg/l), average summer values[1] for different types of surface water in the period 2008-2010.*

| Water type | Chlorophyll-a | Total nitrogen | Total phosphorus |
|---|---|---|---|
| Regional waters affected by agriculture | 46 (21%)[a] | 3.7 | 0.55 |
| All waters | 34 (13%)[a] | 3.1 | 0.25 |
| Coastal water | 9 (0%)[a] | 0.3[b] | - |
| Open sea | 1 (0%)[a] | < 0.5[b] | - |

[1] The average summer values are presented here, as this season is the most significant one for eutrophication.
[a] The percentages in brackets express the proportion of locations with a concentration exceeding 75 µg/l.
[b] Total amount of dissolved inorganic nitrogen.

**Trends in the quality of groundwater and surface water**
<u>*Nitrate concentrations in the period 1992-2010*</u>
In the period 1992-2010, the nitrate concentrations in water leaching from root zones of farms (Figure S2) decreased. This was also the case with farms that exceeded the EU standard of 50 mg/l (Figure S3).

Especially in the Sand region, but also in the Clay region, the nitrate concentrations measured in the latest reporting period (2008-2010) are below those of the preceding reporting period (2004-2007). In the Sand regions, the average concentration decreased from 140 mg/l (1992-1995) to 60 mg/l (2008-2010). Regarding nitrate concentrations in peat regions, there has been no change between the previous and the latest reporting periods.

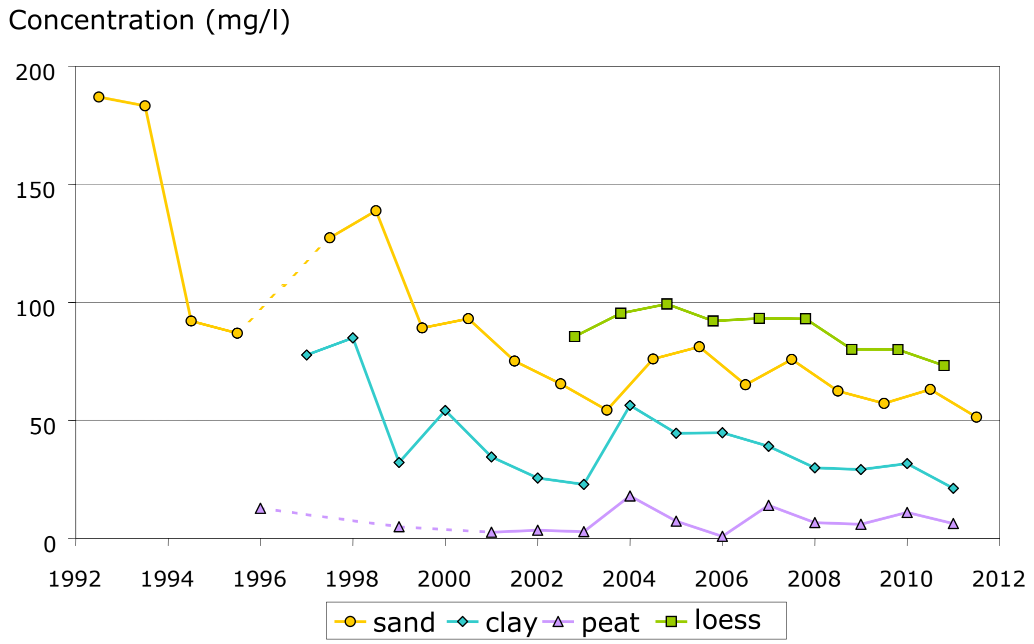


*Figure S2. Nitrate concentrations in water leaching from root zones of farms by region in the period 1992-2011. Average annual measured concentrations.*

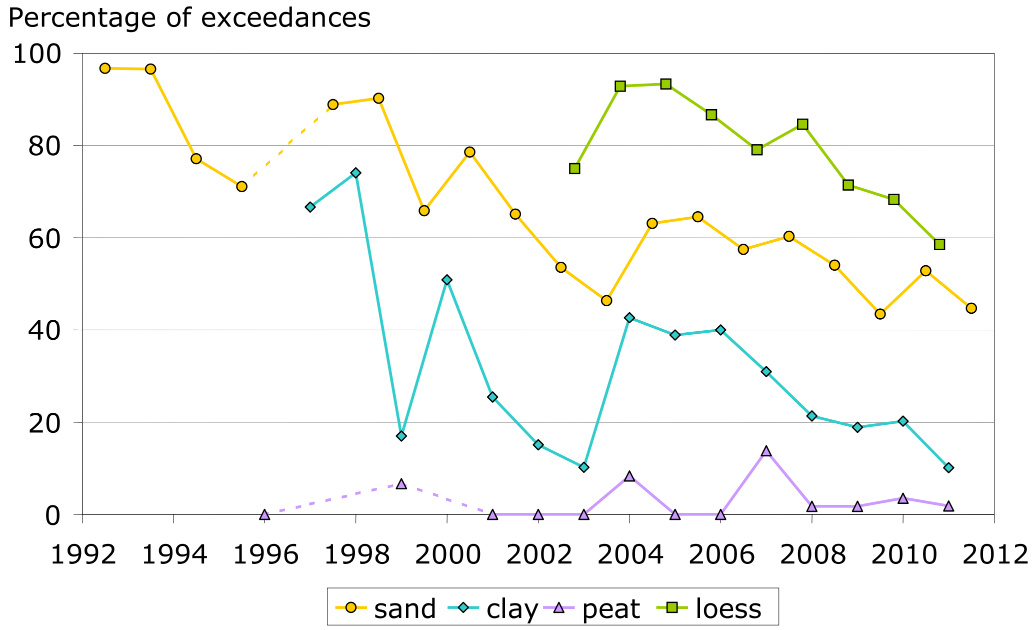


*Figure S3. Percentage of exceedance of the EU standard of 50 mg/l nitrate in water leaching from root zones of farms by region in the period 1992-2011. Exceedance according to measured concentrations.*

From 1984 to 2010, the average annual nitrate concentrations in groundwater at depths of 5 to 30 metres showed no clear trend, with the exception of groundwater at depths of 5 to 15 metres in the areas Sand Central and Sand South. Average annual nitrate concentrations and the exceedance of the EU standard at these depths in the period 2008-2010 were all below those in the period 2004-2007. The nitrate concentration in phreatic groundwater in areas for the extraction of drinking water (at a depth exceeding 30 metres in the Sand region) showed a slight increase between 1992 and 2004. From 2005 to 2010, this concentration was stable. The nitrate concentration in the groundwater of the Clay and Peat regions will probably not change, as the concentrations are low. Moreover, aquifers in these types of soil are often confined, and agricultural activities have little or no effect on the quality of groundwater in Clay or Peat regions.

In the period 1992-2002, the average nitrate concentration in fresh surface waters fell during the winter. In the period 2002-2010, the average nitrate concentration in the winter showed no trend. The winter maximum nitrate concentration in fresh surface waters fell between 1992 and 2010. However, the decrease in the latest reporting period (2008-2010) was negligible compared with the preceding reporting period (2004-2007). In the period 1991-2010, the average nitrate concentration in the winter showed no trend as regards marine and coastal waters. Adjusted for output via rivers (precipitation), the average inorganic nitrogen concentration in marine and coastal waters showed a decrease between 1991 and 2002. After 2002, the inorganic nitrogen concentration became stable.

*Eutrophication in the period 1992-2010*

In the period 1992-2004, the average summer chlorophyll-a concentration decreased in (fresh) regional waters strongly affected by agriculture. This trend did not continue in the period 2004-2010. The average summer total nitrogen concentration shows the same pattern for all (fresh) regional waters, whereas no trend is discernible in the average summer total phosphorus concentration for the period 1992-2010.

All Dutch marine waters are classified as eutrophication problem areas (OSPAR convention). Average summer chlorophyll concentrations in marine and coastal waters showed a modest reduction between 1992 and 2010.

**Impact of action programmes and forecast of the future evolution of water body quality**

It generally takes several years before all intended policy measures are fully implemented in agriculture. Moreover, changes in agricultural practice only have a discernible effect on water quality after some considerable time, particularly regarding the quality of the deeper groundwater and the larger bodies of surface water. This is due to processes in the soil and in the water, and to factors such as the variation in precipitation surplus from year to year. The nitrate concentration in groundwater and the exceedance of the EU target value of 50 mg/l are not solely dependent on human activities; they also depend on weather conditions, soil type and sampling depth. This last factor is related to the local hydrological and geochemical characteristics of the subsoil.

The quality of the water on farms (leaching from the root zone and ditch water) will exhibit the fastest and greatest response to measures that have been implemented as part of the action programmes. It is expected that measures of the fourth Action Programme (2010-2013) will produce noticeable changes between 2014 and 2019.

The effects on the quality of phreatic groundwater at a depth of 5 metres or more will not be manifest until after some decades have passed. Moreover, these effects will be difficult to detect owing to the mixing of groundwater of different ages and origins, as well as to the physical-chemical processes in the subsoil. The impact of the Fourth Action Programme in terms of the quality of surface waters strongly affected by agriculture will probably also be noticeable between 2014 and 2019. The effects will be difficult to demonstrate, and then only after a long time, especially in national and marine waters. This is the result of these waters mixing with water originating elsewhere (for example, water flowing in from other countries by the major rivers), and of chemical processes in the groundwater and surface waters.

Model calculations indicate that the tightening of the nitrogen application limits until 2013 will cause the nitrate concentration in upper groundwater after 2010 to decrease everywhere even further, mainly affecting a number of crops on sandy soil. For the entire sand region, the average nitrate concentration is falling to 50 milligrams per litre. The calculations also indicate that the nitrate objective for the Sand North and Sand Central areas will easily be reached. After adjusting for weather conditions, the groundwater quality is improving in both Sand South and the Loess region to an average of 70 and 60 mg/l respectively. The nitrate objective has not yet been achieved however.

From model calculations, the impact of the surface water due to the run-off and leaching of nutrients will reduce by 4% in the case of nitrogen and 2% in the case of phosphorus, compared with the levels for the 2010 application limits.

Forecasting the evolution of eutrophication due to agricultural activities is even more difficult than it is for nitrate concentrations, the main reasons being:
- the differences in surface waters with regard to their proneness to eutrophication;
- phosphorus concentrations and other factors such as hydromorphology, which also play an important part in the eutrophication process;
- contributions from other sources of nutrient input, such as urban wastewater and cross-border rivers;
- the extreme difficulty with predicting the response times of aquatic ecosystems to a substantial reduction in nutrient inputs and concentrations.

**Conclusions**
The years 1950 to 1987 saw the growth of the nitrogen and phosphorus surpluses in Dutch agriculture. Since 1987, however, the Netherlands has been successfully reducing them. Following the implementation of MINAS in 1998, the nitrogen surplus, which had remained stable for about seven years, underwent a further decrease.

During the reporting period (1992-2010), the water quality in terms of nitrate concentrations and eutrophication improved, thanks to the measures adopted since 1987. The nitrate concentrations in water on farms in the Sand and Clay regions were significantly lower in the period 2008 to 2010 than in preceding periods, which can be ascribed to the lower use of nitrogen after 1998. The nitrate concentrations in deeper groundwater (at depths of 5 to 30 metres) are more or less constant, apart from those in groundwater at a depth of 5 to 15 metres in Sand region. In this region, the nitrate concentration is decreasing.

The water quality should continue to improve between 2014 and 2019, owing to the measures that have been and are being taken during the Fourth Action Programme (2010-2013). Changes in deep groundwater are gradual and, therefore, no sharp changes in nitrate concentrations are to be expected. Concerning eutrophication, the quality of fresh and marine water is expected to stabilise or improve slightly in the near future.

# 1 Introduction

## 1.1 General

This report is part of the Netherlands Member State reporting under Article 10 of the Nitrates Directive and has to be submitted to the European Commission in mid-2012. The report provides an overview of current agricultural practices, and of groundwater and surface water quality in the Netherlands, describes the trends in these waters, and assesses the time scale for the change in water quality due to changes in the aforementioned practices. It deals with the implementation and impact of the measures taken as part of the action programmes, covering the period 1992-2010. If available, the data for 2011 are also presented.

This introductory chapter summarises the goal of the Nitrates Directive and the main obligations arising from it (section 1.2). The two obligations relevant for this report, i.e. reporting (section 1.3) and monitoring (section 1.4), are discussed in detail. The 2012 Member State report covers the fifth reporting phase. A review of the first four reports is given in section 1.5, with a detailed description of the fifth report’s contents given in section 1.6. References (section 1.7) are included at the end of each chapter.

## 1.2 Nitrates Directive

The purpose of the European Nitrates Directive (EU, 1991) is to reduce water pollution attributable to nitrates from agricultural sources, and to prevent further pollution of this type. The Directive obliges Member States to take a number of measures to realise this objective.

First, Member States are obliged to designate vulnerable areas in their territory (Nitrate Vulnerable Zones, or NVZs). These zones drain into fresh surface waters and/or groundwater (Article 3, Annex 1) that contain more than 50 mg/l of nitrate, or might have this concentration if the measures described in the Directive are not taken. This applies to freshwater bodies, estuaries, sea and coastal waters that are now eutrophic or that might become eutrophic in the near future if the measures described in the Directive are not implemented. Second, the Directive obliges Member States to prepare action programmes for the designated NVZs so that the objective of the Directive can be realised (Article 5). Third, Member States are obliged to conduct suitable monitoring programmes to determine the extent of nitrate pollution in waters from agricultural sources and to assess the effectiveness of the action programmes (Article 5(6); see section 1.4 of this report for more information). Each Member State has to submit a report on the preventive measures taken, including the actual and expected results of the action programmes, to the European Commission (Article 10; see section 1.3 for more information).

The Netherlands has not designated any Nitrate Vulnerable Zones. However, it informed the European Commission in 1994 that it would prepare an action programme for the entire territory of the Netherlands, in conformity with the Nitrates Directive. According to a 1994 study (Working Group Designation NVZ, 1994), agriculture is a major source of nitrate emissions into groundwater and/or fresh surface waters and/or coastal waters. The working group therefore concluded that an action programme had to be carried out for the whole country. The research report published recently by Alterra in connection with the

Snijder motion (Schoumans et al., 2010) on the designation of zones susceptible to nitrate reaches a similar conclusion.

## 1.3 Reporting obligations

Annex 1 to the Nitrates Directive sets out the obligation of reporting to the Commission on preventive measures taken and their results, and on the expected results of the action programme measures. This Annex stipulates the information for inclusion in the reports, which have to be brought out every four years. In the Netherlands, this is the joint responsibility of the Ministry of Infrastructure and the Environment (I&M) and the Ministry of Economic Affairs, Agriculture and Innovation (EL&I).

Reporting obligations:

1) A statement of the preventive measures taken pursuant to Article 4. This article states that within two years following publication of the Directive, a code of Good Agricultural Practice (GAP) has to be drawn up, together with a programme for promoting the code.
2) A map showing the following:
   a) Waters identified as being affected or susceptible to being affected by pollution.
   b) The locations of the Nitrate Vulnerable Zones, distinguishing between zones already existing and zones designated since the previous report.
3) A summary of the monitoring results obtained for the purpose of designating NVZs, including a statement of the considerations that led to the designation of each zone and to the revision of the list of zones.
4) A summary of the action programmes drawn up, showing in particular:
   a) The measures required with respect to the application of artificial fertiliser, storage capacity for manure and other restrictions on the use of artificial fertilisers, as well as measures prescribed by the GAP code.
   b) The specifying of a maximum for the amount of nitrogen from manure that is allowed to be applied per ha, i.e. 170 kg/ha.
   c) Any additional or expanded measures taken to supplement measures inadequate for achieving the objective of the Directive.
   d) A summary of the results from the monitoring programmes for assessing the effectiveness of the action programmes.
   e) The assumptions made by the Member State for the likely time scale within which the measures in the action programmes are expected to have an effect, along with an indication of the degree of uncertainty inherent in these assumptions.

This report concentrates on items 4d and 4e of the reporting obligations, with the results being presented so that the effectiveness of the action programmes as a whole can be assessed. Reporting on the results of the monitoring relating to the exemption is done separately and, moreover, every year (Fraters et al., 2008; Zwart et al., 2011; Buis et al., 2012).

## 1.4 Monitoring obligation

Member States that have designated NVZs have different obligations from Member States who apply their action programmes to their entire territory.

Member States that had designated NVZs became obliged to monitor nitrate concentrations in fresh waters and groundwater for at least one year within two years of announcement of the Directive, i.e. before the end of 1993, and to repeat the monitoring programme at least every four years. This is necessary for designating vulnerable zones and revising the list of such zones. The monitoring for the designation of zones does not have to be conducted by the same agency that monitors the effectiveness. Effectiveness of an action programme is monitored for the purpose of studying the effect that the measures taken have on water quality.

Member States applying their action programme to their entire territory, the Netherlands for example, have to monitor the nitrate concentrations in fresh water and groundwater to determine the extent of nitrate pollution from agricultural activities. The Directive does not specify a time limit in this case. Given that the First Action Programme came into effect on 20 December 1995, monitoring needed to be performed before that date in order to establish the baseline.

The Nitrates Directive provides limited advice on how monitoring is to be conducted. In fact, only a few monitoring guidelines are given for the purpose of designating vulnerable zones (Article 6, Annex IV).

In 1998, the European Commission published draft guidelines for monitoring (EC/DG XI, 1998) in accordance with Article 7 of the Directive. Revisions were published in 1999 (EC/DG XI, 1999) and 2003 (EC/DG XI, 2003), but these are still only draft versions. The guidelines are not binding. Their purpose is to define all types of monitoring and suggest possible ways in which Member States might carry them out. In addition, the Commission aims to ensure that the monitoring regimes of the Member States are comparable.
An especially large effort has gone into the monitoring relating to the Water Framework Directive (KRW) and the Groundwater Directive (GR), for which guidance documents were published. A study is also underway into the harmonisation of the monitoring and reporting relating to the Water Framework Directive, Nitrates Directive (NiR) and State of the Environment (SoE).

## 1.5 The initial four Member State reports of the Netherlands

The first Member State Report of the Netherlands was submitted to the Commission in 1996 (LNV, 1996 (Ministry of Agriculture, Nature and Food Quality)). This report relates to the period between 20 December 1991 and 20 December 1995. It does not include any monitoring data to demonstrate the effectiveness of the First Action Programme, as this only came into effect on 20 December 1995. The report provides an overview of the operational monitoring programmes, with the following comments made about the results:

> "The effectiveness of the action programme cannot be properly assessed if only the results of monitoring groundwater and surface waters are considered. Measures aimed at a decrease of nutrient emissions will have a delayed effect on nitrate content, especially in surface waters. Accordingly, the estimate of the surplus on the national agricultural nitrogen balance is an appropriate tool to use when assessing the effectiveness of the

> measures. This tool makes it possible to follow the progress achieved due to reduction measures in agriculture in a more direct way."

This report also states that the effectiveness of the action programme will be reported on within four years.

The second Member State report of the Netherlands was submitted to the Commission in 2001 (LNV, 2001). This report relates to the period from 20 December 1995 to 20 December 1999. It contains the results of the monitoring programmes for assessing the effectiveness of the action programme, and is based on the report of the Working Group - Monitoring Nitrates Directive (Fraters et al., 2000). The following comments on the results of these programmes were included in the Member State report:

> "The report (of the Working Group - Monitoring Nitrates Directive) indicates that there is stabilisation, but not yet a substantial improvement of the environmental quality. This lack of improvement was foreseen because:
> 1. During the reporting period (1995-1999), only the use of manure was regulated, and not the use of artificial fertiliser. The decrease in the amount of nitrogen from manure was often negated by the use of artificial fertiliser. Since 1998, the Netherlands has had regulations that also restrict the use of artificial fertiliser containing nitrogen, i.e. the Mineral Accounting System (MINAS). Hence, the effects of MINAS fall outside this reporting period. Moreover, it is expected that the tightening of the Manure Policy (September 1999) will produce results in 2002 and 2003. This means that improvement of the environmental quality due to this policy will become apparent in the third reporting period.
> 2. Due to transport, decomposition and conversion processes in soil and groundwater, the effects of measures taken are not noticeable yet. It will also take some time before the monitoring results show a decrease in nitrate concentration, although just how long cannot be said. The monitoring results mainly reflect the stabilisation in agricultural practice in the 1980s and early 1990s, when the increasing pressure on the environment was brought to a halt."

The third Member State report of the Netherlands was submitted to the Commission in 2004 (VROM, 2004 (Ministry of Housing, Spatial Planning and the Environment)). This report relates to the period from 20 December 1999 to 20 December 2003. It contains the results of the monitoring programmes for assessing the effectiveness of the action programme, and is based on the report of the Working Group - Monitoring Nitrates Directive (Fraters et al., 2004). The following comments on the results of these programmes were included in the Member State report:

1. In Dutch agriculture, the nitrogen and phosphate surpluses stopped increasing in 1987, and since then, have been decreasing. After the introduction of the MINAS registration system in 1998, the nitrogen surplus, which had remained stable between 1990 and 1998, showed a further decline.
2. Due to policy measures taken since 1987, the water quality in the reporting period improved, as regards nitrate concentrations as well as eutrophication. The nitrate concentration in the upper groundwater on farms clearly decreased between 2000 and 2002, compared with previous periods. This is related to the decrease in nitrogen use since 1998. Nitrate concentrations in deep groundwater (> 30 meters) continue to increase, probably caused by the increase in nitrogen surpluses in the period before 1987.

3. The expectation is that water quality will continue to improve during the next reporting period, thanks to the measures taken during the second Action Program (1999-2003). It is expected to take a few more decades before the effects of these measures start to change the quality of deep groundwater. Despite the initial improvement in water quality, a noticeable improvement in the ecological quality of surface water is not expected in the following reporting period. In other words, the symptoms of eutrophication will not decrease rapidly.
4. The nitrate concentrations in groundwater and the exceedance of the EU target value of 50 mg/l are not solely dependent on human activities; they also depend on weather conditions, soil type and sampling depth. This last factor is related to the hydrological and geochemical characteristics of the subsoil.

The fourth Member State report of the Netherlands was submitted to the Commission in 2008 (Zwart et al., 2008). This report relates to the period from 20 December 2003 to 20 December 2007. It contains the results of the monitoring programmes for assessing the effectiveness of the action programme, and is based on the report of the Working Group - Monitoring Nitrates Directive (Zwart et al., 2008). The following comments on the results of these programmes were included in the Member State report:

1. Whereas the nitrogen and phosphorus surpluses in Dutch agriculture kept growing until 1987, since then the Netherlands has been successful in reducing them. After the introduction of the MINAS registration system in 1998, the nitrogen surplus, which had remained stable for approximately seven years, decreased again.
2. During the reporting period (1992-2006), the water quality in terms of nitrate concentrations and eutrophication improved, thanks to the measures adopted since 1987. The nitrate concentrations in water on farms were significantly lower in the period 2004 to 2006 than in preceding periods, which can be ascribed to less use of nitrogen after 1998. The nitrogen concentrations in deep groundwater (> 30 metres) continue to increase owing to the large emissions of nitrogen in the period before 1987.
3. The expectation is that water quality will continue to improve between 2010 and 2015, thanks to the measures taken during the third Action Program (2004-2007). It will probably be a few decades more until the nitrate concentration in deep groundwater stops increasing and starts to decrease. Concerning eutrophication, no clearly noticeable acceleration of the recovery process is expected.

The nitrate concentration in groundwater and the exceedance of the EU target value of 50 mg/l are not solely dependent on human activities; they also depend on weather conditions, soil type and sampling depth. This last factor is related to the local hydrological and geochemical characteristics of the subsoil.

## 1.6 The fifth Member State report and this report

### *1.6.1 Delineation and accountability*

The Member States have to submit their Nitrates Directive Member State reports to the European Commission in mid-2012. The fifth Member State report covers the period 20 December 2007 to 20 December 2011. It also needs to contain the results of the monitoring programmes for assessing the effectiveness of the action programme (item 4d of section 1.3), as well as the assumptions made by the Member States about the likely time scale within which the designated waters are expected to respond to the measures in the action programme (item 4e of section 1.3).

The Ministries responsible for the Dutch reporting (see section 1.3) requested the Working Group - Monitoring Nitrates Directive to report on the two above-mentioned topics. This report represents the results of the Working Group's activities.

The starting point for preparing this report was a combination of the reporting guidelines published by the Commission in 2000 (EC/DGXI, 2000), together with the subsequently published supplements and revisions. In March 2008, the Commission published a supplement to the reporting guidelines (EC/DGXI, 2008). In November 2011, a revised version of the guidelines for the fifth Member State report was published (EC/DGXI, 2011). As far as possible, changes from the reporting guidelines from 2000 have been taken into account for the preparation of this report. The 2000 guidelines contain a request for the monitoring period results to be published on the basis of three years' monitoring for each period. Because the guidelines have not been revised in this respect, it is not clear whether results for only two monitoring periods have to be given or for all periods (in this case five). It is just as unclear as regards which periods have to be used for comparing results, as prescribed in the guidelines.

For the fourth Member State report (2008), the Working Group recommended (Fraters et al., 2007) that, in order to provide an informative overview of the status and trends of agricultural practice and the aquatic environment, the first and last two periods should be presented in the form of tables. This method is used again in this report for preparing the fifth Member State report. It means that the results of the 1992-1995, 2004-2007 and 2008-2010 monitoring periods are presented in tables. In addition, graphs are provided showing yearly averages for the 1992-2010 period. Moreover, if earlier data are available, often going as far back as the mid-1980s, these are presented as well. To limit the number of maps in the report, only those showing the water quality for the period 2008-2010 and the change in water quality between 2004 and 2010 (fourth and fifth periods) will be included.

### *1.6.2 Structure of the report*

This report consists of an introduction and written account (sections 1 and 2), the results of the monitoring programmes for assessing the effectiveness of the action programmes (sections 3 to 7), a forecast of how the quality of water bodies will evolve in the future (section 8) and a summary of the results from the preceding sections, together with conclusions drawn from them. For the convenience of the reader, this summary is at the beginning of the report. To allow the sections containing the results of the monitoring programmes to be read independently, references are provided at the end of each section.

After the general introduction to the report in section 1, section 2 goes on to describe the national monitoring programme, and the purpose and design of the respective sub-programmes that provide results for this report.

The status of and trends in agricultural practice are described in section 3. The effect of both agricultural practice and changes in this practice on farm water quality is monitored by measuring the nitrate concentration in the upper metre of groundwater. Section 4 contains a description of the effect. In the remaining three sections, the status of and trends in the aquatic environment are described: deep groundwater in section 5, fresh surface waters in section 6, and marine surface waters in section 7.

Groundwater nitrate concentrations are given for four depths: upper metre of groundwater within 5 metres of the soil surface, and 5-15 metres, 15-30 metres, and more than 30 metres below the soil surface. Measurements are taken at different depths, because nitrate concentrations vary considerably with depth. Other important environmental factors considered when measuring nitrate concentrations in groundwater are land use, soil type and aquifer type. These factors are described in sections 4 and 5.

Nitrogen and phosphorus emissions are given for surface waters, along with a description of the water quality. Water quality is presented in terms of nitrate concentrations for the winter period and eutrophication parameters for the summer period. Four types of water are distinguished for fresh surface waters: regional waters affected by agriculture, other regional waters, national waters, and water at drinking water stations. They are given here in order of decreasing impact of agriculture on water quality. Other sources affecting water quality are, for example, effluent from wastewater and sewage treatment plants, sewage overflow during heavy rainstorms, and atmospheric deposits. Marine waters are divided into coastal waters and open sea, making clear the differences in nutrient emissions, which are mainly from rivers, rather than the result of direct discharge.

The forecast for the future evolution of water quality is set out in section 8. The estimates are based for the most part on recent data from the current monitoring programme. (For a detailed forecast, see PBL, 2012.)

The summary of results from the preceding chapters, as well as any corresponding conclusions, are in the section “Summary and conclusions”, at the beginning of this report.

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# 2 National monitoring programmes

## 2.1 Introduction

Several programmes exist in the Netherlands for monitoring agricultural practice and the aquatic environment. Each focuses on one of the following aspects: agricultural practice (section 2.2), effectiveness of the manure policy (section 2.3), groundwater (section 2.4), fresh and marine surface waters (section 2.5), and the water used in the production of drinking water (section 2.6). These programmes are carried out under the responsibility of different institutes and organisations.

This chapter provides a brief description of each programme. In addition to a general description of the collecting of data, information is provided about the processing of these data. They are used for the summaries that illustrate the status of and trends in agricultural practice and the aquatic environment. Details of the data collecting and processing are given in the publications in the list of references.

## 2.2 Monitoring agricultural practice

### *2.2.1 General*

Agricultural practice is monitored in several ways in the Netherlands. The monitoring programmes themselves are discussed in the next sections, followed in 2.2.3 by an explanation of how a mineral balance, the production and excretion of livestock manure and nutrient excretion, and manure storage capacity are calculated.

### *2.2.2 Data collection*

There are two agricultural monitoring programmes in the Netherlands: the Agricultural Census and the Farm Accountancy Data Network (FADN). Compliance with the regulations is also monitored.

**Agricultural Census**
Statistics Netherlands (CBS) collects general information about all farms, such as area of cultivated land and number of farm animals (CBS Statline, 2012). This annual collecting of data is referred to as the “Agricultural Census”.

The lower limit for farms to be included in the census is Standard Revenue of € 3000. Until the end of 2009, the economic size of a farm was expressed in NGEs (Dutch Magnitude Units). As from the beginning of 2010, this was replaced by the concept of Standard Revenue (SO). As a result, the lower limit for farms appearing in Agricultural Census publications changed from 3 NGEs to € 3000 SO. For comparing different periods, the CBS data from 2000 to 2009 inclusive were recalculated on the basis of SO criteria and categories.
SO is a standardised measure of the economic size of a farm, based on the average annual revenue per crop or animal category. SO standards are set separately for each crop and animal category. They are based on five-year averages and updated every three years. The SO of a farm is the sum of all its SOs for crops and animals.

**Farm Accountancy Data Network**
The Agricultural Economics Research Institute (LEI, part of Wageningen University and Research Centre) collects information of a more specific nature about farm economics and technical management, via the Farm Accountancy Data Network (FADN) (Lodder and De Veer, 1985; Vrolijk, 2002; Poppe, 2004). This farm management information includes environmentally relevant data such as mineral balances (inputs and outputs of minerals), the use of pesticides, water and energy consumption, use of inorganic fertilisers, import and export of minerals (input and output of minerals, including changes in stock), and grazing frequency.

The FADN represents 1500 farms from the Agricultural Census, selected by stratified random sampling, thus forming a representative sample of Dutch agriculture. The FADN network is part of a larger EU network (EU Council Regulation 79/65/EEC). Farms included in the FADN were visited each year. Between 15% and 20% of the farms used to be replaced every year, so that the FADN network would remain representative of Dutch agriculture. Research showed that stopping the active replacement of companies after five or six years would not make the data less representative (Vrolijk et al, 2010). Replacement every five or six years was considered necessary in the past, otherwise participants would have had access to more information than non-participants would have. With the recent steep increase in computerisation (Internet and the like), this distinction hardly seems relevant. Accordingly, since 2006 the replacement has been limited to farms that stop operating, move to another region, or cease to participate for some other reason. As a result, the annual replacement of farms is no more than 3% to 5%.

The FADN represents about 75% of the total number of farms and about 91% (in NGEs) of registered agricultural production in the Netherlands. As the change from NGEs to SO units was recent, the NGE will continue to be used as the unit for economic measurement in reports utilising FADN data.

To ensure the representative nature of the FADN, farms smaller than 16 NGEs, where agriculture is generally not the main activity, are excluded from the network. Farms larger than 1200 NGEs (mostly greenhouse nurseries) are not completely suitable for data collection and are therefore also excluded. Currently, the FADN covers more than 90% of Dutch agricultural area (Vrolijk et al., 2010). Past years show similar results.

**Monitoring compliance with the regulations**
Compliance with regulations is largely monitored from the mineral production returns that each farmer has to complete and send back to Dienst Regelingen (DR, the government’s regulatory service). Monitoring is not usually conducted in relation to an individual measure. From 2006, the policy has been in line with the EU directives, so that the emphasis is more on livestock manure and inorganic fertilisers, rather than on total mineral flows. Data collected by the General Inspection Service (AID/NVWA) shows the extent of compliance with the regulations governing legal obligations relating to matters such as manure application (quantity, timing and application method) and manure processing contracts.

Dienst Regelingen of the Ministry of Economic Affairs, Agriculture and Innovation (EL&I/DR) has prepared a summary of the activities relating to manure application guidelines and demonstration projects.

### 2.2.3 *Data processing*

**Nitrogen and phosphorus balances**

Each year, Statistics Netherlands calculates the nitrogen and phosphorus balances of the agricultural sector. All balance items are based on statistical data, except for atmospheric deposition, which is based on model calculations made by RIVM (Erisman et al., 1998; Van Jaarsveld, 1995) using statistical data on emissions into the air (Van Amstel et al., 2000). The surplus on the nutrient balance represents the difference between the input and output items. The destination of the balance surplus is not specified because leaching, output, denitrification and accumulation can only be estimated by model calculations. The method used for the calculation of the balance items was described by Statistics Netherlands in 1992 (CBS, 1992). Since 1992, minor changes have been made to the method. Until 2000, these were published in every fourth issue of the quarterly bulletin *Milieustatistieken* (statistics on the environment) of Statistics Netherlands, together with the final balances for the two years before the previous one, and the provisional balance for the previous year (see, for example, Fong, 2000 and earlier issues). Since 2000, this information has been published on the Internet (see, for example, CBS, 2012 and prior years).

**Nutrient excretion and production**

In the above-mentioned balance calculations, the mineral excretion from Dutch national livestock is calculated according to the difference between fodder consumption and animal products. Statistics Netherlands also calculates the manure and mineral production of the livestock based on a nutrient balance per animal in combination with the number of animals from the Agricultural Census. This method is based on the following:

1. Excretion factors calculated for each nutrient from the excretion balance, i.e. defined as the difference between the intake via feed and the retention in animal products.
2. Statistics and technical records of a particular year as source material for basic figures, supplementary to expert knowledge and feeding standards. This makes it possible from the calculations to follow not only year-to-year changes in feed composition, but also zootechnical developments affecting the efficiency of milk and meat production. Statistics are the preferred choice for source material, since they reflect continuity of method, outcome and time of publication. Basic information is used from animal feed statistics (compound feed and its nutritional value, use and production of roughage, quantity of feed per animal, in kg, et cetera) and from animal production statistics (milk production per cow, protein content of milk, egg production per hen, meat growth per animal, birth weight of piglets, et cetera).
3. Actual emission factors are calculated each year per animal category (as defined in the Agricultural Census). This means that the results derived from the technical records and statistics have to be harmonised in this respect. Care should be taken to check whether basic data refer to counted animals, housed animals or born animals.

The two calculations of the nitrogen content of manure are not completely independent of one another. Differences between nitrogen excretion (508 million kg N in Figure 3.2) and the sum of the nitrogen produced in manure and ammonia volatilisation (424 million plus 60 million kg N in Figure 3.2) are mainly due to the use of species-specific data on animal life cycles, animal production, et cetera in the calculation of manure production.

**Manure storage capacity**
Manure storage capacity on livestock farms has been included in the Agricultural Census for only a few years of the monitoring periods (1993, 2003, 2007 and 2010). Part of the questionnaire deals with the storage capacity for animal manure on the farm itself. Here the answers have to be in the form of the storage capacity in months for different types of manure. The data are presented in Table 3.11.

Data on the production and storage capacity of manure at each farm can also be obtained from the Farm Accountancy Data Network (FADN, see section 2.2.2), which is a representative sample of Dutch farms. In the FADN, the data only relate to liquid manure and not solid manure. These are the data used in this report (chapter 4).

## 2.3 Monitoring effectiveness of the manure policy

### *2.3.1 General*

The effects of the action programme are monitored via standard programmes for groundwater and surface water, and a special programme known as Landelijk Meetnet effecten Mestbeleid (LMM), based on a national network for measuring the effects of the Manure Policy. LMM was developed to measure the effect of the Dutch Manure Policy on nutrient emissions, especially nitrate emissions, from agricultural sources into groundwater and surface water, and to monitor the effects of changes in agricultural practice on these emissions. Consequently, LMM can also identify the impact of the action programmes.

The LMM programme monitors both water quality and farm management, i.e. agricultural practice. LMM’s policy measures have the aim of changing farm management in such a way that water quality improves. The quality of groundwater and surface waters is generally affected not only by agricultural practice, but also by other sources of pollution and by environmental factors such as the weather. To exclude other, diffuse sources of pollution as much as possible, the quality of water that leaches from root zones and ditchwater is monitored on farms. This type of water reveals the effects of recent agricultural activities (carried out less than four years ago). To distinguish between the effects of measures on water quality and the effects of interfering factors, such as weather, these factors are monitored as well (see Fraters et al., 2004). The next section (2.3.2) provides more details on LMM data collection, followed in section 2.3.3 by a discussion of the data processing.

### *2.3.2 Data collection*

**LMM and FADN**
When the LMM monitoring programme commenced in the sandy regions in 1992, it was decided that linking LMM and FADN (see section 2.2.2) would have many advantages. Linking the two networks would make both farm management and water quality data available to all participating farms. In 1996, after the evaluation of the initial four-year period, it was decided to continue this collaboration. Because of the nature of Dutch agriculture and the high level of dynamics, the advantages of linking the FADN and the LMM to each other were obvious. The decision to use a group of farms with a changing composition for the FADN was taken in the mid-1960s. Monitoring a fixed group independent of the FADN would mean doubling the FADN's activities. The dynamic nature of the

Dutch farming sector ensures that even a fixed group of participants has a changing composition (Fraters et al., 2005). Account needs to be taken of the fact that both the FADN and LMM exclude some farms from participation. To keep the selection of participants representative, farms smaller than 16 NGEs or larger than 1200 NGEs are excluded from the FADN (see section 2.2.2). In addition to these FADN thresholds, the LMM uses a minimum participation criterion of 10 hectares of land per farm for inclusion in its network.

The monitoring network was expanded in 2006 owing to the EU granting exemption for the application per ha of 250 kg of nitrogen together with livestock manure. Not all farms in the exempt measuring network meet the conditions for inclusion in the standard monitoring programme. These farms are not suitable because they are not randomly selected. The monitoring group now has a fixed composition, except for changes arising from developments at individual farms.

**Main soil type regions**
The Netherlands applies the Nitrates Directive action programme to its entire territory. Even so, legislation distinguishes between main types of soil, with measures based on soil vulnerability to nitrate leaching. Accordingly, the monitoring programmes focus on the most important main soil-type regions in the Netherlands, i.e., sandy, loess, clay and peat regions. For the sandy and loess regions, consideration is given to differences in vulnerability, the result of dry or wet soil conditions (groundwater traps, or GTs) for example.

All these regions together can be regarded as a group of similar groundwater bodies. The status of the aquatic environment on farms is described for the four regions (each named according to the dominant soil type). Each region comprises one or more areas.

In all, 11 GTs have been distinguished, based on the average high and low groundwater levels (GHG and GLG respectively) in a hydrological year (from April to April). Averages are first calculated using the three highest values and the three lowest values in a year. Then the average for a number of successive years is calculated. GTs are mainly identified from estimates made in the field, using soil characteristics in combination with measurements. The effect of a GT on the nitrate concentration in the top metre of groundwater was studied by Boumans et al. (1989), who described the effect using the factor of relative nitrate concentration (RNC), with the concentration found in soils with GT VII* (lowest GHG and GLG) having the factor RNC 1.

**Main farm types**
Within each region, the LMM focuses on the main farm types with respect to acreage (i.e. arable farms and dairy farms). To some extent, the LMM also includes other farm types. These are factory farms (with mainly pigs and/or poultry) in sandy regions, and other livestock farms in sandy, clay and loess regions. The reason for the restriction on this group is to limit the variation in farm practice and water quality within the sample, and, hence, increase the ability to detect changes in farm practice and water quality.

**Sampling and other data collection methods**
The water quality on farms is monitored by sampling the water leaching from root zones and ditchwater (if present). Leaching water is measured by taking samples from different types of water: from soil water in the unsaturated zone

beneath the root zone, at a depth of between 1.5 and 3.0 metres below the surface if the groundwater is more than 5 metres below the surface; from the top metre of phreatic groundwater if the groundwater is less than 5 metres below the surface; and from drain water if the plots of land are drained by pipes. Supplementary data on environmental parameters, such as the quantity of precipitation and evapotranspiration, the percentage of land area for each soil type and GT, are collected and utilised, with the aid of models, to explain the effect of these parameters on the measurements (see section 2.3.3 and Fraters et al., 2004).

**Sampling unit**
The sampling unit used in the LMM is the farm. It was chosen because Dutch legislation regulates agricultural practices at farm level, farm management can be monitored more easily at farm level than on any other scale (e.g. plot level), and because farm management is already monitored at farm level in the FADN (section 2.2.2.).

**Sampling frequency**
Sampling frequency varies according to programme and region. The sampling frequency depends on the expected change in water quality over time, and on the variation in quality by time and space. For groundwater and surface waters, changes in nitrate concentrations over time need to be relatively large if the targets are to be reached. The current sampling frequency in the LMM is based on a statistical analysis of the results of research conducted in the period 1992-2002. This comprises research into the sandy regions in the period 1992-1995 (Fraters et al., 1998), and in the clay regions (Fraters et al., 2001) and peat regions (Fraters et al., 2002) in the period 1995-2002. In these periods, samples were taken from farms every year.

The above research revealed three major sources of variation in nitrate concentration (in decreasing order of significance):

1. Differences in nitrate concentration from farm to farm;
2. Differences in nitrate concentration from year to year on the same farm;
3. Differences in nitrate concentration from sampling point to sampling point on the same farm in any particular year.

A fourth source of this variation was differences in nitrate concentration according to farm type. The effect of this was relatively small, however. The results of the statistical analysis show that taking a limited number of samples from a large number of farms, and only taking samples a limited number of times from each farm for as long as it participates in the LMM, is more effective than frequently taking a large number of samples from a limited number of farms. A primary justification for such an approach is the fact that differences in nitrate concentration from farm to farm constitute the main source of variation.

Apart from statistical considerations, organisational and financial aspects also play a role in setting up a monitoring programme. For example, there is the effort needed to include a farm in the measuring network and maintain contact with the participant, the travelling time to go from one farm to another, and the number of samples that a sampling team can take from a farm each day. From this standpoint, it is less costly to take many samples from a farm, the number of samples being in line with the number that can be taken in one day.

Moreover, a limiting factor is the number of farms participating in the FADN that are suitable for joining the LMM.

Until 2006, the number of farms in the FADN that were potentially eligible for participation in the LMM programme was large. In the sandy, loess and peat regions, it appeared that the most productive and cost-effective method was to take samples from farms only in their first, fourth and seventh years of participation. In the clay regions, where most water drains away artificially through pipes, and samples are taken from the drain water, it appeared to be more productive and cost-effective to take the samples from farms each year.

There was a change in 2006 owing to the European Commission granting exemption for the application per ha of 250 kg of nitrogen together with livestock manure. Since that year, samples have been taken annually from every participating farm.

Since the start of the LMM, the information on agricultural practices from all participating farms has been recorded each year. Owing to circumstances, however, information is not always available from the year preceding the one in which the samples were taken.

The relationship over time between the information collected in the FADN and the actual sampling period per region is illustrated by Table 2.1.

*Table 2.1. Relationship between year of information on agricultural practices and year of water sampling for all regions in the LMM.*

| Month | Jan-Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agricultural information | | | | | | | | | | | | | | | | | |
| Soil water loess region | | | | | | | | | | | | | | | | | |
| Groundwater sandy regions | | | | | | | | | | | | | | | | | |
| Groundwater clay regions[1] | | | | | | | | | | | | | | | | | |
| Groundwater peat regions[1] | | | | | | | | | | | | | | | | | |
| Drain + ditch water all regions[2] | | | | | | | | | | | | | | | | | |

[1] Start of the sampling depends on the quantity of precipitation, as enough has to have fallen before leaching into groundwater occurs. Sampling begins as soon as the drain water in the area can be sampled, but no later than 1 December.

[2] Start of sampling from the drains depends on the quantity of precipitation, as enough has to have fallen in order to obtain output via drains. As soon as drains start to output water, the sampling of drain and ditch water begins.

**Loess region**
The loess region has been part of the LMM since 2001, the first year that data on agricultural practices were recorded in the FADN. The first data on the quality of groundwater dates from 2002. Water-quality data from the Provincial Soil Moisture Network for Limburg is added to the LMM data to obtain a picture of changes over a longer period. Instead of the farm as sampling unit, the Provincial Soil Monitoring Network uses the plot. As such, the design differs from that of the LMM (IWACO, 1999; Voortman et al., 1994). Apart from crop types, no information on agricultural practices is available for the plots in question.

**Sample size**
Between 1992 and 2006, the number of participating farms varied from year to year for all regions (see Table 2.2). Since 2007, the number of farms per region has been reasonably stable. Moreover, data on agricultural practices and water quality are available for nearly all farms. In total, approximately 3,574 samplings were conducted for evaluation purposes at representative farms. For the period 1992-2007, the numbers in brackets are somewhat less than those in earlier reports, because LEI had been using probability limits for the recorded data since 2009. With hindsight consequently, the results have been labelled as unreliable and are no longer being reported.

The number of distinct farms per reporting period and farm type where samples were obtained (Table 2.3) is larger than the number of farms in any single year (Table 2.2), especially in the period before 2006. This is because, in the period concerned, samples were obtained from a different group of farms each year. As a result, the average number of samples per annum in any four-year period is well below 4.

### 2.3.3 *Data processing*

**Nutrient surpluses**
The nitrogen and phosphate surpluses referred to in section 4 were calculated by a method derived from that used and described by Schröder et al. (2004, 2007). This means that, alongside the input quantities of nitrogen and phosphate in organic manure and inorganic fertilisers and the output quantities in crops, allowance is also made for other sources of input such as net mineralisation of organic substances in the soil, nitrogen fixation due to leguminous plants, and atmospheric deposition. When calculating nutrient surpluses for the soil balance, a state of equilibrium is assumed. It is expected that, in the long term, the input of organic nitrogen in the form of crop residues and organic manure is equal to the annual decomposition. An exception to this rule is made for peat soil and dal soil (a sandy subsoil covered with a layer of lumps of young peat). With these types of soil, an input due to mineralisation is taken into account: 160 kg N per hectare for grassland on peat, and 20 kg N per hectare for grassland or other crops on peat and dal soil. It is known that net mineralisation is a phenomenon of these soils, the result of groundwater-level management, which is necessary for using them for cultivation. Schröder et al. (2004, 2007) calculate the surplus for the soil balance by starting from the contribution of nutrients to the soil. In this study, a method was employed that uses farm data to calculate the surplus on the soil balance.

**Nitrogen in livestock manure**
For the calculation shown in chapter 4 to determine the nutrient usage via livestock manure, the production of manure on the farm concerned is calculated first. In the case of nitrogen, this concerns the net production, after deducting the nitrogen lost from stables and storage in the form of gas. The manure produced by grazing livestock is calculated by multiplying the average number of animals present by the appropriate legal standard of excretion (Dienst Regelingen, 2006). Exempt from this are farms that use special guidelines (Handreiking). To determine the manure produced by housed animals, the number of such animals is multiplied by the appropriate national standard of excretion as established by the Working Group Uniform Mineral and Manure Excretions (Van Bruggen, 2007). For more details, see Buis et al. (2012).

*Table 2.2. Number of representative farms where water quality was measured in the period 1992-2011 (broken down by farm type and year)* [1].

| | Sandy regions | | | Clay regions | | | Peat regions | Loess region | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Dairy farms | Arable farms | Other farms | Dairy farms | Arable farms | Other farms | Dairy farms | Dairy farms | Arable farms | Other farms |
| 1992 | 67 (55) | 18 (16) | 7 (3) | | | | | | | |
| 1993 | 64 (53) | 19 (19) | 5 (3) | | | | | | | |
| 1994 | 32 (22) | | 3 (0) | | | | | | | |
| 1995 | 62 (45) | 18 (16) | 3 (1) | | | | | | | |
| 1996 | | | | | | | 16 (14) | | | |
| 1997 | 14 (13) | 10 (9) | 3 (2) | 2 (2) | 4 (4) | | | | | |
| 1998 | 18 (18) | 11 (11) | 12 (5) | 15 (15) | 11 (10) | 1 (1) | | | | |
| 1999 | 17 (16) | 8 (8) | 16 (6) | 23 (14) | 26 (25) | 4 (4) | 15 (11) | | | |
| 2000 | 23 (21) | 8 (8) | 11 (7) | 26 (23) | 27 (25) | 4 (4) | | | | |
| 2001 | 30 (-) | 8 (-) | 5 (-) | 26 (-) | 25 (-) | 4 (-) | 8 (-) | | | |
| 2002 | 31 (24) | 10 (5) | 15 (6) | 25 (11) | 22 (12) | 6 (3) | 20 (8) | 7 (5) | 5 (1) | 4 (2) |
| 2003 | 40 (31) | 17 (14) | 25 (13) | 30 (13) | 16 (6) | 3 (1) | 9 (8) | 7 (6) | 4 (3) | 3 (2) |
| 2004 | 68 (59) | 15 (14) | 20 (7) | 28 (15) | 36 (26) | 4 (0) | 12 (10) | 6 (4) | 7 (2) | 2 (1) |
| 2005 | 67 (62) | 14 (10) | 29 (14) | 22 (20) | 28 (25) | 4 (2) | 21 (21) | 7 (5) | 6 (3) | 2 (1) |
| 2006 | 128 (115) | 15 (13) | 31 (14) | 21 (19) | 27 (20) | 7 (7) | 20 (17) | 22 (7) | 13 (2) | 8 (2) |
| 2007 | 127 (123) | 30 (29) | 42 (22) | 49 (48) | 21 (20) | 14 (12) | 58 (58) | 19 (19) | 13 (10) | 7 (7) |
| 2008 | 117 (111) | 33 (32) | 48 (23) | 50 (48) | 23 (21) | 16 (13) | 57 (57) | 18 (18) | 12 (10) | 12 (9) |
| 2009 | 124 (119) | 32 (31) | 42 (23) | 49 (48) | 29 (27) | 12 (7) | 57 (56) | 18 (18) | 13 (12) | 10 (9) |
| 2010 | 119 (113) | 30 (28) | 44 (24) | 50 (47) | 26 (24) | 13 (9) | 57 (56) | 18 (18) | 12 (12) | 11 (8) |
| 2011 | 116 (107) | 31 (31) | 32 (20) | 51 (50) | 27 (26) | 11 (7) | 55 (54) | * | * | * |

[1] The number in brackets is the number of farms for which data on agricultural practices were collected the year before. Since 2009, LEI has been using probability limits for fertilisation with livestock manure, inorganic fertiliser, other organic manure and total fertilisation. Farms that exceed these limits are considered sources of extreme observations and are therefore not included.

- No FADN data is available for 2000.

* Sampling data for 2011 from the loess region were not yet available when this report was prepared.

*Table 2.3. Number of representative farms in the LMM where water quality was measured in the period 1992-2011 (broken down by farm type and year)[1].*

| | Sandy regions | | | Clay regions | | | Peat regions | Loess region | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Dairy farms | Arable farms | Other farms | Dairy farms | Arable farms | Other farms | Dairy farms | Dairy farms | Arable farms | Other farms |
| 1992-1995 | 71(3.2) | 19(2.9) | 7(2.6) | | | | | | | |
| 1996-1999 | 48(1.0) | 28(1.0) | 31(1.0) | 24(1.7) | 29(1.4) | 4(1.3) | 16(1.9) | | | |
| 2000-2003 | 89(1.4) | 32(1.3) | 42(1.3) | 49(2.2) | 38(2.4) | 9(1.9) | 24(1.5) | 7(2.0) | 6(1.5) | 4(1.8) |
| 2004-2007 | 168(2.3) | 46(1.6) | 80(1.5) | 69(1.8) | 44(2.5) | 20(1.5) | 62(1.8) | 23(2.3) | 18(2.2) | 9(2.1) |
| 2008-2011 | 129(3.7) | 38(3.3) | 62(2.7) | 59(3.4) | 32(3.3) | 16(3.3) | 60(3.8) | 18(3.0)^ | 15(2.5)^ | 13(2.5)^ |

[1] The figure in brackets is the average number of years in which samples were obtained from a farm in the period shown in the “Year” column.

^ Data from the loess region for 2011 were not yet available. The figures shown are for the period 2008-2010.

In addition, the quantity of nutrients is recorded for all fertilisers input and output and for all fertiliser stocks (inorganic fertiliser, livestock manure and other organic fertilisers). In principle, the quantity of nitrogen and phosphate in fertilisers input and output is recorded, based on sampling. If no sampling has been conducted, standard content sizes for each type of fertiliser are used (Dienst Regelingen, 2006). Opening and closing stock levels are always calculated based on standard amounts (Dienst Regelingen, 2006).

The formula for the total quantity of fertiliser used at farm level is:

> Fertiliser used on farm = Production + Opening stock level – Closing stock level + Input – Output

The quantity of different fertilisers used on agricultural land is recorded directly in the information network.
Apart from type and quantity, time of application is also documented. The formula for the quantity of fertiliser used on grassland is:

> Fertiliser used on grassland = Fertiliser used on farm – Fertiliser used on arable land

The fertiliser used on grassland comprises fertiliser that is spread and manure excreted by grazing animals on grassland (grazing manure). The quantity of nutrients in grazing manure is calculated for each animal category by multiplying the percentage of a year that the animals spend grazing by the standard of excretion (Dienst Regelingen, 2006).

For more details, see Buis et al. (2012).

**Calculating annual averages**
Annual average concentrations and other parameters are taken as the average of the annual farm averages. The average value for a period is taken as the average of all farm averages for the period. An exception to this are the loess-region data from the Province of Limburg (BVM loess). These are based on average values per plot instead of farm, a consequence of the different design for this monitoring programme (section 2.3.2). Loess-region data from the LMM are, in common with the data for the other regions, based on farm averages.

**Statistical analyses and observed effects**
For the statistical analysis of the relationship between farm management and the nitrate concentration in water that leaches from root zones, the residual maximum likelihood (REML) method is used (Payne, 2000). A statistical method is used in order to distinguish the effect of the Manure Policy, and to filter out the effects of differences in weather patterns and sample sizes from year to year (Boumans et al., 2001; 1997). This method is currently available for the programmes in the sandy and clay regions. A detailed description of the method is given in Fraters et al. (2004). Making the correction for environmental parameters used in the method more accurate is described in Boumans and Fraters (2011).

## 2.4 Monitoring status and trends in groundwater

### *2.4.1 General*

Monitoring deeper groundwater (more than 5 metres below the surface) in the Netherlands is carried out similarly to that in many other countries (Koreimann et al., 1996), by using permanent wells specially placed for the purpose of monitoring. These monitoring wells are located just outside fields to make sampling easier and to avoid hindering the work there. The first filter is at least one or two metres below the average of the lowest groundwater levels, but not more than a few metres below. This ensures (a) that the well screen is not in the unsaturated zone, and (b) that the groundwater sampled originated from the adjoining plot. The quality of the groundwater at this depth reflects the effect of agricultural practices of about ten years ago.

Preparation of this report utilised data from the National Groundwater Quality Monitoring Network (LMG).

### 2.4.2 *Data collection*

**LMG design**

The National Groundwater Quality Monitoring Network (LMG), established between 1979 and 1984, comprises about 360 monitoring sites spread throughout the Netherlands (Van Duijvenbooden, 1987). The main criteria for site selection were type of soil, land use and hydrogeological conditions. At each location, groundwater is sampled at depths of 5-15 metres and 15-30 metres below ground. Table 2.4a and b show the number of wells sampled for this study, broken down by soil type, land use and sampling depth.

*Table 2.4a. Number of wells for which complete[1] data series are available for the period 1984-2010, broken down by soil type, land use and sampling depth.*

| Land use | Depth | Sand | Clay | Peat | Other |
|---|---|---|---|---|---|
| Agriculture | 5-15 | 111 | 61 | 31 | 6 |
| | 15-30 | 110 | 60 | 31 | 5 |
| Nature | 5-15 | 55 | 4 | 4 | 3 |
| | 15-30 | 52 | 4 | 4 | 2 |
| Other | 5-15 | 36 | 18 | 2 | 6 |
| | 15-30 | 37 | 16 | 2 | 3 |

[1] Series were complete, or sufficient data were available to make estimates for locations that were missing data (see Fraters et al., 2004).

*Table 2.4b. Number of wells for which complete[1] data series are available for the period 1984-2010 for the soil type sand, broken down by sand region and sampling depth.*

| | Sand North | Sand Central | Sand South | Outside sand regions |
|---|---|---|---|---|
| 5-15 m depth | 32 | 24 | 32 | 23 |
| 15-30 m depth | 32 | 24 | 31 | 23 |

**Sampling frequency**
Locations were sampled annually between 1984 and 1998 (see results of Reijnders et al., 1998 and Pebesma and De Kwaadsteniet, 1997). After an evaluation in 1998 (Wever and Bronswijk, 1998), the frequency of sampling was reduced for certain combinations of soil type and depths. Shallow monitoring wells in sand regions are still sampled every year, whereas in other regions (clay and peat), they are sampled every two years. Deep wells are sampled every four years, as are shallow well screens at monitoring sites with a high chloride concentration (above 1000 mg/l due to marine effects). Finally, wells dominated by local conditions are eliminated (for example, wells near rivers and local sources of pollution). As a result, the number of wells sampled each year has been reduced from 756 to about 350. RIVM manages the network, and is responsible for both interpreting and reporting the data.

#### *2.4.3 Data processing*

Owing to the design of the LMG, there are locations (monitoring wells) that are not sampled each year. In order to avoid spurious trends that are a consequence of the network's design, an estimate is made of all missing data by interpolating from the data that are available. For data missing at the beginning and end of a series, the initial and final available values respectively are used to estimate them. Annual average concentrations are calculated by simply averaging the measured concentrations. Period average concentrations are calculated by averaging the period averages per location. More details on the data processing are given in Fraters et al. (2004).

The data presented in this report may deviate slightly from the data presented in the national Environmental Balance. In keeping with the previous report, a larger number of monitoring wells were used for analysis for this study. This approach resulted from the application of less strict criteria with respect to data missing for the period 1984-2010.

For the LMG wells in sandy soil, the average was determined separately for each of the areas Sand North, Sand Central and Sand South. The division into three areas was based on the 13 different areas that are used within the LMM. Moreover, this division is the same as that used for the Evaluation of the Fertilisers Act (EMW, Hooijboer et al., in preparation). Accordingly, LMG wells in sandy soil, but outside the LMM sand region are not part of this analysis.

| | |
|---|---|
| Sand North | LMM areas: North Sand Area I, North Sand Area II and Peat Districts. |
| Sand Central | LMM areas: Central Sand Area plus East Sand Area. |
| Sand South | LMM area: only South Sand Area. |

### 2.5 Monitoring status and trends in water used for drinking water production

#### *2.5.1 General*

Water production companies carry out monitoring programmes focusing on quality control of the water resource (both groundwater and surface waters), the production process and the end product. These companies have a legal obligation to report the results annually to the Netherlands’ Human Environment and Transport Inspectorate, with the data management and reporting carried out by RIVM. The report utilises data on the quality of the groundwater used for the production of drinking water. Owing to the generally great depth from where groundwater is extracted, there is a substantial time lag between the measurement and the effect on the water used for production.

### 2.5.2 *Data collection*

Since July 2010, drinking water in the Netherlands has been supplied by 10 drinking water companies (Versteegh and Dik, 2011). About 65% of the drinking water originates from groundwater (Joosten et al., 1998). In 2010, there were 186 drinking water production sites utilising groundwater. Of this number, 108 were using phreatic (unconfined) groundwater and 78 artesian (confined) groundwater. There are about 25 sites where drinking water is produced from riverbank groundwater, dune infiltration water and surface water (see Table 2.5). The average depth of the groundwater from phreatic aquifers utilised for drinking water production is 45 metres; the average depth of the filters is between 30 and 65 metres. Of these sources, 70% are at an average depth exceeding 30 metres, and 30% are at a depth of less than 30 metres.

Concentration is measured per string of wells, and a monitoring site often comprises multiple strings. For each monitoring site, the minimum, maximum and average values of the strings are determined. Measurements are taken at each site several times a year (from three to six times, in some cases more often).

For this report, the annual average of the string averages was determined, as well as the annual maximum of the string maximums.

### 2.5.3 *Data processing*

For processing the data on drinking water, a supplementary database was created to tackle the issue of the changing number of drinking water production sites in the period 1992-2010. The database was constructed in two stages. First, minor information deficiencies were remedied. If no data were available for a specific site in a specific year, the average of the available values in the period from two years before to two years after the year concerned was used as an estimate. If no data were available for the aforementioned period, the production facility was classified as a site without data. Then, all sites that were still missing data were removed from the database, so that only sites with data (measured or estimated) remained.

The drinking water data are used in the section on groundwater for the production facilities that utilise phreatic and confined groundwater (see chapter 5, in particular section 5.4). These data are also used in chapter 6 (included in the surface water database) for production sites that directly or indirectly utilise surface water.

*Table 2.5. Number of monitoring sites for drinking water production in the Netherlands in the period 1992-2010.*

| Year | Phreatic groundwater | Artesian groundwater | Surface water | Dune infiltration | River bank infiltration |
|---|---|---|---|---|---|
| 1992 | 127 | 86 | 10 | 8 | 13 |
| 1993 | 126 | 85 | 11 | 9 | 14 |
| 1994 | 125 | 87 | 11 | 8 | 14 |
| 1995 | 123 | 86 | 12 | 8 | 15 |
| 1996 | 123 | 86 | 12 | 8 | 14 |
| 1997 | 121 | 87 | 11 | 7 | 14 |
| 1998 | 120 | 86 | 11 | 6 | 13 |
| 1999 | 117 | 86 | 11 | 7 | 13 |
| 2000 | 117 | 87 | 11 | 5 | 12 |
| 2001 | 113 | 82 | 9 | 5 | 12 |
| 2002 | 105 | 84 | 7 | 4 | 13 |
| 2003 | 108 | 82 | 7 | 4 | 13 |
| 2004 | 106 | 81 | 5 | 4 | 13 |
| 2005 | 102 | 78 | 3 | 5 | 12 |
| 2006 | 102 | 78 | 4 | 4 | 13 |
| 2007 | 101 | 78 | 4 | 4 | 12 |
| 2008 | 94 | 74 | 4 | 4 | 12 |
| 2009 | 98 | 74 | 4 | 4 | 11 |
| 2010 | 95 | 74 | 4 | 4 | 9 |

Figures representing annual averages and maxima for the 1992-2010 period are derived from the supplementary database. Each annual average and annual maximum is the average of averages and the average of maxima, respectively, of all drinking water production sites, for a particular year.

The tables and maps showing the status for each period and the trends between periods are derived from the original database. For each drinking water production site an average value is calculated per period, the value being based on between one and three annual averages or maxima. Only the sites monitored in both these periods are used for comparison purposes.

## 2.6 Monitoring status of and trends in surface water quality

### *2.6.1 General*

The surface water monitoring networks comprise the monitoring networks for regional and large freshwater bodies, as well as those for coastal and marine waters. The large freshwater bodies, coastal waters and marine waters are collectively known as the main water system. Even a regional monitoring location covers an area larger than a farm, thus distinguishing it from the LMM (see section 2.3). As a result, the influence of other sources of pollution and the time between measurement and effect increase by steps in the order regional waters, large fresh water bodies, coastal waters and open sea. Details of the data collection are given in the next section, 2.6.2. Section 2.6.3 deals with the data processing.

### 2.6.2 *Data collection*

National as well as regional authorities monitor the quality of surface waters. The national authorities are responsible for monitoring the water status of the country as a whole (MWTL), and the local authorities for the regional monitoring networks (RWSNs).

**Monitoring the water status of the country as a whole (MWTL)**
The Directorate-General of Public Works and Water Management (RWS) of the Ministry of Infrastructure and the Environment (I&M) collects data from 39 monitoring locations at sea (including the Zeeland estuary) and from around 55 locations in large (national) fresh surface waters, such as larger rivers, canals and lakes. At sea, the frequency of sampling is once a month in winter and twice a month in summer. From the fresh surface waters, samples are generally taken every four weeks.

The RWS Water Department is responsible for the collection and presentation of marine water data and fresh surface water data.

**Regional monitoring networks**
The 26 water authorities have their own regional monitoring networks, comprising several thousands of monitoring sites in regional fresh water bodies. The frequency of sampling varies but is usually once every four weeks.

Every year, the RWS Water Department in collaboration with Informatiehuis Water (IHW) examines the water quality data obtained from these monitoring networks. In 2010, this survey covered data from around 450 monitoring sites in fresh water, which reflected the quality of the regional waters. In 1992, only some 250 sites were used. The water quality at these sites is affected not only by agriculture but also by other factors, in summer by the quality of water originating from the main water system.

The data presented in this report might deviate slightly from the data presented in the 2008 report (Zwart et al., 2008). For the current report, the same locations as in 2010 were used. For all these locations, the historical data were employed in such a way that the two previous periods, i.e. from 2004 to 2007 and 2008 to 2010, covered the same number of locations. These locations are sites in the KRW monitoring network of the water managers, supplemented by additional monitoring sites from outside the network.

For all monitoring sites, the water authorities have determined whether or not it is strongly affected by agriculture. In this report, consideration is given to two types of locations: locations strongly affected by agriculture, and main locations.

The data in the report here might also deviate slightly from those in the reports for the Evaluation of the Fertilisers Act 2012 (EMW, Klein et al., 2012b). Separate data were selected for the EMW by Deltares in consultation with the water authorities (Klein et al., 2012a, 2012b). Since these studies and reports were ongoing simultaneously, coupled with the uncertainty of whether the results of the EMW would be ready in time, it was decided in the case of the Nitrates Directive report to use the same procedure as in 2008.

### 2.6.3 *Data processing*

**Nitrate concentration**
The nitrate data that are obtained from measurements in fresh water relate to both nitrate and nitrite. From most monitoring sites, only combined data on nitrate and nitrite were available. There were just a few sites where separate data on nitrate had been kept up to date for a couple of years. Because nitrite concentrations in freshwater are very low compared with nitrate concentrations, the nitrate and nitrite ones are both presented here under the heading “Nitrate”.

**Annual average values**
Figures showing winter and summer averages and maxima for the previous period are based on the data collected at different locations. The winter and summer averages are respectively the averages of the winter and summer averages of all monitoring sites in surface waters. The same approach is used to calculate the winter and summer maxima.

**Definition of summer and winter**
The six summer months are the most critical period with respect to eutrophication. The EU standard for nitrate is primarily aimed at assessing the effects of agriculture on surface water quality. In this context, the winter months, when leaching plays a significant role, are of particular importance. The winter period as regards fresh surface waters lasts from October to March inclusive.

In marine waters however, there is still considerable biological activity in October and November. These months are therefore not taken into account for the calculation of the winter average. The data from measurements at sea also indicate that by March biological growth is already underway and therefore nitrogen is then present in biomass. The March data are therefore not suitable for nutrient trend analyses. Accordingly, the winter period for analysing marine water is defined as December to February inclusive. To measure changes in water quality (eutrophication), the nitrogen concentrations in marine water are compared year by year. To avoid a distorted picture emerging from these comparisons, the data are analysed for the months when there is almost no biological activity.

**Differences in salinity**
During the winter period, the nutrient concentration in marine water is more or less constant, and shows a clear linear relationship with the salinity, the nutrient concentration becoming greater as the saline content decreases. In other words, the nutrient concentration increases the further the distance from a river-mouth. In order to compensate for differences in salinity at the various locations from year to year (due to differences in river outflows), nutrient concentrations are usually normalised for salinity (Bovelander and Langenberg, 2004).

For the present study of trends in nutrient concentration, no salinity correction has been made for the results presented in the context of the reporting guidelines. Consequently, the conclusions presented here that are based on years of in-depth studies of trends in nutrient concentration are affected by year-to-year differences in river outflows (because of differences in precipitation, et cetera), and therefore have to be treated with caution. Accordingly, additional figures are provided on inorganic nitrogen concentrations for which a correction has been made in respect of a number of monitoring sites in Dutch coastal waters. Dissolved inorganic nitrogen (DIN) is the sum of nitrite nitrogen ($NO_2$-

N), nitrate nitrogen ($NO_3$-N) and ammonium nitrogen ($NH_4$-N), with DIN standardised to a salinity of 30 PSU (Practical Salinity Units). The water in the Dutch part of the North Sea contains on average about 3.5% sodium chloride (NaCl), the equivalent of 35 PSU. This presentation of data is in accordance with the OSPAR Procedure, and shows the long-term trend in inorganic nitrogen concentrations corrected for the effects of precipitation.

## 2.7 References

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# 3 Agricultural practice

## 3.1 Introduction

This chapter deals with the development of agricultural practice in the Netherlands in general, and with use of nitrogen and phosphorus in Dutch agriculture in particular, for the period 1992-2011. The main topics discussed are the changes in land use, number of farms, livestock, et cetera resulting from policy measures as well as from autonomous developments (section 3.2). The nitrogen and phosphorus balances of agriculture are discussed in section 3.3, followed by a description of the other developments in agricultural practice in section 3.4.

To begin with, a summary is given of the Dutch policy measures taken in the framework of the first (1995-1999), second (1999-2003) and third (2004-2009) Action Programmes. In this context, three periods can be distinguished that do not exactly coincide with the action programme periods, i.e. 1996-1998, 1999-2005 and 2006-2010. More information is provided about this in the subsequent sections.
Between 1987 and 2000, measures were taken by means of fertiliser legislation to limit the maximum quantity of livestock manure that could be used. As part of this legislation, the application standards concerning the quantity of phosphate in fertiliser were tightened by setting a maximum for the use of livestock manure (see Table 3.1). In this way, the maximum quantity of nitrogen deposited on the land via livestock manure was also further limited. Moreover, rules were drawn up in this period governing the time of year when livestock manure could be applied as well as the method of application.

*Table 3.1. Manure application standards in the period 1987-2000 in kg $P_2O_5$ per ha*

| Year | Grassland | Silage maize | Arable land |
|---|---|---|---|
| 1987-1990 | 250 | 350 | 125 |
| 1991-1992 | 250 | 250 | 125 |
| 1993 | 200 | 200 | 125 |
| 1994 | 200 | 150 | 125 |
| 1995 | 150 | 110 | 110 |
| 1996-1997 | 135 | 110 | 110 |
| 1998-1999 | 120 | 100 | 100 |
| 2000 | 85 | 85 | 85 |

*Source: LNV, 2001b, 1997, 1993b.*

Between 1996 and 1998, the desired changes in agricultural practice occurred, in the form of a reduction in the quantity of manure being produced (manure production rights). In addition, a system of manure bookkeeping was introduced on livestock farms. During this period, all farms were subject to the following statutory regulations:

1. Maximum quantities for minerals that were allowed to be applied (application standards).
2. Designated time of the year when the application of manure was prohibited because of the risk of nitrogen leaching.
3. Prescribed method for applying manure to reduce ammonia emissions.
4. Covering of manure storage facilities to prevent ammonia emissions.

In 1998, the Dutch government introduced MINAS, the farm-level system for mineral accounting, based on the mineral balances of nitrogen (N) and phosphorus (P) (farm gate balance). Under this system, limits were set for the permitted levels of the N and P surpluses on farms (MINAS loss standards). MINAS did not regulate inorganic fertiliser and fixation separately, but performed accounting for the overall flow of minerals (including feed, livestock, animal products, et cetera). Farmers could therefore switch between the various components, provided they kept to the loss standards. In this way, the system regulated the N and P surplus of farms (farm gate balance). A certain N and P surplus was considered acceptable and was free of levy. The loss standards for nitrogen were tightened in the period 1998-2005 (Table 3.2). If a farmer had a surplus exceeding the loss standard, he had to pay a levy, with the levies increasing progressively between 1998 and 2003. The MINAS system was implemented in stages. On the introduction in 1998, it initially applied to livestock farms with a high animal density (above 2.5 LU/ha). In 2001, MINAS was extended to all farms. In addition, lower loss standards were set for cultivated land on sand and loess soils, which are vulnerable to nitrogen leaching.

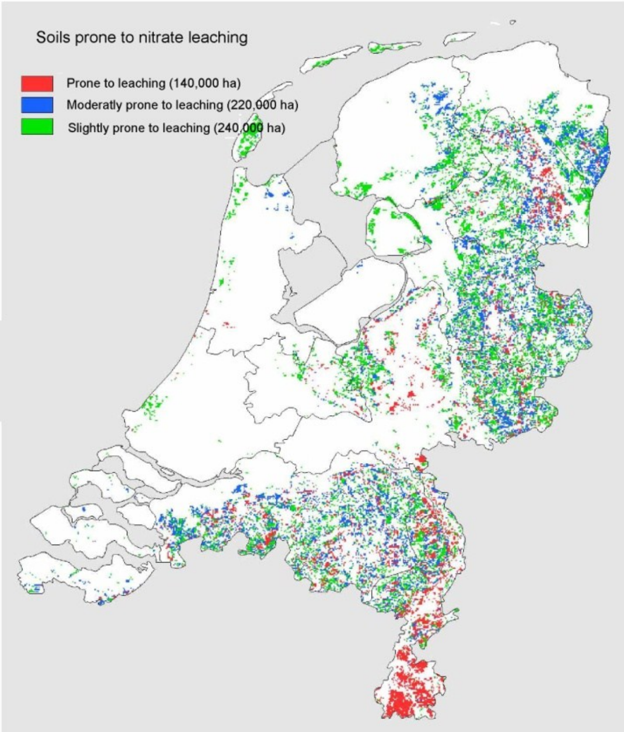
*Table 3.2. Nitrogen loss standard for 1998-2005, in kg N/ha for arable land and grassland on clay, peat, sand and loess soils[1].*

| | Grassland | | Arable land | |
|---|---|---|---|---|
| Year | All types | Sand[1] | All types | Sand/Loess |
| 1998-1999 | 300 | 300 | 175 | 175 |
| 2000 | 275 | 275 | 150 | 150 |
| 2001 | 250 | 250 | 150 | 125 |
| 2002 | 220 | 190 | 150 | 110/100[1] |
| 2003 | 220 | 190 | 150 | 110/100[1] |
| 2004 | 180 | 160 | 135 | 100/80[1] |
| 2005 | 180 | 160 | 125 | 100/80[1] |

[1] Vulnerable soils are sand and loess soils prone to nitrate leaching, or soils with groundwater levels below average.

*Source: LNV, 2001b, 1997; LEI, 2007.*

The MINAS system had a greater impact than the previous system, which was based solely on application standards for livestock manure. The MINAS system also included the regulation of inorganic-fertiliser nitrogen and nitrogen fixation by legumes (arable land only). In 2002, special lower nitrogen loss standards were introduced for farms with soils prone to nitrate leaching. Overall, 140,000 ha of land were designated as having soil prone to nitrate leaching (see Map 3.1). The current system of application standards no longer includes this distinction, owing to the complexity of implementation and maintenance.




*Map 3.1. Map of the Netherlands showing the areas with soil prone to nitrate leaching (red areas).*
*Source: LNV, 2001a.*

On 1 January 2002, the Manure Transfer Contracts (MAO) system came into force to effect compliance with the application standards stipulated by the Nitrates Directive. Livestock farmers who produced too much manure were obliged to enter into manure transfer contracts with, for example, arable farms, less intensive livestock farms or manure processors. For calculating the exceedance of the allowable manure production level, the application limit was 170 kg N/ha (implemented in stages), with a higher limit of 250 kg N/ha for grassland. These limits were established in line with the Dutch notification of exemption at the time. Farmers unable to enter into manure transfer contracts for their excess manure had to reduce their livestock numbers. This change in policy was accompanied by extensive advisory campaigns and demonstration projects. In October 2003, the European Court of Justice rejected MINAS on the grounds of it being an improper implementation of the Nitrates Directive, following which the Dutch government decided to abandon MINAS and MAO. The MAO system was abolished early in 2005.

In January 2006, the Netherlands adopted a manure policy based on application standards instead of loss standards. Compared with MINAS, the new manure policy, including application standards for nitrogen in livestock manure and inorganic fertilisers as laid down by the Nitrates Directive, imposes more restrictions on the use of nitrogen and phosphorus.

The policy provides for different limits on the use of nitrogen from livestock manure, on the use of total nitrogen, and on the use of total phosphorus. The application standard for nitrogen from livestock manure is 170 kg N per ha. Farms with at least 70% grassland can adhere to a standard of 250 kg N per ha in the period 2006-2013, provided they follow a fertilising plan according to set rules. Application standards for the use of total active nitrogen differ by crop and soil type, and vary over time. After 2006, these nitrogen application standards were tightened on occasions. To show all the variations would require a table spanning several pages. Because of the size, the reader is referred to the website of the DR portal (Dienst Regelingen, 2012a and 2012b).

The Dutch manure policy in force since 2006 applies to all manure from animals kept for professional purposes or for profit. This policy has a wider scope of application than the pre-2006 policy, for example, horse manure is subject to the new legislation. There are also new regulations governing the application methods for manure and inorganic fertiliser, mainly concerning:

- the time of year when the application of manure is permitted;
- the ploughing up of grassland;
- the obligation to grow a catch crop after the cultivation of maize, to prevent nitrogen leaching.

## 3.2 Developments in agriculture

### 3.2.1 *Land use*

The Nitrates Directive action programme applies to the whole of the Netherlands. Land use is therefore reported at a national level (see Table 3.3). The Netherlands has a land surface area of 3.37 million ha, of which 1.85 million ha (55%) is cultivated (CBS, 2012). Land use in the first, fourth and fifth reporting periods is shown in the table below.

*Table 3.3. Land use in the Netherlands (x 1,000 ha).*

| | 1992-1995 | 2004-2007 | 2008-2011* |
|---|---|---|---|
| Grassland | 1057 | 985 | 962 |
| permanent | 1021 | 779 | 778 |
| temporary[1] | 36 | 206 | 184 |
| | | | |
| Silage maize | 224 | 225 | 236 |
| Other arable crops | 576 | 572 | 529 |
| Horticulture | 110 | 114 | 118 |
| Total cultivated area | 1967 | 1897 | 1845 |
| | | | |
| Fallow land | 11 | 24 | 7 |
| Nature and forest areas | 452 | 484 | 485 |
| Other land use | 959 | 971 | 1035 |
| Total land surface area[2] | 3388 | 3376 | 3372 |

[1] Grassland less than five years in use by a farm.
[2] Data available for only 1993, 2006 and 2008.
**Provisional figures.*
*Source: CBS (2012).*

The total cultivated area steadily decreased between 1992 and 2011 by about 122,000 ha (6.2%) because of nature development, expansion of urban areas and construction of roads.

### 3.2.2 *Number of farms*

The total number of farms shrank by 38% during the period 1992-2011 (Table 3.4), the size of the decrease varying by farm type. The number of dairy farms contracted by 33%, horticultural farms by 45%, and pig and poultry farms by 40%. Regarding arable farms, their number fell the least (19%).

*Table 3.4. Number of farms by main farm type.*

| | 1992-1995 | 2004-2007 | 2008-2011 |
|---|---|---|---|
| Arable farms | 14718 | 12868 | 11858 |
| Horticultural farms[1] | 22408 | 14963 | 12381 |
| Grazing livestock farms | 56355 | 39874 | 37937 |
| Factory farms | 10997 | 7596 | 6582 |
| Combination farms | 12831 | 5130 | 3961 |
| All farm types | 117309 | 80430 | 72719 |

[1] Including farms under permanent cultivation.

*Source: CBS (2012).*

The growth of organic farming at the end of the 1990s stagnated between 2004 and 2007 (Figure 3.1). During that period, the number of farms and the land area in use for organic agriculture remained more or less stable (MNP 2007). After 2007, the number of farms increased a mere 3.5%, whereas the total acreage grew by over 15% in the same period. In 2010, 45,733 ha were in use as organic farmland. Of Dutch agriculture, 2.4% is organic (PBL, 2012a).

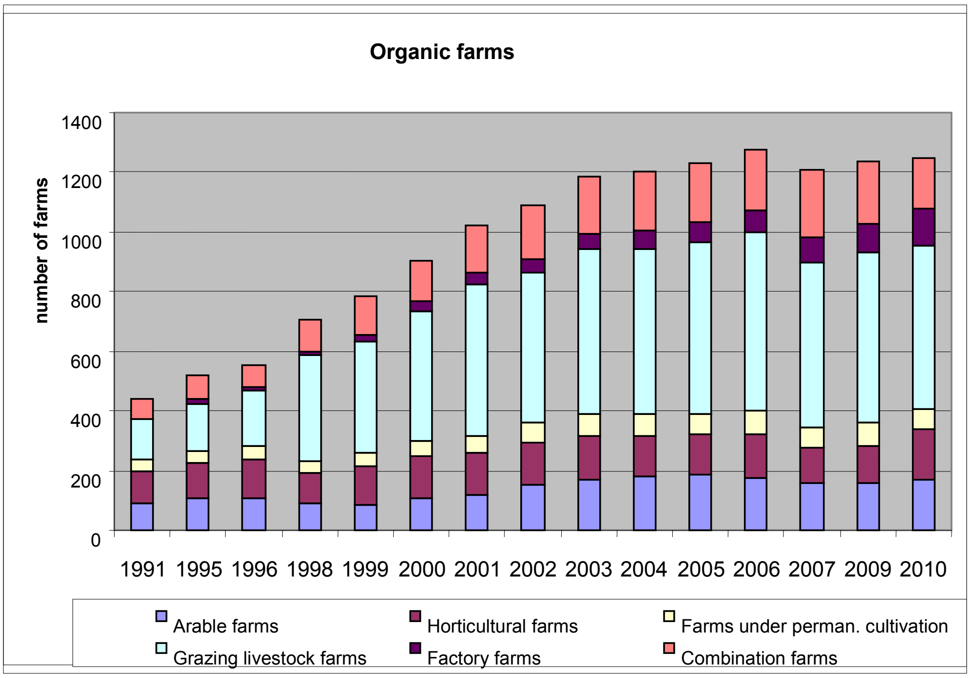



*Figure 3.1. Number of organic farms in the Netherlands.*

### 3.2.3 *Livestock*

Between 1992 and 2011, the number of cattle and pigs fell by 18% and 16% respectively. By contrast, poultry numbers rose by 4% (Table 3.5). There was a decrease in the period 1992-2007, however, with the numbers in the period 2008-2011 being slightly above those in the period 2004-2007. As the milk quota limit the number of dairy cows, an increase in milk production per cow led to a reduction in the number of cows needed to produce the permitted quantity of milk.

*Table 3.5. Number of farm animals (in millions).*

| | 1992-1995 | 2004-2007 | 2008-2011 |
|---|---|---|---|
| Cattle | 4.8 | 3.8 | 3.9 |
| Pigs | 14.5 | 11.4 | 12.2 |
| Poultry | 94.2 | 90.8 | 97.9 |
| Sheep and goats | 1.9 | 1.6 | 1.5 |

*Source: CBS (2012).*

### 3.2.4 *Nitrogen and phosphorus produced in livestock manure*

In the period 1992-2010, the nitrogen produced in livestock manure per animal decreased for all animal species (see Table 3.6). This was mainly due to a combination of lower nitrogen content in fodder and improved fodder conversion efficiency. The calculated amount of nitrogen produced per animal is greater than the amount of nitrogen in livestock manure applied to the soil as fertiliser (see Figure 3.2) because part of the nitrogen is lost via volatilisation during storage and application.

*Table 3.6. Gross nitrogen excretion per animal per year (kg N per animal per year).*

| | 1992-1995 | 2004-2007 | 2008-2010 |
|---|---|---|---|
| Dairy cows | 155.0 | 136.5 | 131.8 |
| Young female livestock (1-2 years) | 95.6 | 74.7 | 73.6 |
| Meat-type pigs | 14.6 | 12.6 | 12.6 |
| Sows (with piglets) | 31.3 | 31.5 | 30.4 |
| Broilers | 0.62 | 0.53 | 0.52 |
| Laying hens | 0.85 | 0.74 | 0.77 |

*Source: CBS (2012).*

From 2008 to 2011, the total annual quantity of nitrogen produced by livestock amounted to 487 million kg (see Table 3.7), which is about 30% below the annual production in the period 1992-1995. This decrease was caused mainly by a reduction in manure nitrogen produced by cattle (down 36%) and pigs (down 30%), a consequence of less nitrogen produced per animal and a smaller livestock number. Between 2008 and 2010, nitrogen production was slightly more (2.7%) than in the period before (2004-2007). Of the total nitrogen produced by Dutch livestock, 61% originates from cattle, approximately 22% from pigs, and about 13% from poultry.

*Table 3.7. Nitrogen produced in livestock manure (kg N millions).*

| | 1992-1995 | 2004-2007 | 2008-2011* |
|---|---|---|---|
| Cattle excl. veal calves | 437 | 283 | 281 |
| Veal calves | 8 | 13 | 15 |
| Pigs | 153 | 101 | 107 |
| Poultry | 70 | 57 | 63 |
| Horses and ponies | 5 | 7 | 7 |
| Other | 24 | 14 | 14 |
| All livestock | 697 | 474 | 487 |

**Provisional figures.*
*Source: CBS (2012).*

The phosphorus produced in manure by Dutch livestock decreased by about 23% between the first and fifth reporting periods (see Table 3.8), mainly the result of a decrease in phosphorus production by pigs and cattle. Compared with the previous reporting period (2004-2007), the phosphorus produced in livestock manure rose slightly (5.4%).
Between 2008 and 2011, half the phosphorus produced came from cattle, a quarter from pigs and less than one sixth from poultry.

*Table 3.8. Phosphorus produced in livestock manure (kg P millions).*

| | 1992-1995 | 2004-2007 | 2008-2011* |
|---|---|---|---|
| Cattle excl. veal calves | 52 | 38 | 39 |
| Veal calves | 1 | 2 | 2 |
| Pigs | 29 | 18 | 20 |
| Poultry | 13 | 11 | 12 |
| Horses and ponies | 1 | 1 | 1 |
| Other | 4 | 2 | 2 |
| All livestock | 100 | 73 | 77 |

**Provisional figures.*
*Source: CBS (2012).*

As from 2006, the Netherlands has had permission from the European Commission to use a higher application standard of 250 kg N per hectare from grazing livestock manure for farms with at least 70% grassland (exemption).
In the exemption is a condition agreed with the European Commission that the excretion of nitrogen and phosphorus by Dutch livestock be subject to an upper limit. Specifically, the excretion must not exceed the 2002 level, i.e., be no more than 75.5 million kg P (173 million kg phosphate) and 504 million kg N (including losses in the form of gas). Subsequent to the exceedance of the upper limit for phosphate from 2008 to 2010 inclusive, both targets were reached in 2011 (provisional figures; PBL, 2012b).

## 3.3 Nutrient balances

### *3.3.1 Nitrogen balance of agriculture*

Figure 3.2 shows the N flows in Dutch agriculture for 2009. This flowchart combines the flows internal to the livestock production system with the nutrient flows to the soil.

Input of the flowchart comprises imported fodder, purchased inorganic fertilisers and a number of other inputs, including atmospheric nitrogen deposition from other sources in the Netherlands and abroad (mainly as $NO_x$). Output is a combination of the sale and export of agricultural products, the export and processing of manure, and the emission and transport of ammonia via the air. The figure illustrates the importance of the different flows. There are two major return flows: first, harvested crops used as fodder for livestock, and second, the atmospheric deposition of ammonia from livestock manure and inorganic fertilisers onto cultivated soil.

The difference between the input and output is the surplus on the national farm gate balance (shaded blue). In the figure is also shown the surplus on the national soil balance (shaded yellow). The difference between these two surpluses, due to a difference in the calculation of excretion and of manure production, is about 5% (see section 2.2.3).

Compared with 2005 (Figure 2 in the previous report), the use of inorganic fertiliser dropped sharply (down 19%). The excretion of nitrogen in livestock manure increased a little (up 5%). By contrast, the processing and export of manure together grew by such an extent (up 64%) that the surplus contracted by 19%.

### *3.3.2 Nitrogen and phosphorus soil balances*

The nitrogen surplus on the soil balance (net nitrogen input to the soil, calculated using the Statistics Netherlands' method described in section 2.2.3) was 267 million kg on average for the period 2008-2010 (Table 3.9), 18% less than for the period before. The surplus shown in Table 3.9 corresponds to the item "Other" on the national soil balance shown in Figure 3.2. The effect of this surplus on the environment, i.e. the destination of the N surplus, cannot be determined from statistical data. The surplus probably leaches partly into groundwater and/or surface water, and is partly reduced through denitrification.

The link connecting the calculation of the soil surface balance to that of the farm gate balance is the production of livestock manure. For the flowchart of Figure 3.2, excretion is calculated as the difference between the consumed fodder and the national agricultural product. Manure production is also computed per animal in a similar way and multiplied by the total number of animals.

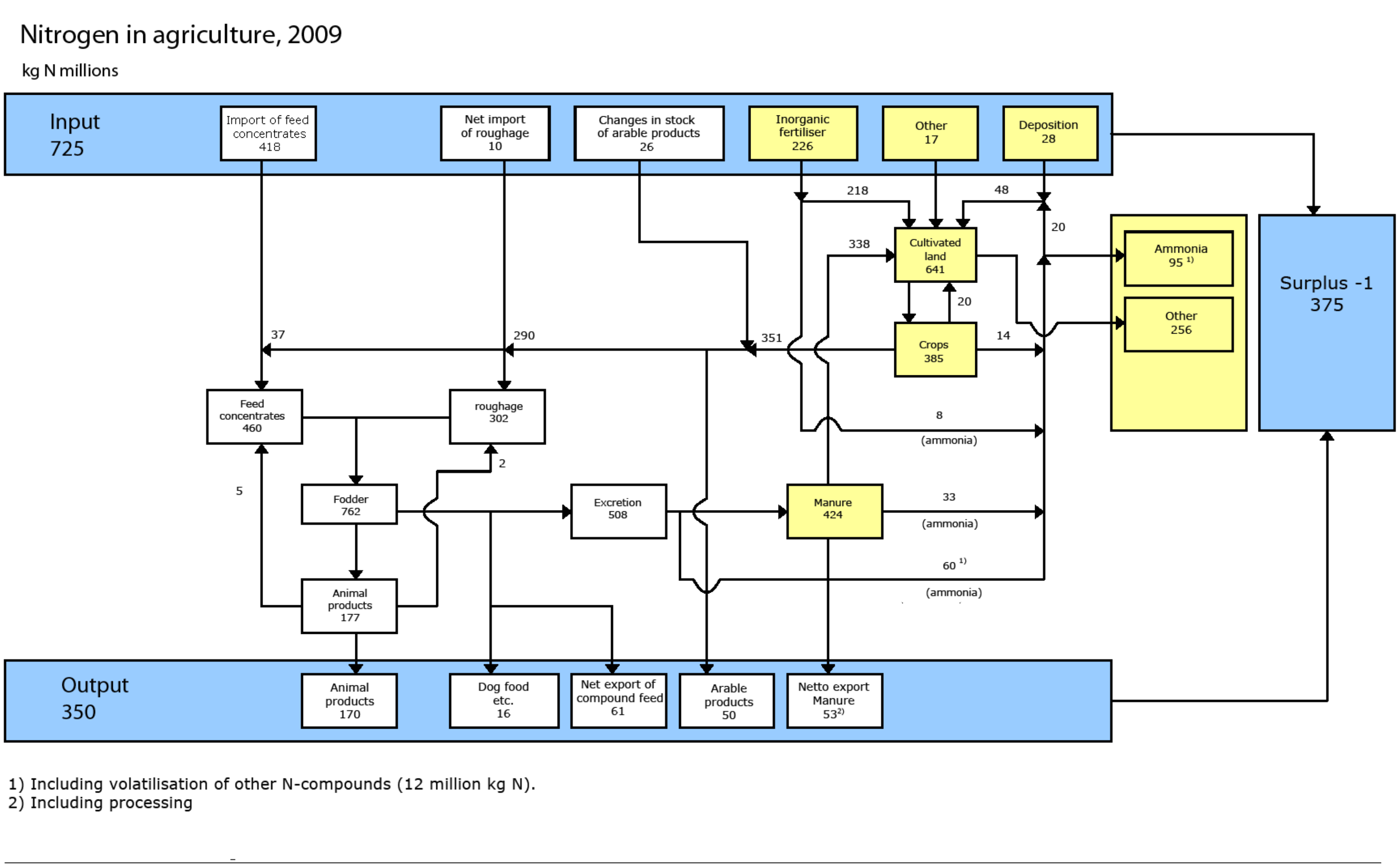



*Figure 3.2. Diagram of the nitrogen flows within Dutch agriculture, 2009.*
*Source: CBS (2012).*

*Table 3.9. Nitrogen balance of cultivated land (kg N millions per annum).*

| | 1992-1995 | 2004-2007 | 2008-2010* |
|---|---|---|---|
| Input[1] via: | | | |
| Livestock manure | 495 | 349 | 344 |
| Inorganic fertilisers | 382 | 270 | 222 |
| Other[2] | 39 | 38 | 36 |
| Atmospheric deposition | 75 | 57 | 51 |
| Total input | 991 | 713 | 653 |
| Total output (crops) | 481 | 390 | 386 |
| Surplus | 510 | 324 | 267 |

[1] Excluding ammonia emissions from livestock manure and inorganic fertilisers.
[2] Including crop residues, seeds and suchlike, and other organic fertilisers (compost).
*Provisional figures.
*Source: CBS (2012).*

The largest inputs of nitrogen are from livestock manure and inorganic fertilisers, corrected for ammonia emissions during grazing and application. Total nitrogen input shows a decline of over 8% between the periods 2004-2007 and 2008-2010. The largest input item (livestock manure) shows a decrease exceeding 30% between the periods 1992-1995 and 2008-2010, whereas the inorganic fertiliser input is down 42%. All the nitrogen output is in harvested agricultural crops. Harvests differ from year to year because of variable weather conditions. It is likely that nitrogen uptake has decreased, although nothing indicates that harvests have become smaller due to the use of fertilisers with lower nitrogen content. The output of nitrogen fell by 20% between the periods 1992-1995 and 2004-2007.

The average phosphorus surplus on the soil balance was 16 million kg from 2008 to 2010 (Table 3.10). The main input items were livestock manure and, to a lesser extent, inorganic fertilisers. During the period 1992-2010, the input from livestock dropped by over 34%, from inorganic fertiliser by more than 65%. As the output in harvested crops fell by only 8%, the surplus decreased by 75%.

*Table 3.10. Phosphorus balance of cultivated land (kg P millions per annum).*

| | 1992-1995 | 2004-2007 | 2008-2010* |
|---|---|---|---|
| Input via: | | | |
| Livestock manure | 93 | 65 | 61 |
| Inorganic fertilisers | 30 | 19 | 7 |
| Atmospheric deposition | 0 | 0 | |
| Other[1] | 5 | 4 | 3 |
| *Total input* | 128 | 88 | 71 |
| *Total output (crops)* | 60 | 55 | 55 |
| *Surplus* | 68 | 33 | 16 |

[1] Including crop residues, seeds and suchlike, and other organic fertilisers (compost).
*Source: CBS (2012).*

In order to place the effects of weather and other influences in a broader perspective, the trends in nitrogen and phosphorus surpluses since 1970 onwards are shown in Figure 3.3, with 1970 as reference year (1970 index = 100; first year for which nutrient balances were calculated).

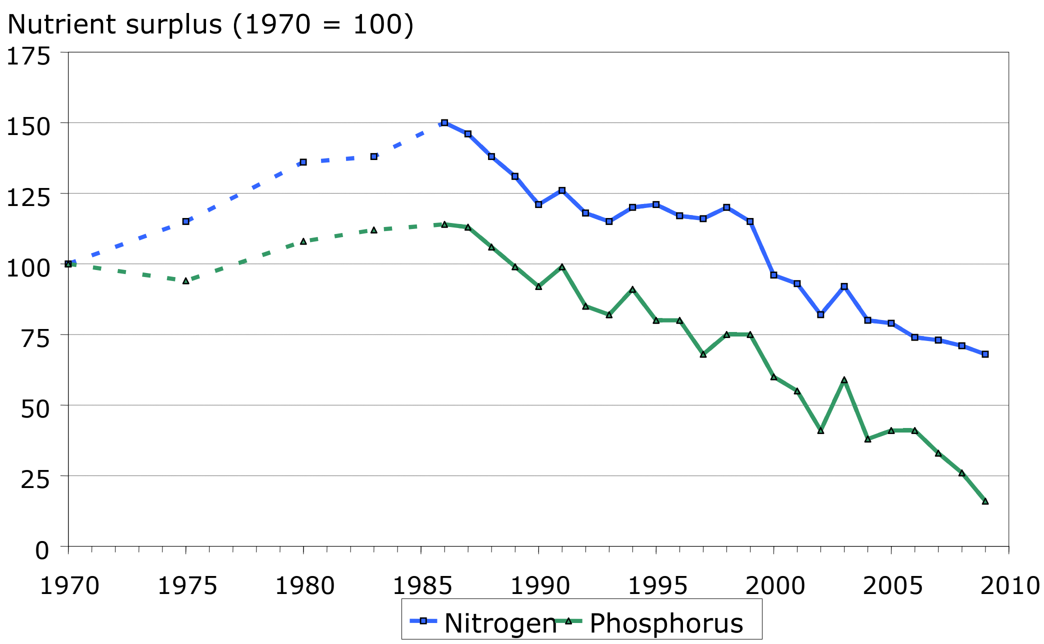



*Figure 3.3. Trends in the nitrogen and phosphorus surpluses in Dutch agriculture in the period 1970-2009, with 1970 values defined as 100.*
*Source: CBS, 2012a.*

The nitrogen surplus shows an almost constant decrease throughout the period 1986-1990. This trend is flat between 1991 and 1998. The year-to-year fluctuations shown in Figure 3.3 are mainly attributable to differences in harvest resulting from annually changing weather conditions. The nitrogen surplus shows a substantial decrease after 1998, largely attributable to the new statutory system based on the farm gate balance (MINAS) introduced in 1998. Especially affected were dairy farms, where the use of nitrogen fertiliser shrank by 40% to 50% (Fraters et al., 2004). The phosphorus surplus shows an almost constant decrease throughout the period 1986-2002, mainly the result of less manure produced because of reduced livestock numbers and feeding practices being more efficient (see Table 3.6). After 2002, the nitrogen and phosphorus surpluses stopped decreasing temporarily, but resumed falling from 2005 until 2009.

## 3.4 Developments in agricultural practice

### *3.4.1 Introduction*

The previous section dealt with the use of nitrogen and phosphorus. This section considers other aspects of agricultural practice. First the changes are described regarding manure transport and processing, fertilising methods and timing, fertilisation close to waterways, green manure crops and irrigation (section 3.4.2). Figures are then given showing manure storage capacity in the Netherlands (section 3.4.3), followed by an explanation of fertilisation advice, demonstration projects and guidance (section 3.4.4). Other developments are also discussed, such as green manure crops, irrigation and limitation of ammonia emissions. The last part of 3.4 (section 3.4.6) considers compliance with the code of Good Agricultural Practice, the Mineral Accounting System, manure transfer contracts, and other aspects of agricultural regulations.

### *3.4.2 Legislation governing manure application and nitrogen surplus*

#### 3.4.2.1 Transport and processing of manure

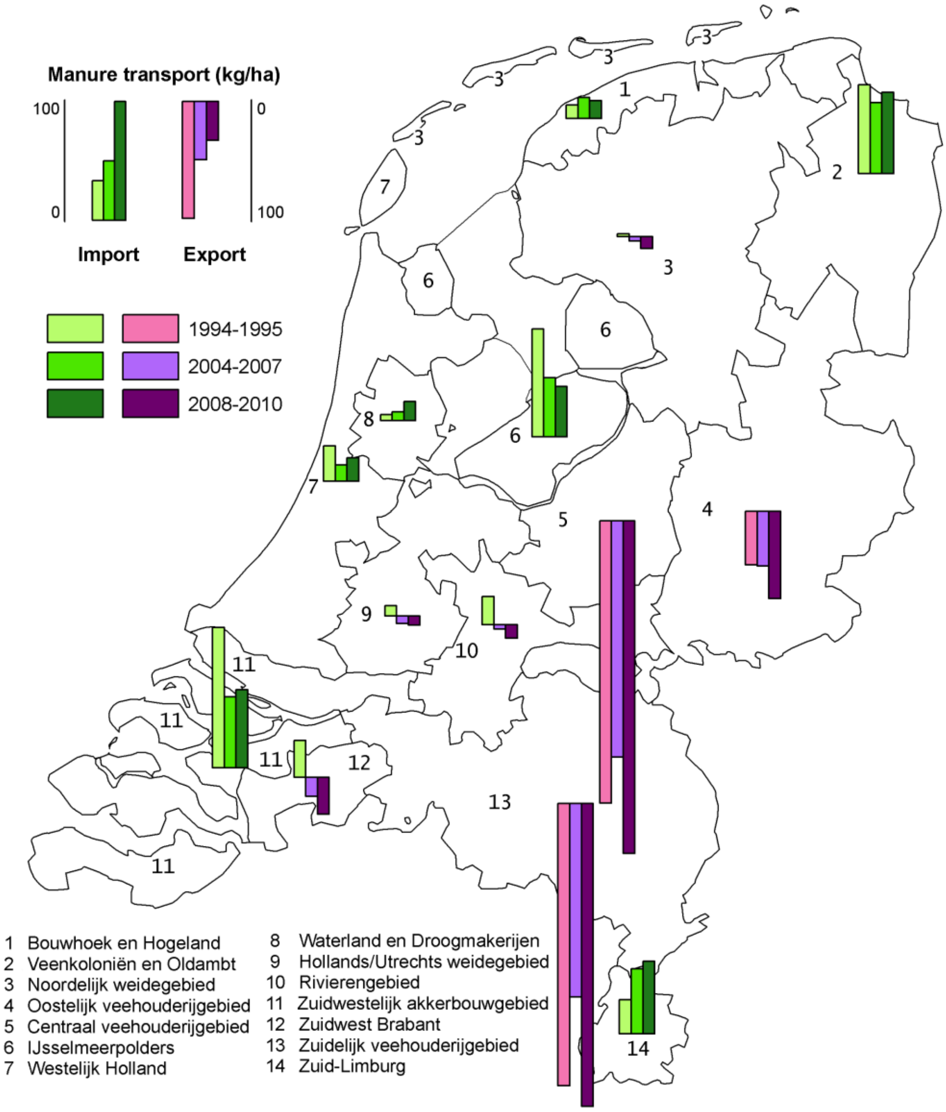
Due to the tightening of the application standards for livestock manure, increasing quantities of manure had to be transported from farms with a nitrogen and/or phosphate surplus to other farms that had space to accommodate it. Initially, as much of the excess manure as possible was transferred to nearby farms. However, manure increasingly needed to be transported over greater distances, mainly from areas where there were many farms with a surplus and where there was a surplus at the regional level.
Map 3.2 shows the average import or export distance according to agricultural area for the years 1994-1995, 2004-2007 and 2008-2010, expressed as the quantity of nitrogen per hectare. Net import (green) means that on balance nitrogen was imported into an area in the form of manure, and net export (pink or lilac) means that on balance nitrogen was exported from the area concerned.

This map shows that manure transport was mainly from the central livestock area (5 on the map) and the southern livestock area (13), to the southwest arable area (11), the IJsselmeerpolders (6), and the Peat Districts and Oldambt (2). In almost all areas with substantial net transport (2, 4, 5, 6, 7, 10, 11, 12 and 13), this decreased between the periods 1994-1995 and 2004-2007. In the latest reporting period (2008-2010), a number of areas experienced an increase in net transport compared with the period before (2004-2007).

The processing and export of livestock manure to other countries have also increased significantly over the past few years. Between 2003 and 2007, processing and export accounted for the removal of 25 million kg N on average from agriculture. In the latest reporting period, the quantity was twice that amount, about 50 million kg.

#### 3.4.2.2 Manure application, fertilisation method and timing

From 1993 to 1997, both the timing and method of manure application became subject to an increasing number of limitations. The rules for the method of application were specifically targeted at limiting the emission of ammonia into the atmosphere (see section 3.1). Since 1995, sand and loess soils (see Map 3.3) may only be fertilised between 1 February and 1 September using low-emission methods. At present, grassland and arable land on clay and peat soils may be fertilised between 1 February and 15 September.




*Map 3.2. Transport of nitrogen in livestock manure.*
*Source: CBS (2012).*

In addition to the requirements for the timing of fertilisation as described above, the application of fertiliser to soil partially or completely covered with snow has been prohibited in the Netherlands since 1994. This ban was extended in 1998 to include the fertilising of completely or partially frozen soil (though this rarely occurred in practice due to the requirement to work the fertiliser into the soil, which is difficult if it is frozen).

It has also been prohibited since 1999 to use livestock manure or nitrogen fertiliser if the top layer of the soil is waterlogged. In practice, this already rarely occurred because the equipment needed for spreading fertiliser by a low-emission method is heavy and therefore causes considerable damage to the grass and soil structure in wet conditions.

Since 2006, manure spread on arable land has to be directly worked into the soil. Before then, the manure could be spread first and subsequently worked into the soil.

*Map 3.3. Sand and loess areas in the Netherlands (yellow areas). Source: LNV, 1991.*

#### 3.4.2.3 Fertilisation close to waterways

The requirement to spread manure by a low-emission method not only limits ammonia emissions and the associated nitrogen deposition, but also improves the quality of surface water. With the aid of techniques that limit ammonia emissions, manure is both spread and worked better into or under the sods, thus preventing the manure running off and directly entering watercourses.

In addition, the ban on fertilising sand and loess soils during the winter months prevents the spreading of manure during the wettest period of the year. As a result, the chance of nitrogen entering watercourses due to surface run-off is small.

Since 2000, surface water has also been protected against pollution by the Discharge Open Cultivation and Livestock Farming Decree (LOTV), which includes rules concerning the method (distance) of fertilising near watercourses. A strip of land next to a watercourse, known as a buffer strip, must not be fertilised. The width of this buffer strip varies from 0.25 to 6 metres (in special cases, as much as 14 metres wide) and corresponds to the width of the strip that must not be sprayed with pesticides. When spreading fertiliser alongside watercourses and/or their buffer strips, it is obligatory to use a limiter to prevent the fertiliser from entering the watercourse or its buffer strip. These rules are generally complied with. On about 91% of farms, the buffer strip has the required width (Vroomen and Van Veen, 2004). The Inspectorate concluded in 2006 that verifying compliance with the LOTV, especially concerning surprise checks, was substandard (Transport and Water Management Inspectorate, 2006). Projects are being employed to ascertain the effectiveness of buffer strips, as well as the factors that determine success or failure, both in practice and at policy level (STOWA, 2010a, 2010b).

### 3.4.3 *Manure storage capacity*

Since 2006, Dutch manure policy has operated under the assumption that farms are able to store their manure from 1 September to 1 March, i.e., for half a year. From 1993 to 2010, there was a steady increase in storage capacity (Table 3.11), with the percentage of farms having less than six months' storage capacity decreasing for all farm categories. In 2010, 96% of the dairy farms, 95% of the pig farms and 87% of the intensive calf rearing farms had storage facilities sufficient for at least six months' storage of manure production.

*Table 3.11. Trend in available storage capacity (liquid manure) for various categories of livestock farms[1].*

| | 1993 | 2003 | 2007 | 2010 |
|---|---|---|---|---|
| | | *% of farms* | | |
| Dairy farms | | | | |
| 0-5 months | 45 | 24 | 4 | 4 |
| 6-9 months | 45 | 66 | 75 | 73 |
| 10-12 months | 7 | 9 | 14 | 15 |
| > 12 months | 2 | 1 | 8 | 8 |
| Calf rearing farms | | | | |
| 0-5 months | 61 | 35 | 14 | 13 |
| 6-9 months | 29 | 40 | 47 | 44 |
| 10-12 months | 7 | 22 | 28 | 32 |
| > 12 months | 2 | 3 | 11 | 10 |
| Pig farms | | | | |
| 0-5 months | 30 | 11 | 5 | 5 |
| 6-9 months | 41 | 43 | 37 | 36 |
| 10-12 months | 23 | 37 | 36 | 46 |
| > 12 months | 6 | 9 | 22 | 13 |

[1] Percentage of farms with the period average capacity expressed in months for storing liquid manure. Due to the irregular collection of data, only one year (1993, 2003, 2007 and 2010) of data is available for each period.

*Source: CBS, 2012a*

### 3.4.4 *Fertilisation: recommendations, guidelines and demonstrations*

Fertilisation recommendations for arable crops, as well as for grassland and other feed crops, have scarcely changed in the past five years. Since 2006 however, policymaking has drawn many more distinctions between different crops and soil types concerning the standards for total nitrogen (see section 3.4.2). In prior years, all arable crops were treated alike within the MINAS system, without taking into account the differences in mineral needs between crops.

### 3.4.5 *Other developments*

#### 3.4.5.1 Green manure crops

Cultivating winter grains on arable land is a suitable method in the Netherlands for preventing nitrate leaching. These grains are sown in the autumn and not fertilised until the following spring. The acreage with green manure crops is highly variable from year to year and dependent on the weather conditions in the autumn. There was a slight reduction in this acreage between 1992 and 2011 (Table 3.12), but this was in line with the reduction in agricultural land as a whole (Table 3.3).

*Table 3.12. Cultivated land area (x 1,000 ha) in the Netherlands with crop cover in the winter (unfertilised)[1].*

| | 1992-1995 | | 2004-2007 | | 2008-2011* | |
|---|---|---|---|---|---|---|
| Grassland[2] | 1057 | *54* | 985 | *52* | 962 | *52* |
| Winter wheat | 110 | *6* | 120 | *6* | 129 | *7* |
| Winter barley | 4.0 | *0.2* | 3.2 | *0.2* | 4.6 | *0.2* |
| Green manure crops | 14.4 | *0.7* | 0.9 | *0.0* | 2.0 | *0.1* |
| Total | 1186 | *60* | 1109 | *58* | 1098 | *60* |

[1] The percentage of the total area fertilised with livestock manure and/or inorganic fertiliser is shown in italics in Table 3.3.
[2] Permanent as well as temporary grassland (see Table 3.3).
*Provisional figures for 2011.
*Source: CBS, 2012, various tables.*

Since 2006, it has been compulsory to sow sand soil with a winter crop after cultivating silage maize there. The Netherlands Food and Consumer Product Safety Authority (NVWA) conducts random inspections to check that this is done. A winter crop is not fertilised, its purpose being to absorb the nitrogen the silage maize did not. No systematically collected data were available on the area sown with winter crops after the cultivation of silage maize.

#### 3.4.5.2 Irrigation

No cultivated land is irrigated in the Netherlands by allowing it to be temporarily submerged under water. If crops suffer from lack of water, they have to be irrigated using a sprinkler system. From 1992 to 1999, sprinkling was used several times a year to irrigate between 123,000 and 309,000 ha of land in the Netherlands (see Table 3.13), which represented 7% to 17% of cultivated land treated with fertiliser (Hoogeveen et al., 2003). The area irrigated by sprinkling is larger in dry years and smaller in wet years. In 1997, 60% of the sprinkling was on grassland, 13% on land where potatoes were being grown, and 7% on land where outdoor vegetables were being grown (Meeusen et al., 2000). Data for the years 2001 to 2009 originate from LEI (see Table 3.13). 2001, 2002 and 2005 were wet years, so that less irrigation by sprinkling was required.

Water used for irrigation is mostly groundwater (65%-80%). In normal and dry years, around 20% is surface water, while in wet years, the figure is about 15% (Hoogeveen et al., 2003).

*Table 3.13. Cultivated land area (x 1,000 ha) in the Netherlands irrigated at least once a year by sprinkling between 1992 and 2009.*

| Year | 1992 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| Weather | | Dry | | Wet | |
| Acreage (x 1000 ha) | 265 | 309 | 198 | 123 | 161 |

Source: Hoogeveen et al., 2003: Meeusen et al., 2000.

| Year | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| Weather | Wet (?) | | Dry | | |
| Acreage (x 1000 ha) | 22 | 69 | 278 | 105 | 82 |

| Year | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|
| Weather | Dry | | | |
| Acreage (x 1000 ha) | 180 | 110 | 86 | 121 |

*Source: LEI, 2011, period 2001-2009.*

3.4.5.3 Limiting ammonia emissions

Part of the nitrogen emission from agriculture is in the form of gas (ammonia for example). Most of these gas-type nitrogen compounds eventually end up in the soil and water via deposition from the atmosphere. A series of government measures has limited this type of emission, with the result that non-volatilised nitrogen remains behind in the fertiliser.

In the period 1992-2010, ammonia emissions declined by 55% (Table 3.14), the main causes being the reduction in the amount of manure produced by livestock and the obligation to apply manure using low-emission methods. After the prohibition on the spreading of manure above ground had come into force in the 1990s, it was no longer permitted from 2008 onwards to spread manure on agricultural land and work it into the soil in two passes. The effect of this ban was studied in 2010, from which it appeared that on agricultural land manure was mainly being injected into the soil. This is highly effective, and together with other modifications to fertilisation practices led to a decrease in emissions since 2005 of some 10 million kg.

*Table 3.14. Ammonia emissions from agriculture (in kg $NH_3$ millions).*

| | 1992-1995 | 2004-2007 | 2008-2010 |
|---|---|---|---|
| Livestock manure | 223 | 108 | 97 |
| stable and storage | 88 | 55 | 55 |
| application | 118 | 51 | 40 |
| grazing | 17 | 3 | 2 |
| Inorganic fertilisers | 13 | 14 | 10 |
| Agriculture total | 236 | 122 | 107 |

*Source: Pollutant Release and Transfer Register, 2012.*

*3.4.6 Compliance with fertiliser legislation*

For the implementation of the new manure policy, order enforcement is utilised. Current policy is based on the following standards and rules:

- Primary standards:
    - Nitrogen application standard;
    - Phosphate application standard;
    - Manure application standard.

- Secondary standards:
    - Duty of accountability for manure;
    - Timing for application of manure and organic fertilisers, and other regulations for manure and organic fertilisers;
    - Administrative obligations: determination of quantity, minimum storage of manure;
    - Animal rights regime for pigs and chickens.

- Tertiary standards:
    - Monitoring compliance with the administrative obligations that are important for the checks relating to the primary and secondary standards.

The information in Tables 3.15 and 3.16 originates from Dienst Regelingen (DR).

**Dienst Regelingen administrative checks**
Dienst Regelingen inspected the registered data of farms for 2009 to check compliance with the primary standards and the duty of accountability. This concerned two main target groups: farmers and manure transporters (intermediaries). If the information was incomplete, supplementary information was requested from the party concerned. The results from the sample survey are shown in Table 3.15.

*Table 3.15. Overview of compliance at farm level, based on a random sample (sampling date 1 March 2011)*

| | Number of farms investigated | Fines | | Objections | | | **Collected** |
|---|---|---|---|---|---|---|---|
| Target group | | Number of farms | % of farms | Number | % | Valid | |
| Grazing livestock | 207 | 7 | 3% | 2 | 29% | 1 | 6 |
| Arable | 64 | 2 | 3% | - | - | - | 2 |
| Factory farm animals | 45 | 3 | 7% | 1 | 33% | 1 | 3 |
| Horticulture | 33 | - | - | - | - | - | - |
| Mixed | 32 | - | - | - | - | - | - |
| Intermediary | 3 | - | - | - | - | - | - |
| Total | 384 | 12 | 3% | 3 | 1% | 0 | **11** |

Table 3.16 shows the number of violations broken down according to the three application standards and the duty of accountability. The 12 farms that received fines violated standards 14 times in total. There is no discernible trend in the types of standard violated simultaneously by a farm. The observed compliance levels are well above the desired expected levels.

*Table 3.16. Overview of compliance at standard level, based on an administrative sample (sampling date 1 March 2011)*

| Standard | Number Investigated | Violations | Compliance percentage Observed | Target |
|---|---|---|---|---|
| Nitrogen application standard | 380 | 3 | 99,2% | 85% |
| Phosphate application standard | 380 | 2 | 99.5% | 75% |
| Livestock manure application standard | 380 | 9 | 97,6% | 85% |
| Duty of accountability | 4 | 0 | 100% | 85% |

Besides the above-mentioned checks, preventive enforcement is also an important instrument. This is an instrument focussed on increasing the support for target-group policy measures such as communication, removal of grievances, and giving warnings to correct mistakes. Communication in the form of brochures, newsletters, advertisements, information meetings, etc. is itself an important instrument (Dienst Regelingen, 2010).

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# 4 Effects of action programmes on agricultural practice and nitrate leaching

## 4.1 Introduction

The effect of the Dutch action programmes on nitrate emissions from agricultural sources into groundwater and surface water, and the effects of changes in agricultural practice on these emissions are assessed as part of LMM (the programme based on a national network for monitoring the effects of the Manure Policy). To this end, agricultural practice and the quality of the water that leaches from root zones are both monitored on farms (see chapter 2).

This chapter presents the results for the four main soil type regions in the Netherlands: the Sand, Clay, Peat and Loess regions. The Loess region was only added to the LMM programme in 2002, and in contrast to the other regions, no earlier LMM data is available on them. Each significant region comprises one or more areas. Approximately 46% of the Dutch agricultural area is in the Sand region, 1.5% in the Loess region, 40% in the Clay region and 12.5% in the Peat region.

Arable and dairy farming account for the largest share of land use in the Netherlands. (Together, they represent over 60% of the acreage in each region, as shown in Table 4.1.) Dairy farming accounts for the largest shares in the Peat, Sand and Loess regions. In the Clay region, arable and dairy farming both account for significant shares of land use. LMM covers 76% to 83% of the agricultural area in the different regions.

*Table 4.1. Overview of the agricultural area represented by LMM, broken down by farm type and region (% of agricultural area).*

| | Arable | Dairy | Other[1] | Non-LMM[2] |
|---|---|---|---|---|
| Sand/Loess regions | 14% | 46% | 23% | 17% |
| Clay region | 38% | 31% | 11% | 20% |
| Peat region | - | 76% | - | 24% |

[1] The category "Other" relates to other livestock farms, the composition varying by region (see section 2.3.2).
[2] "Non-LMM" includes farm types that are not covered by LMM, as well as farms that do not satisfy the LMM criteria for acreage and/or economic size. This report does not include these farms.

In the next section (4.2), the data on agricultural practice are presented for the periods 1991-1994, 2003-2006 and 2007-2010. (The first period only applies to Sand regions; for Clay and Peat regions, the period is 1995-1998.) Section 4.3 describes the nitrate concentrations in water that leaches from the root zones of a farm. There is a difference of one year between the reporting period for the farm data and the reporting period for the quality of the water that leaches from the root zone of a farm. Specifically, the farm data from 1991 to 1994 are compared with the on-farm water quality between 1992 and 1995 (see also section 2.3.2). It is assumed that the main factor affecting on-farm water quality in year x is farm practice in year x-1. The relationship between changes in agricultural practice and nitrate concentrations in on-farm water are discussed in section 4.4.

## 4.2 Agricultural practice

This section describes the general characteristics of agricultural practice followed by farms that are part of LMM (Table 4.2 arable farms, Table 4.3 dairy farms, and Table 4.4 other livestock farms). The average size of the LMM farms is slightly larger than the average for all Dutch farms, because farms smaller than 10 ha are excluded from LMM (see section 2.3.2). The purpose of presenting data here on LMM farms is to provide background information for identifying trends in the quality of water at these farms. Developments in agricultural practice for the Netherlands as a whole are described in chapter 3.

Arable LMM farms in the Sand and Clay regions were approximately the same size on average (about 90 ha) between 2007 and 2010 (Table 4.2). In the preceding periods, arable farms were clearly larger in the Clay region than in the Sand region. There are also some differences in the cropping plans. In the Sand region, an average of 56% of farm acreage is used for the cultivation of potatoes and sugar beet, whereas in the Clay regions the comparable figure is 32%.

Dairy farms in LMM cover a smaller area than arable farms. Currently, dairy farms in the Sand and Loess regions are smaller (about 47 ha on average) than those in the Clay and Peat regions (about 59 ha on average; Table 4.3). The percentage of grassland is highest for dairy farms in the Peat region (92%) and lowest for farms in the Loess region (73%). On the remaining land, dairy farms cultivate mainly maize, apart from the Loess region, where crops different from grass and maize are grown on 9% of the land.

The LMM group of other livestock farms in the Sand, Clay and Loess regions resemble dairy farms more than arable farms. With these farms, their characteristics fluctuate considerably more over time, showing less evidence of trends (Table 4.4).

Over the years, however, a general tendency has emerged for LMM farms to become larger, with livestock density increasing slightly in recent years, and the use of inorganic fertilisers decreasing, although not much more in the past few years.

The application of nitrogen from livestock manure on arable farms went up from 15 to 20 kg per ha (Table 4.2). During the same period, the application of nitrogen from livestock manure on dairy farms in Sand and Clay regions went down, particularly between 1995 and 2002 (Table 4.3). In the Peat region, the application of this form of nitrogen on dairy farms was smaller, and in the Loess region, it increased slightly. Over time, other livestock farms have started to apply less nitrogen from livestock manure (Table 4.4). This is true for the Sand and Clay regions, as well as the Loess region.

In general, the application of nitrogen from inorganic fertiliser showed a clear decrease. Only dairy farms in the Clay and Loess regions and the other livestock farms in the Sand and Clay regions showed an increase, mostly limited, in the application of inorganic fertiliser nitrogen during the period 2007-2010 (Table 4.3).

*Table 4.2. Arable farms in the Netherlands that are part of LMM; leading characteristics of agricultural practice for farms in the Sand, Clay and Loess regions[1] for each reporting period.*

| Table 22 | Sand region | | | Clay region | | | Loess region |
|---|---|---|---|---|---|---|---|
| Arable farms | 91-94 | 03-06 | 07-10 | 95-98 | 03-06 | 07-10 | 07-10 |
| Area (ha) | 58 | 89 | 89 | 78 | 98 | 95 | 58 |
| % potatoes | 43 | 42 | 36 | 32 | 22 | 22 | 12 |
| % sugar beets | 21 | 19 | 20 | 13 | 13 | 10 | 22 |
| % cereals | 20 | 28 | 28 | 31 | 33 | 39 | 47 |
| % other crops | 16 | 12 | 16 | 24 | 33 | 30 | 19 |
| Nitrogen from livestock manure (kg/ha) | 128 | 124 | 143 | 79 | 90 | 102 | 122 |
| Inorganic fertiliser nitrogen (kg/ha) | 122 | 88 | 75 | 141 | 133 | 124 | 101 |
| Nitrogen surplus in soil (kg/ha) | 170 | 128 | 123 | 117 | 123 | 122 | 121 |

[1] Arable farming is rare in peat regions; Clay and Peat regions have been part of LMM since 1996, and the loess region since 2002.

*Table 4.3. Dairy farms in the Netherlands that are part of LMM; leading characteristics of agricultural practice for farms in the Sand, Clay, Peat and Loess regions[1] for each reporting period.*

| Table 23 | Sand region | | | Clay region | | | Peat region | | Loess region | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dairy farms | 91-94 | 03-06 | 07-10 | 95-98 | 03-06 | 07-10 | 03-06 | 07-10 | 03-06 | 07-10 |
| Area (ha) | 31 | 45 | 49 | 36 | 51 | 57 | 60 | 62 | 46 | 44 |
| % grassland | 79 | 73 | 76 | 94 | 78 | 82 | 92 | 92 | 63 | 73 |
| % maize | 20 | 22 | 22 | 4 | 16 | 14 | 7 | 8 | 14 | 18 |
| % other crops | 1 | 5 | 2 | 2 | 6 | 3 | 2 | 0 | 23 | 9 |
| Livestock (LU/ha) | 3.1 | 2.3 | 2.4 | 2.6 | 2.2 | 2.3 | 2.0 | 2.1 | 1.8 | 2.1 |
| Nitrogen from livestock manure (kg/ha) | 357 | 266 | 248 | 321 | 267 | 241 | 244 | 237 | 216 | 230 |
| Inorganic fertiliser nitrogen (kg/ha) | 256 | 129 | 120 | 285 | 144 | 147 | 115 | 114 | 63 | 92 |
| % manure storage [2] | 106 | 136 | 146 | 154 | 137 | 157 | 139 | 156 | 107 | 142 |
| Nitrogen surplus in soil (kg/ha) | 325 | 187 | 178 | 397 | 178 | 195 | 209 | 236 | 89 | 154 |

[1] Clay and Peat regions have been part of LMM since 1996, and the Loess region since 2002.
[2] Percentage of total manure production that can be stored on a farm for six months.

The average storage capacity for livestock manure is sufficient to store it for six months, the longest period during which spreading is prohibited (September - January) plus one extra month. Over time, the storage capacity on dairy farms has increased (see Table 3.11).

*Table 4.4. Other livestock farms in the Netherlands that are part of LMM; leading characteristics of agricultural practice for farms in the Sand and Clay regions[1] for each reporting period.*

| | Sand region | | Clay region |
|---|---|---|---|
| Other livestock farms | 03-06 | 07-10 | 07-10 |
| Area (ha) | 53 | 47 | 62 |
| % grassland | 58 | 66 | 66 |
| % maize | 16 | 16 | 9 |
| % potatoes, sugar beets, cereals | 17 | 13 | 20 |
| % other crops | 10 | 5 | 5 |
| Livestock (LU/ha) | 3.0 | 3.4 | 1.8 |
| Nitrogen from livestock manure (kg/ha) | 197 | 223 | 180 |
| Inorganic fertiliser nitrogen (kg/ha) | 87 | 97 | 104 |
| % manure storage [2] | 131 | 191 | 256 |
| Nitrogen surplus in soil (kg/ha) | 140 | 194 | 168 |

[1] The Clay region has been part of LMM since 1996, and the Loess region since 2002. Other types of livestock farms are rare in peat regions. There were very few livestock farms in the Sand region in the period 1991-1994, in the Clay region in the period 1995-1998, and in the Loess region in the period 2003-2006. Accordingly, the data must be used with care.

[2] Percentage of total manure production that can be stored on a farm for six months.

Calculated by the LEI method (section 2.3.3), the average nitrogen surpluses of farms monitored as part of the LMM programme differed between farm types and, to a lesser extent, between soil type areas (see Figure 4.1). The reduction in nitrogen surplus is comparable to that shown in Figure 3.3, and is due to the decreasing use of inorganic fertilisers and, to a lesser extent, of livestock manure. During the period 2007-2010, many farm types and regions saw their nitrogen surpluses increase, in most cases only to a limited extent.

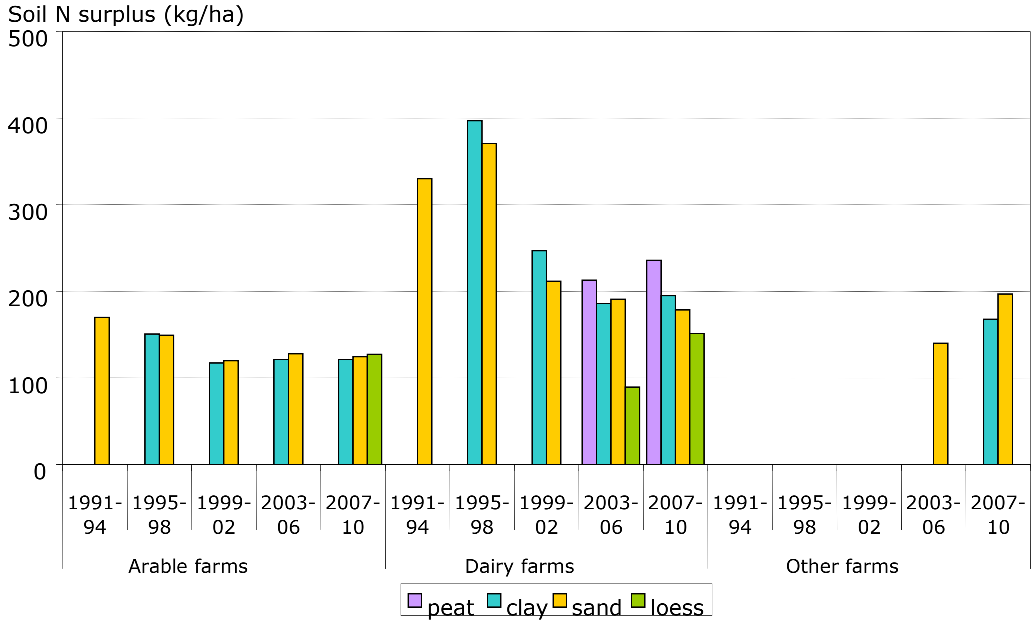


*Figure 4.1. Average nitrogen surplus on the farm gate balance (calculated by the LEI method, see section 2.3.3) of arable, dairy and other types of farms in the Sand, Loess, Clay and Peat regions, from 1991 to 2010.*

## 4.3 Nitrate in water that leaches from a root zone

### *4.3.1 Overview at national level*

The average nitrate concentration in water that leaches from the root zones (leaching water) on farms in LMM varies from region to region. It is lowest in Peat region, higher in Clay region, and highest in Sand and Loess regions (see Figure 4.2). Nitrate is the main component of nitrogen in the leaching water on farms in the Sand, Loess and Clay regions (about 85%, over 95% and about 80%, respectively; see Figure 4.3). It is a smaller component of the nitrogen in leaching water and ditchwater in the Peat region (under 30%). In the Peat region, ammonia is the main form of nitrogen in leaching water (30%-60%) and of organic nitrogen in ditchwater (25%-50%). The ammonium concentration in the groundwater of the Peat region increases with the depth at which the water is located (Van der Grift, 2003), the cause being attributed to the mineralisation of organic material (Meinardi, 2005).

The status and trend of the nitrate concentration differs between regions, as well as between farm types within a region (see Figure 4.2).

During the first three periods, the nitrate concentration in the Sand region decreased for all farm types. In the fourth period, the average nitrate concentration at arable farms and at other livestock farms was up, whereas the concentration at dairy farms was the same as in the period before. In the fifth and latest period, the average nitrate concentration decreased for all farm types. For arable and other livestock farms, their average concentrations reverted to the levels in the period 2000-2003. The highest nitrate concentrations measured in the Sand region were at other livestock farms. In the first two reporting periods, nitrate concentration at dairy farms was higher than at arable farms. By contrast, in the next three reporting periods, the average concentration at dairy farms was actually lower than at arable farms.

In the Clay region, there was a clear reduction in the nitrate concentration at dairy farms between the second and third periods. By contrast, the concentration at arable and other livestock farms changed only marginally (see Figure 4.2). The number of other livestock farms was relatively small during the initial periods (see Table 2.2). Measurements taken in the fourth period show an increase in average nitrate concentration for all farm types, followed by a decrease during the period 2008-2011, the same as in the Sand region.

In the Peat region, the low average nitrate concentrations at dairy farms are exhibiting a trend comparable to that in the clay regions. There was a decrease between 2000 and 2003, followed by an increase between 2004 and 2007 and a decrease in the latest period (see Figure 4.2).

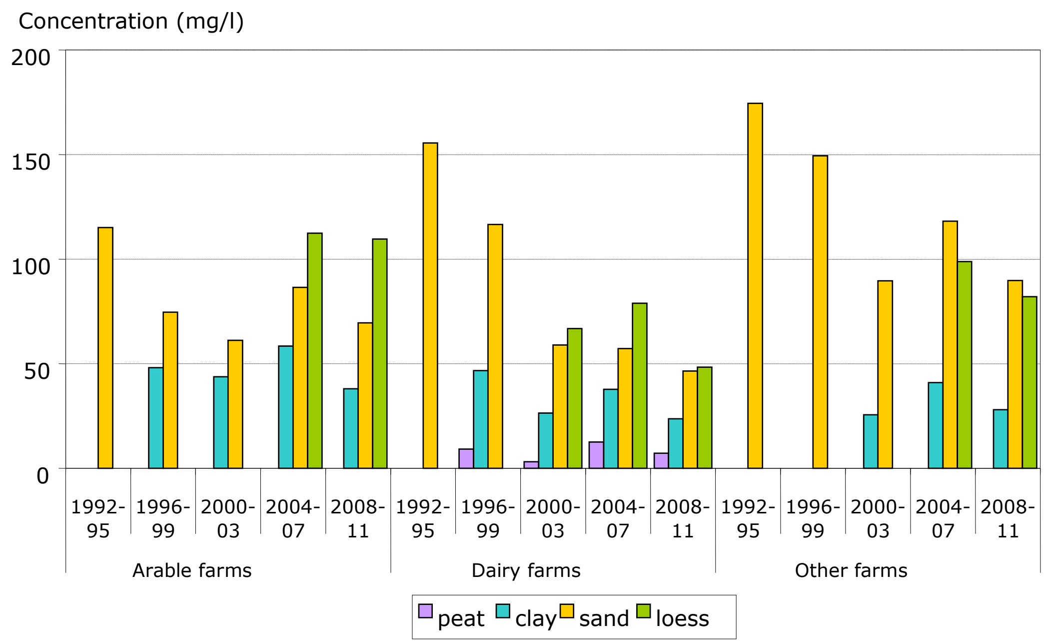


*Figure 4.2. Average nitrate concentration in the water leaching from root zones of arable, dairy and other livestock farms, by region in the period 1992-2011 (2010 in the case of the Loess region).*

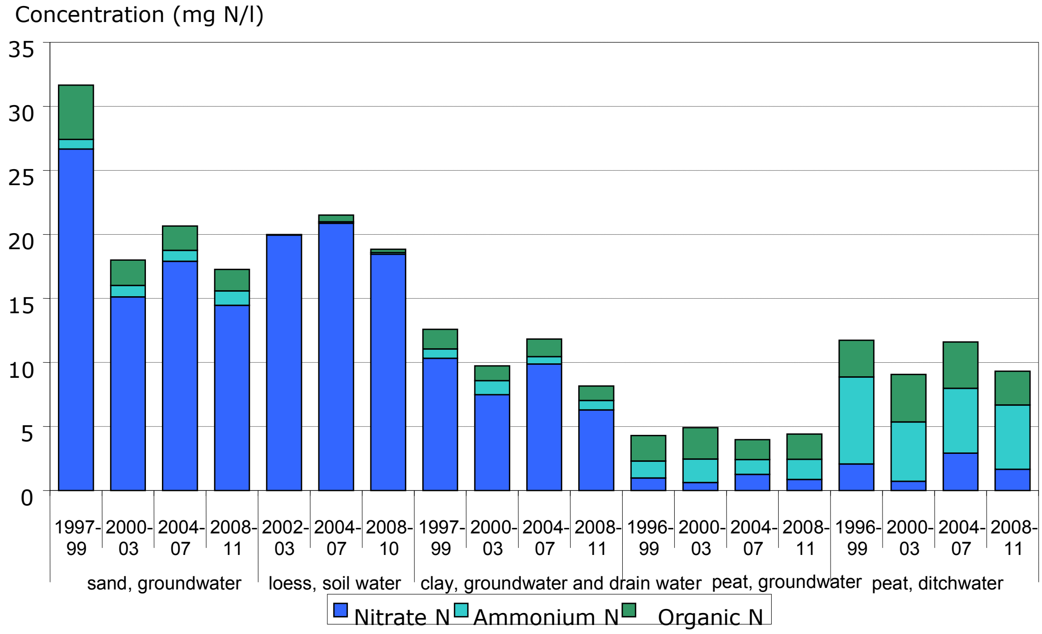


*Figure 4.3. Nitrogen concentration (mg/l) in the water leaching from the root zones of farms in the Sand, Loess, Clay and Peat regions of the Netherlands, in the periods 1996-1999, 2000-2003, 2004-2007 and 2008-2011.*

From 1992 to 2003, the nitrate concentrations measured in the leaching water on farms in the Sand regions showed a clear decrease, followed by a period of stabilisation. After 2008, there could be a further reduction (seeFigure 4.4). Following a time of stable, high nitrate concentration between 2002 and 2007, the Loess region showed a slight decline in the years 2008 to 2010. For the entire period, the Clay regions exhibited a downward trend, apart from a few years, 2004 being one of them. The explanation for the high concentration might be the relatively dry 2003. No discernible trend can be seen in the leaching water on farms in the Peat region. The higher concentrations in 2004 and 2007 are attributable to the greater proportion of farms that exceeded the EU standard of 50 mg/l (Figure 4.5).

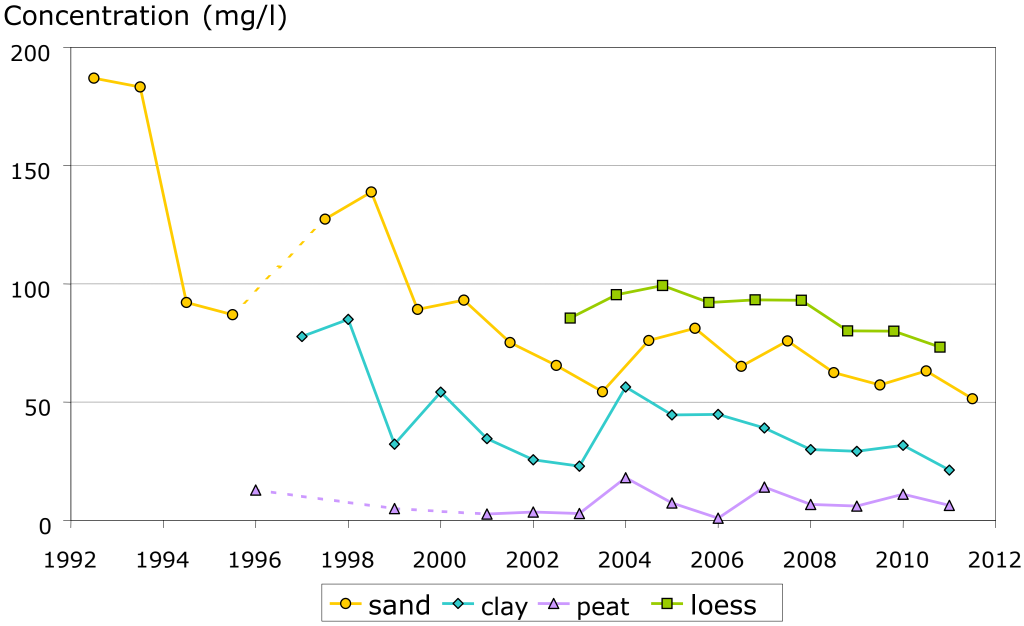


*Figure 4.4. Nitrate concentrations in water leaching from root zones of farms by region in the period 1992-2011. Annual average of measured concentrations.*

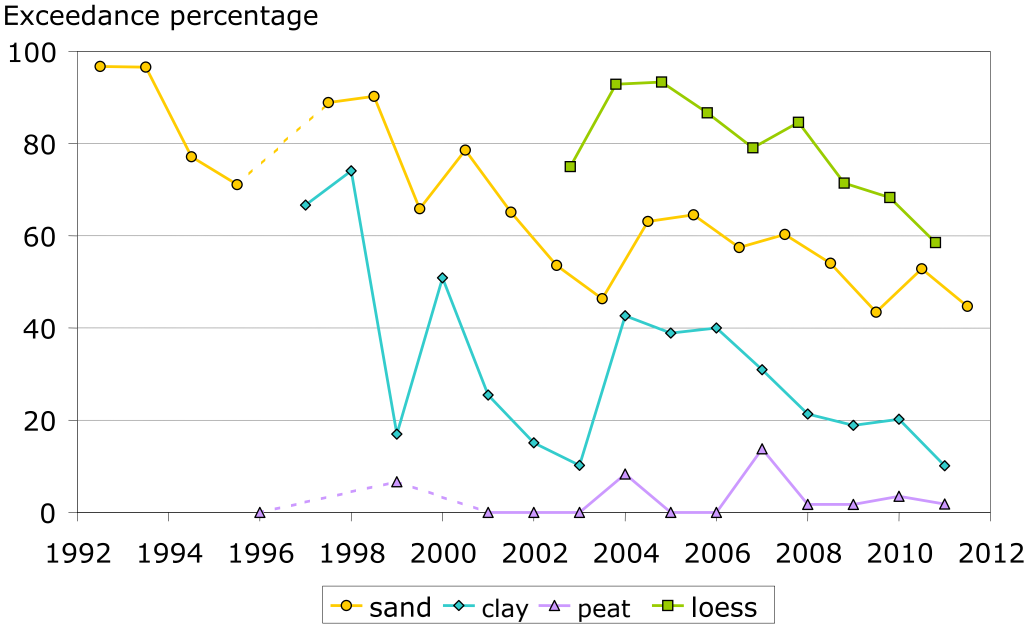


*Figure 4.5. Percentage of exceedances of the EU standard of 50 mg/l nitrate in water leaching from root zones of farms by region in the period 1992-2011. Exceedance according to measured concentrations.*

The average nitrate concentration varied sharply from year to year, the main cause of the fluctuations being differences in precipitation surplus. This leads to differences in the degree of dilution and the depth of the groundwater table (Boumans et al., 2001; 1997). Moreover, a rise by the groundwater table results in more denitrification. There were also changes in the composition of the group of farms being monitored. From 1996 to 2006, LMM was a variable monitoring network (Table 2.3 and section 2.3.2), causing year-to-year differences to be greater than those in the period after 2006. Since 2006, LMM has been a fixed monitoring network, although some farms cease operating and are then replaced. Apart from this, some farms buy and/or sell land, or are parties to land exchange transactions. Such changes led to differences in the proportions of soil types within LMM from year to year. In this way, any future increase in the percentage of peat soil on farms in the Sand region will in time result in lower measured nitrate concentrations, even if the nitrogen surplus does not change. A statistical model has been developed to determine the effects of the Manure Policy. It was designed so that the effect of such interfering factors is calculated, enabling a nitrate concentration curve to be estimated, with these interfering factors filtered out. This curve represents the standardised nitrate concentration (Fraters et al., 2004, Boumans and Fraters, 2011).

There was a marked reduction in the standardised nitrate concentration in the leaching water on farms in the Sand region from about 135 mg/l in the period 1992-1995 to about 70 mg/l in the period 2004-2007 (Figure 4.6). The standardised nitrate concentration also fell in the Clay region, although the data series was still relatively small (see section 2.3.2).

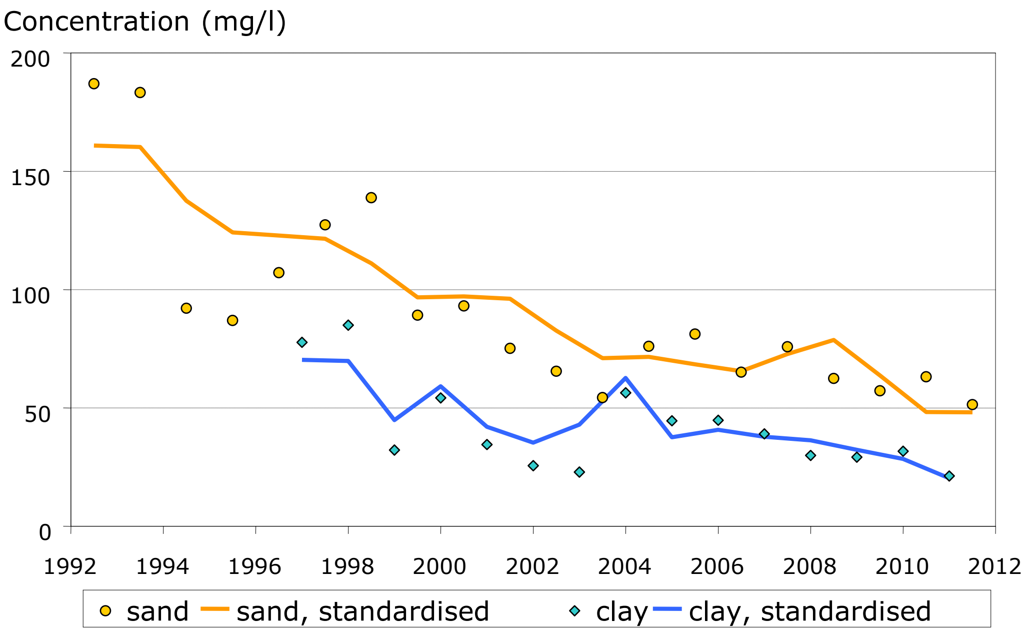


*Figure 4.6. Nitrate concentrations in water leaching from root zones of farms in the Sand and Clay regions in the period 1992-2011. Average annual measured and standardised concentrations.*

The percentage of farms with a nitrate concentration above the EU standard of 50 mg/l (see Figure 4.5) shows a falling trend similar to that in the nitrate concentration (Figure 4.4). The EU standard was most often exceeded in the Loess region. In the Sand region, there were more exceedances of the standard than in the Clay and Peat regions. The concentration in the Peat region is rarely above 50 mg/l. Despite the modest fall in average nitrate concentration on the Loess region (from 100 mg/l to 80 mg/l), the exceedance percentage has dropped by 30 percentage points since 2005. The exceedance percentage has fallen substantially since monitoring began. Variation from year to year is attributable to interfering factors. Even if allowance is made for them, the percentage of exceedances of the EU standard still shows a decline (Figure 4.7). The standardised exceedance in the Sand regions fell from about 95% in the period 1992-1995 to about 50% in the period 2008-2011.

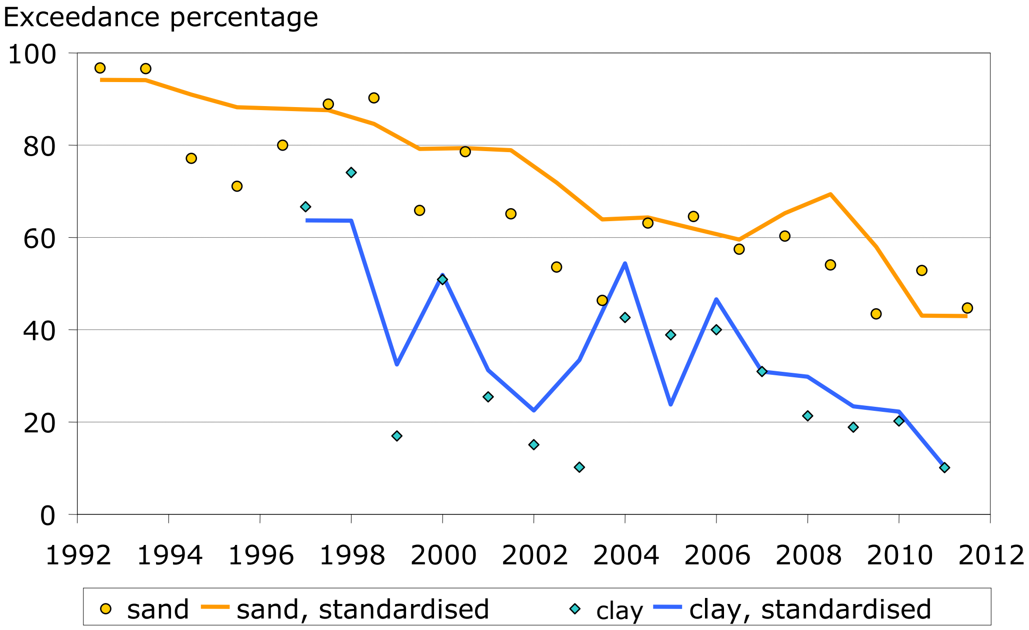


*Figure 4.7. Percentage of exceedances of the EU standard of 50 mg/l nitrate in water leaching from root zones onto farms in the Sand and Clay regions in the period 1992-2011. Exceedance based on measured and standardised concentrations.*

The following sections contain information by region, in the form of cumulative frequency diagrams and other representations. Although these types of diagram are highly informative, they require some explanation. With the aid of Figure 4.8, this paragraph explains how such a diagram has to be interpreted. It can be determined from the diagram that in the period 2008-2011 some 30% of the monitored arable farms had an average nitrate concentration below the EU standard of 50 mg/l, while 20% of these farms had a concentration above 100 mg/l. Follow the horizontal 50 mg/l line (EU standard, red line) from the y-axis until it intersects the cumulative frequency curve for the period 2008-2011 (squares). Then trace a vertical line downwards from the point of intersection of the 50 mg/l line to the x axis. Where it meets the x-axis is the percentage of farms that had a measured nitrate concentration below 50 mg/l. It is also possible to see from the curve that in this period some 80% of arable farms had an average concentration lower than 100 mg/l, and hence that 20% had a higher concentration. Trace a (vertical) line from the 80% point on the x axis until it intersects the cumulative frequency curve for the period 2008-2011 (squares). Then from the point of intersection, trace a horizontal line to the y-axis. Where it meets the y-axis is the concentration not exceeded by (80% of) farms, 100 mg/l in this example.

### 4.3.2 *Sand and Loess regions*

Between the first and second monitoring periods, there was a reduction in the nitrate concentrations in the upper groundwater of arable farms. Between the second and subsequent periods, no clear trends are discernible; the nitrate concentrations just hover around the level of the second period (see Figure 4.8). The percentage of arable farms with a period average nitrate concentration below the EU standard rose from 5% in the first period to roughly 30% in the fifth period.

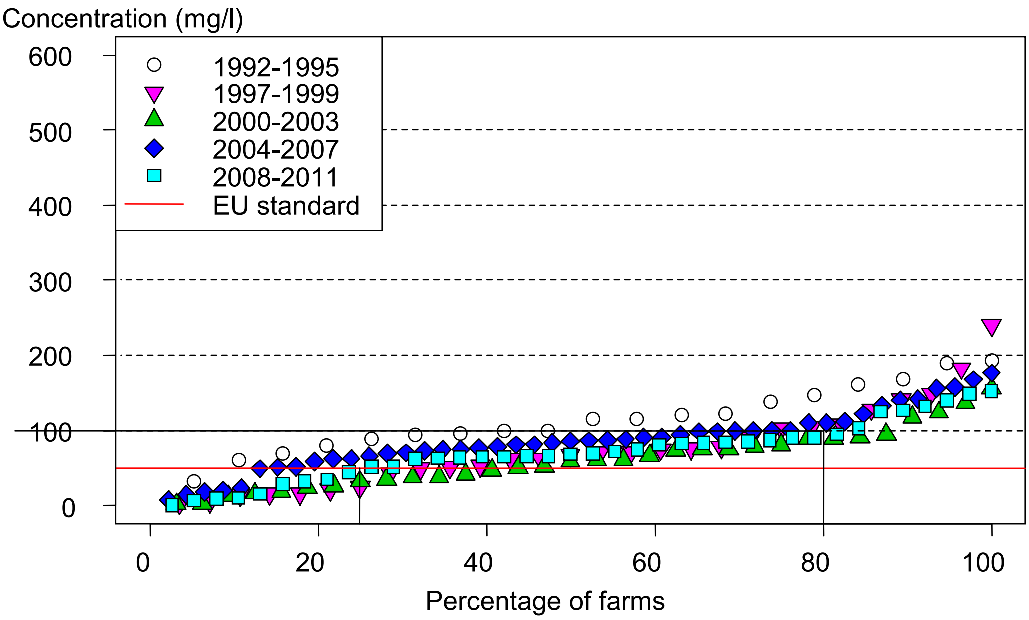


*Figure 4.8. Nitrate concentration in water leaching from the root zones of arable farms in the Sand region, shown as a cumulative frequency diagram of the farm average per period.*

At dairy farms, nitrate concentrations diminished gradually during the first three periods. They became stable in the fourth period, and then resumed their fall in the fifth period (Figure 4.9). The percentage of dairy farms with a concentration less than the EU standard grew from approximately 5% in the period 1992-1995 to over 60% in the period 2008-2011.

At other livestock farms in the Sand regions, nitrate concentrations decreased between the second and third monitoring periods. Between the third and fourth periods, the concentrations went up (Figure 4.10), but during the fifth period, they dropped to a level comparable to that of the third period. The percentage of other livestock farms with a period average concentration below the EU standard rose from about 5% in the period 1997-1999 to around 35% in the period 2008-2011.

Nitrate concentrations differ between the three areas of the Sand regions: they are higher in Sand South, and lower in Sand Central and Sand North (Figure 4.11). After 1992, the nitrate concentrations fell in all three sand areas, and stabilised after 2002, the same as the fall and stabilisation observed in the sand regions as a whole (Figure 4.4). Sand Central witnessed the largest decline, from 200 mg/l in the period 1992-1993 to 50 mg/l in the period 2008-2011. After monitoring commenced, the average nitrate concentration in Sand South went down from 240 mg/l to 100 mg/l in the period 2004-2011. The nitrate concentrations in Sand North decreased from 150 mg/l to less than 50 mg/l during the period 2008-2011.

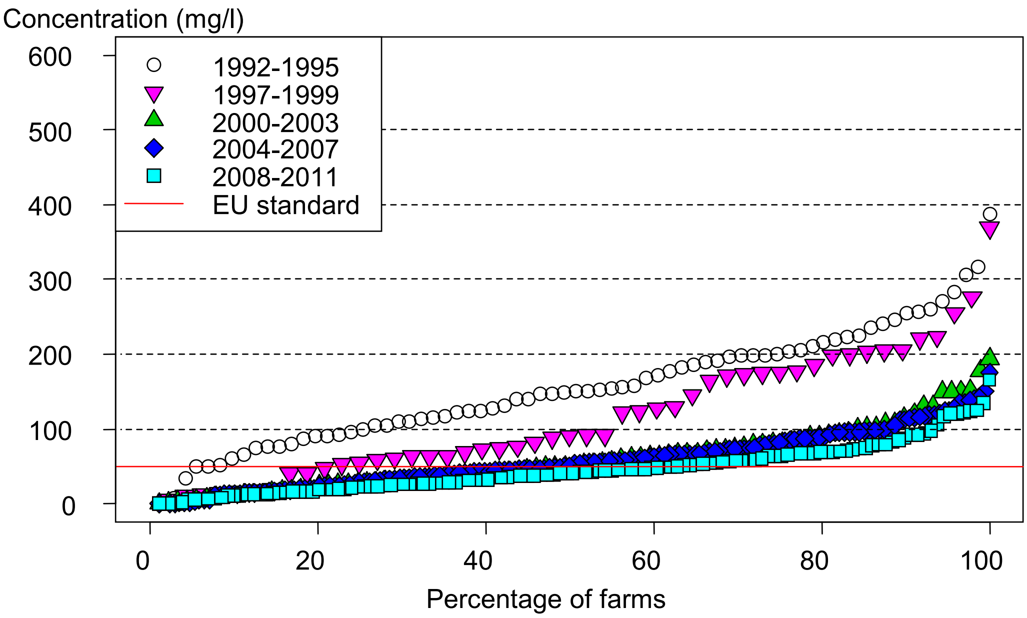


*Figure 4.9. Nitrate concentration in water leaching from the root zones of dairy farms in the Sand regions, shown as a cumulative frequency diagram of the farm average per period.*

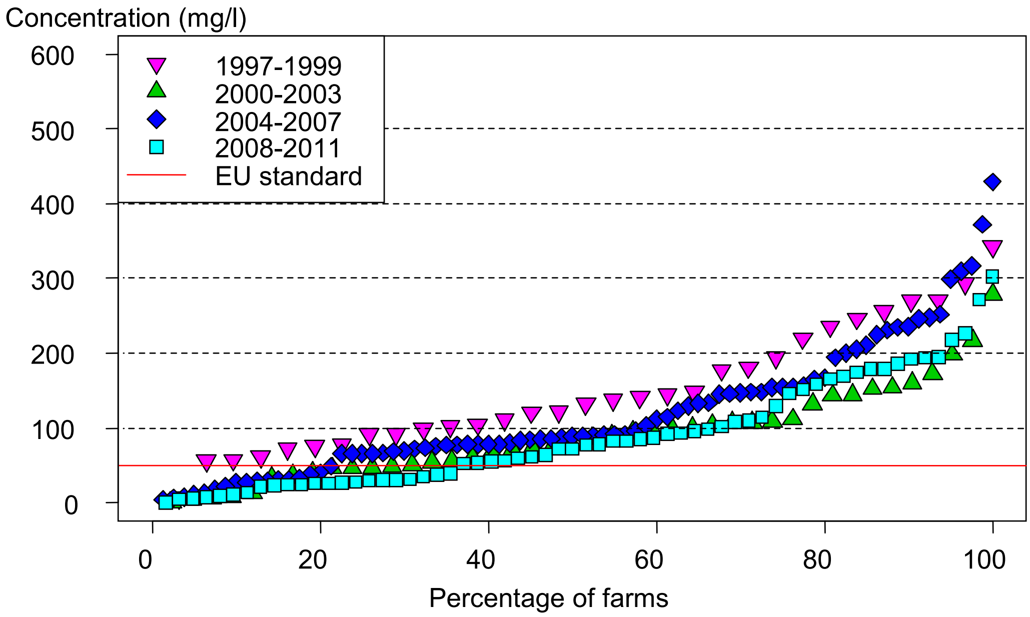


*Figure 4.10. Nitrate concentration in water leaching from the root zones of other livestock farms in the Sand regions, shown as a cumulative frequency diagram of the farm average per period.*

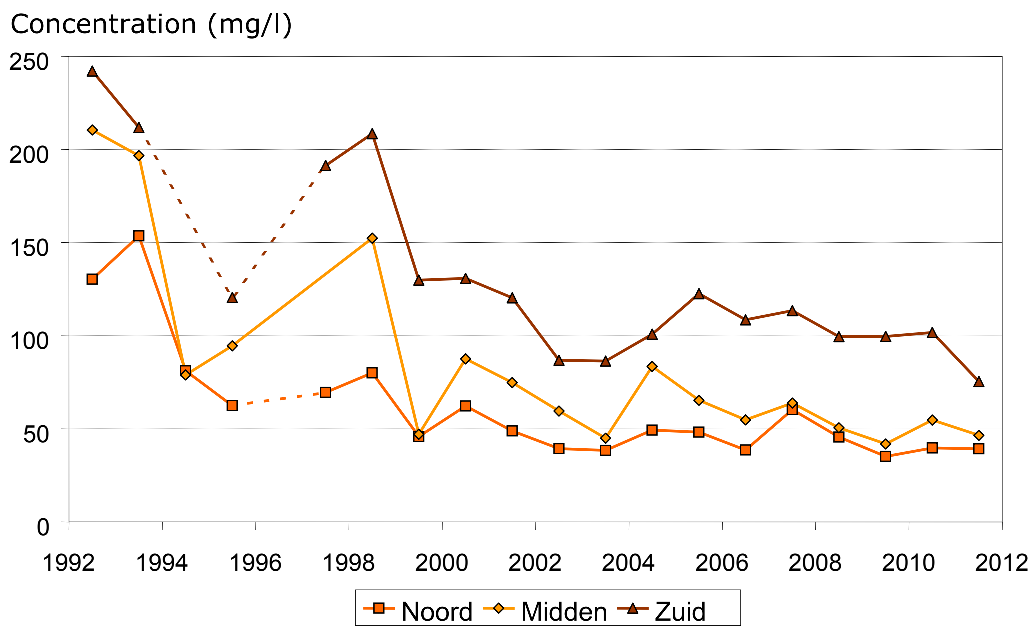


*Figure 4.11. Nitrate concentrations (annual average of measured concentrations) in water leaching from root zones onto farms in the Sand North, Sand Central and Sand South areas in the period 1992-2011.*

The trend of the nitrate concentrations in the Loess region, measured as part of the Soil Moisture Monitoring Network (BVM) of the province of Limburg, is comparable to that shown by the LMM farms in the sand regions (see Figure 4.12). The concentrations at the LMM farms in the Loess region are certainly higher than those measured in the BVM. The cause of the discrepancy between the BVM data and the LMM data could be a combination of unit-scale differences (farm versus plot) and different proportions of the acreage for the various crop types in both monitoring networks. Willems and Fraters (1995) showed that the scale used for presenting the monitoring results affects the percentage exceedance of the standard, even if the total average nitrate concentration is the same.

The percentage of agricultural plots in the BVM with a nitrate concentration below the EU standard increased from about 10% in the period 1996-1999 to about 40% in the period 2004-2006 (see Figure 4.13). The percentage of LMM farms with a concentration below the EU standard was in the range 10%-20% in the third and fourth periods (Figure 4.14). During the fifth period, the percentage climbed to 35%.

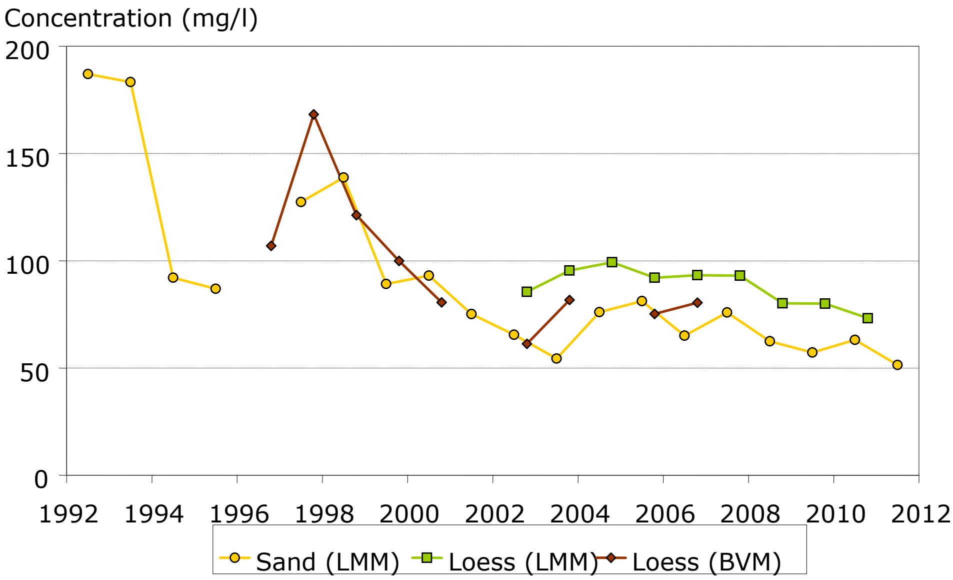


*Figure 4.12. Nitrate concentration in water leaching from root zones in the Sand regions (LMM) and Loess region (BVM plots and LMM farms) in the period 1992-2011.*
*Source: RIVM (sand / LMM loess); Province of Limburg (BVM loess).*

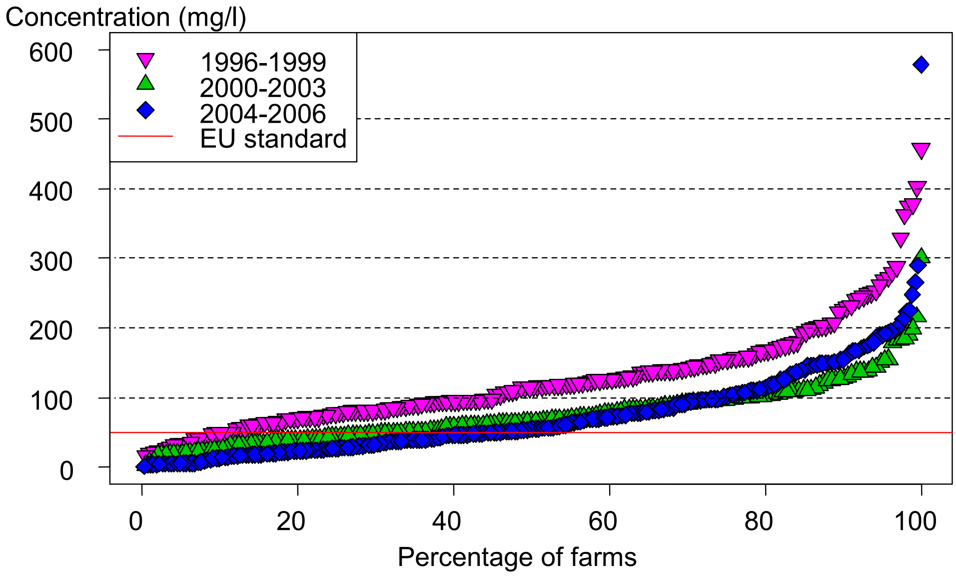


*Figure 4.13. Nitrate concentration in water leaching from the root zones of BVM plots used for farming in the Loess region, shown as a cumulative frequency diagram of the plot average per period.*
*Source: Province of Limburg*

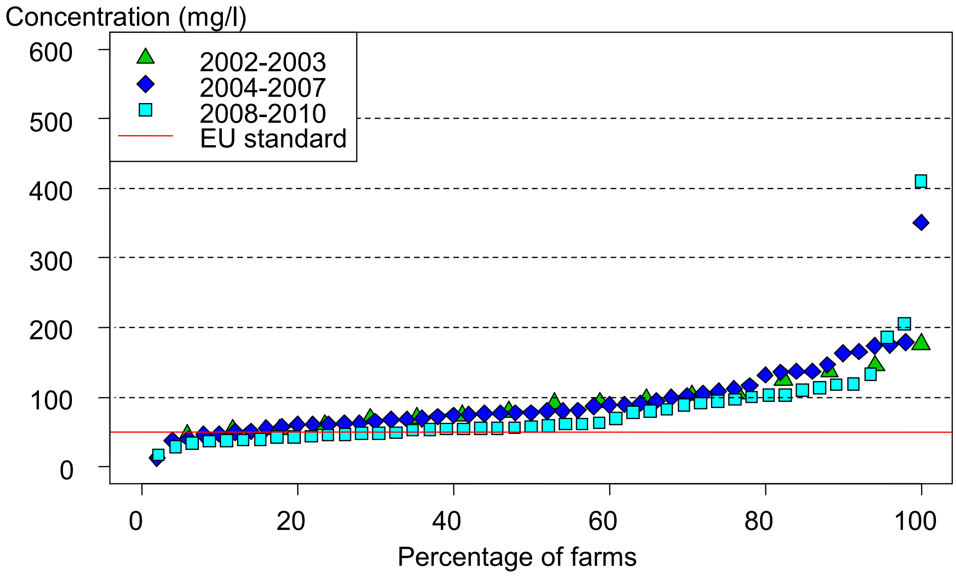


*Figure 4.14. Nitrate concentration in water leaching from the root zones of LMM farms in the Loess region, shown as a cumulative frequency diagram of the farm average per period.*
*Source: RIVM.*

### 4.3.3 *Clay regions*

On arable farms in Clay regions, the nitrate concentrations in water leaching from root zones did not change between 1997-2003, but did increase in the period 2004-2007, only to return in the period 2008-2011 to the previous level (Figure 4.15). The percentages of arable farms with a nitrate concentration less than the EU standard were 55% and 70% respectively in the second and third periods. This percentage dropped to around 40% in period four, but climbed in period five to almost 80% (see Figure 4.15). Nitrate concentrations at dairy farms did not change as much from 1997 to 2011, the percentage of them that did not exceed the EU standard being in the range 70% to 90% (see Figure 4.16).

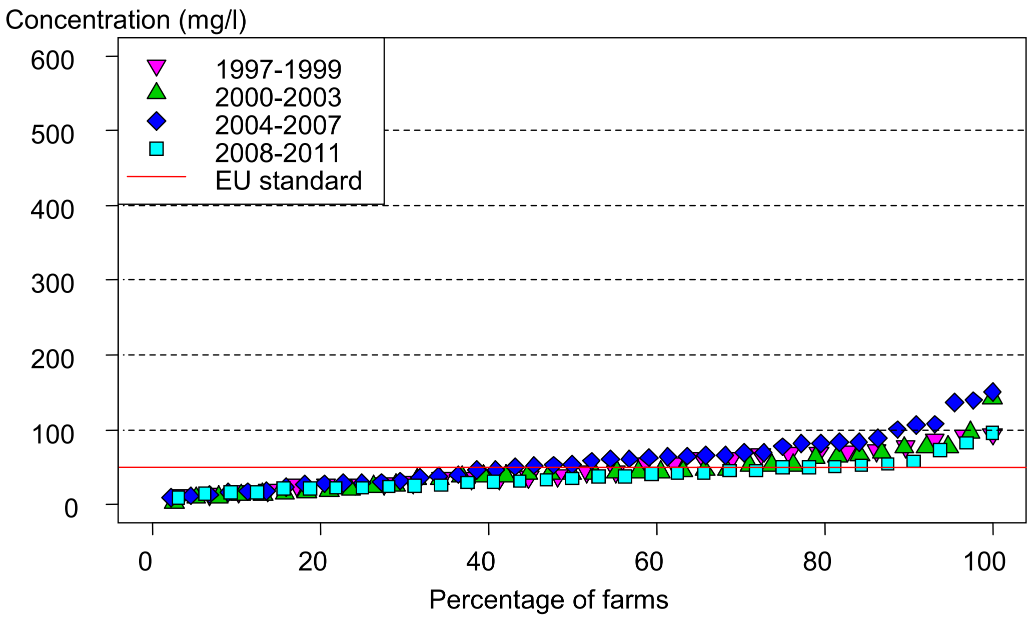


*Figure 4.15. Nitrate concentration in water leaching from the root zones of arable farms in the Clay regions, shown as a cumulative frequency diagram of the farm average per period.*

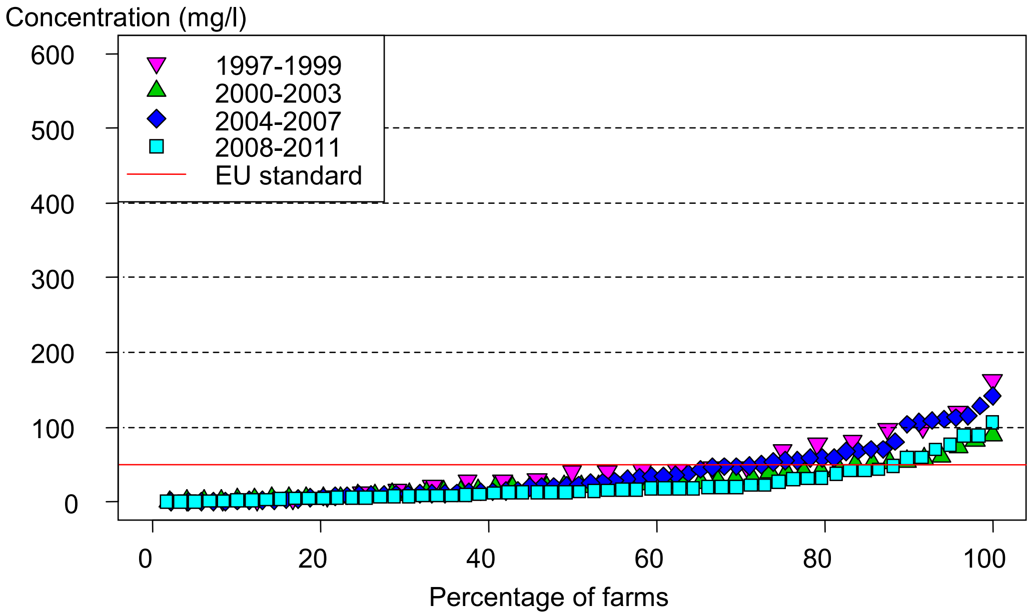


*Figure 4.16. Nitrate concentration in water leaching from the root zones of specialised dairy farms in the Clay regions, shown as a cumulative frequency diagram of the farm average per period.*

### 4.3.4 *Peat regions*

The average nitrate concentrations in water that leached from root zones were usually below 25 mg/l for dairy farms in the Peat regions (Figure 4.17). There were only isolated cases of the EU standard of 50 mg/l being exceeded in the period 2004-2007, with 90% to 100% of the farms meeting the standard. The average nitrate concentrations in ditchwater were mostly below 10 mg/l (see Figure 4.18), and no exceedances of the EU standard of 50 mg/l occurred during any of the monitoring periods.

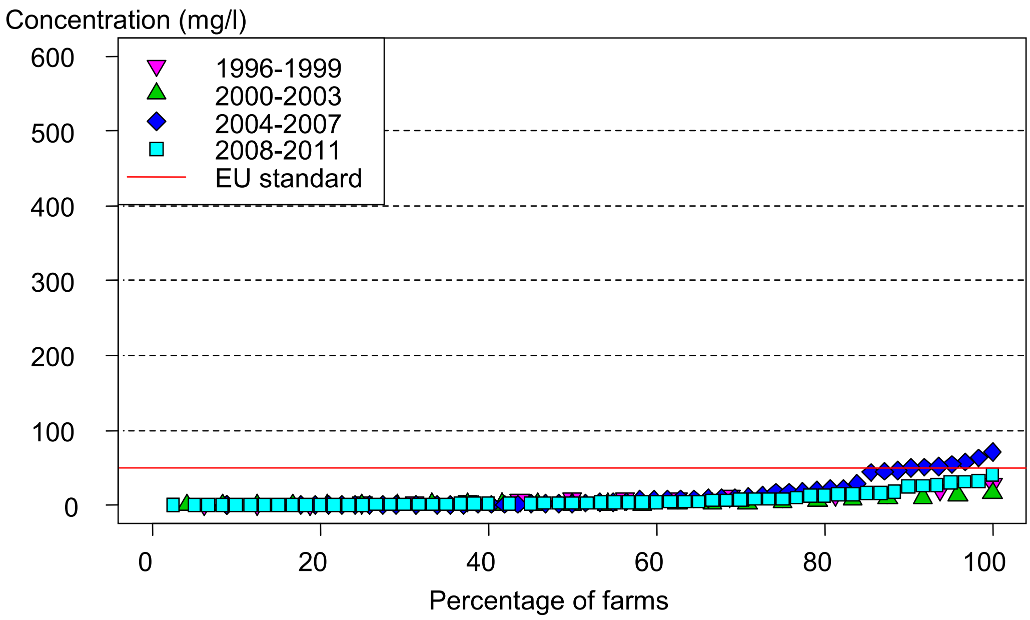


*Figure 4.17. Nitrate concentration in water leaching from the root zones of dairy farms in the Peat regions, shown as a cumulative frequency diagram of the farm average per period.*

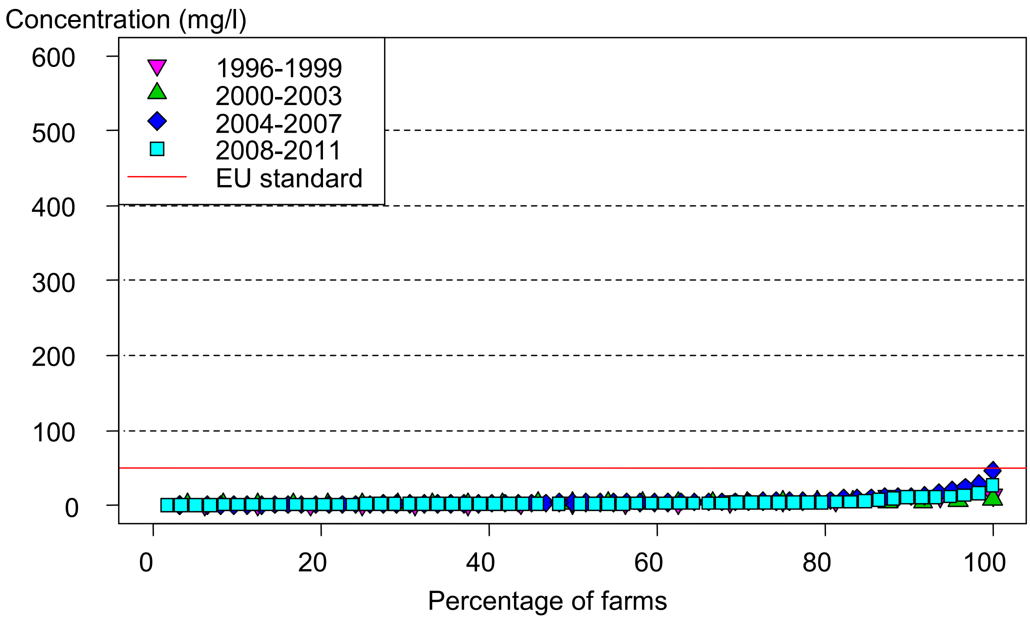


*Figure 4.18. Nitrate concentration in ditchwater of dairy farms in the Peat regions in winter, shown as a cumulative frequency diagram of farm average per period.*

## 4.4 Relationship between trends in agricultural practice and nitrate concentration

The nitrogen surplus decreased in the period 1991-2010. At arable farms and other livestock farms, however, there was in most cases a nitrogen surplus in the latest period (2007-2010) that was slightly higher than in the period before (2003-2006). In general, there was a decrease in the application of inorganic fertiliser at LMM farms between 1991 and 2010. There was also a reduction in the quantity of livestock manure at most dairy farms. At arable farms and other livestock farms, there was mostly an increase in the application of livestock manure.

The effects of the above are clearly visible in the decline of nitrate concentrations during the period 1992-2011, especially at dairy farms. Although the nitrate concentration at arable farms and other livestock farms has certainly fallen slightly compared with the initial period, it seems to have stabilised in the past few years.

Depending on the hydrogeological conditions, the impact of changes in agricultural practice on the leaching from root zones becomes detectible in three to five years.

In addition to the effects of measures adopted for agricultural practice, factors such as variation in weather conditions, climate and hydrogeological processes also influence the increase or decrease in nitrate leaching. Such factors can hide the effects of measures on water quality.

## 4.5 References

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# 5 Groundwater quality

## 5.1 Introduction

The nitrate concentration in Netherlands' groundwater shows a wide variation spatially as well as in terms of depth. Spatial variation is only partly accounted for by changes in land use and nitrogen emissions. Other causes are the year-to-year changes in net precipitation, soil type, and the geohydrological characteristics of aquifers (see also chapter 4).

In general, the nitrate concentration in groundwater is low under peat soil, relatively high under sand soil, and average under clay soil (Van Vliet et al., 2010, Reijnders et al., 2004). Nitrate concentration usually decreases with an increase in the depth of the groundwater. This is caused by the reduction in nitrate concentration during transport (denitrification), the mixing of waters of different ages, and the lateral transport due to the presence of resistant layers that partially or completely inhibit downward movement.

This chapter comprises three parts, each dealing with one of the three depths at which groundwater is monitored in the Netherlands: 5-15 metres, 15-30 metres and more than 30 metres. Chapter 4 deals with the top metre of the groundwater.

## 5.2 Nitrate in groundwater at a depth of 5–15 metres

In the period 1992-2010, the nitrate concentration in groundwater at a depth of 5-15 metres below the surface for Dutch farm soil was on average 24 mg/l, with a range of 20-28 mg/l (Figure 5.1). The highest concentration was measured in 1996, about ten years after the peak in nitrogen surplus on the national nitrogen balance (Figure 3.3). In 2008, there was a strikingly low average nitrate concentration for farm soil. This is attributable to two wells that had high nitrate concentrations (around 150 mg/l) for almost the entire monitoring period, but where precisely in 2008 virtually no nitrate was detected. Validation indicates no question of extreme values (a low value had been measured before), and there is no evidence of a measuring mistake.

For nature reserves and areas used for other purposes (including orchards and urban areas), the concentration had an average value of about 13 mg/l and fluctuated between 10 and 21 mg/l (Figure 5.1). From 2001 to 2009, it was especially changeable regarding other land use. The sudden rising and falling is almost entirely due to one well where, between 2001 and 2009, the nitrate concentration climbed from less than 30 mg/l to almost 500.

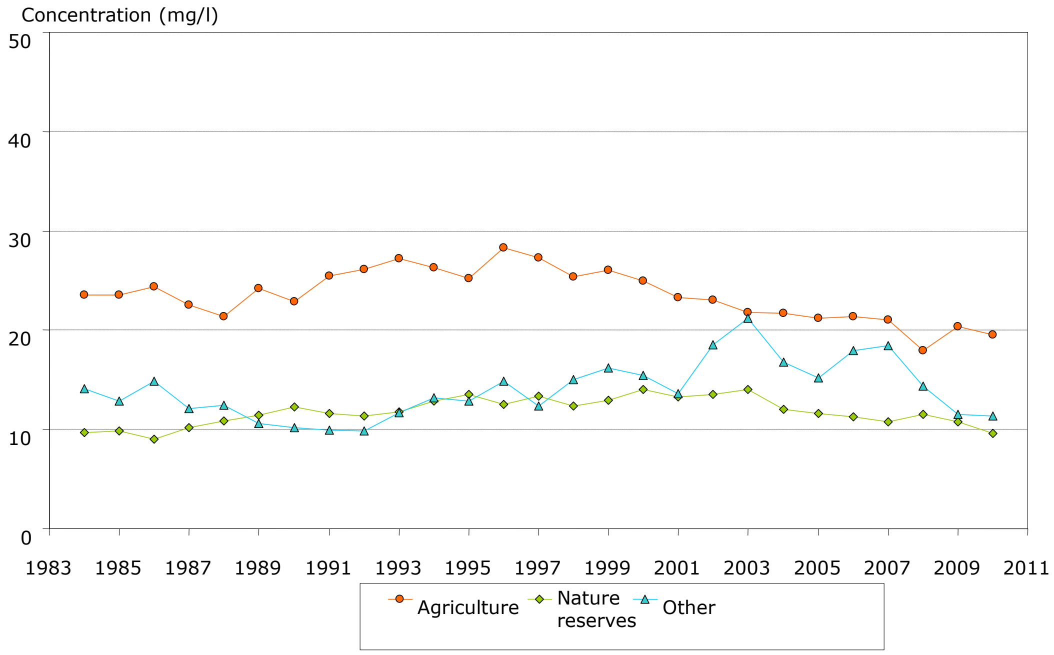



*Figure 5.1. Average annual nitrate concentration (mg/l) in groundwater at a depth of 5-15 metres below the surface in the Netherlands by land use type for the period 1984-2010.*

The nitrate concentration in groundwater originating from farming on sand soil (30 to 45 mg/l) was higher than in clay soil and peat soil (< 10 mg/l and < 5 mg/l respectively; Figure 5.2). Prior to 1992, concentrations were mostly below 40 mg/l, whereas in the period 1992-2000, concentrations hovered between 42 and 47 mg/l. After 2001, the average nitrate concentration remained below 40 mg/l, gradually falling to 33 mg/l in 2010.

Between 2008 and 2010, the EU standard of 50 mg/l for nitrate was exceeded at 10% of the groundwater monitoring wells at a depth of 5 to 15 metres. For agricultural areas, the figure was 12%; for nature reserves, about 5%; and for other areas about 9% (Figure 5.3 and Table 5.1). There were slight variations from year to year.

The EU standard was exceeded at 19% of the monitoring sites in farming areas on sand soil, whereas there were no more exceedances in the clay and peat regions (Figure 5.4).

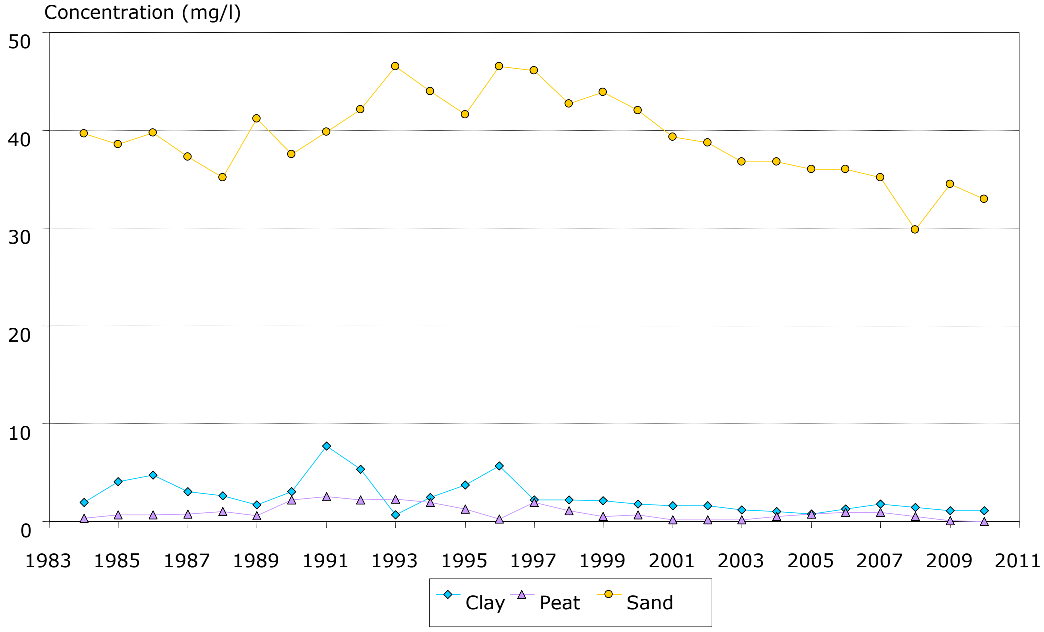



*Figure 5.2. Average annual nitrate concentration (mg/l) in groundwater at a depth of 5-15 metres below the surface in agricultural areas by soil type for the period 1984-2010.*

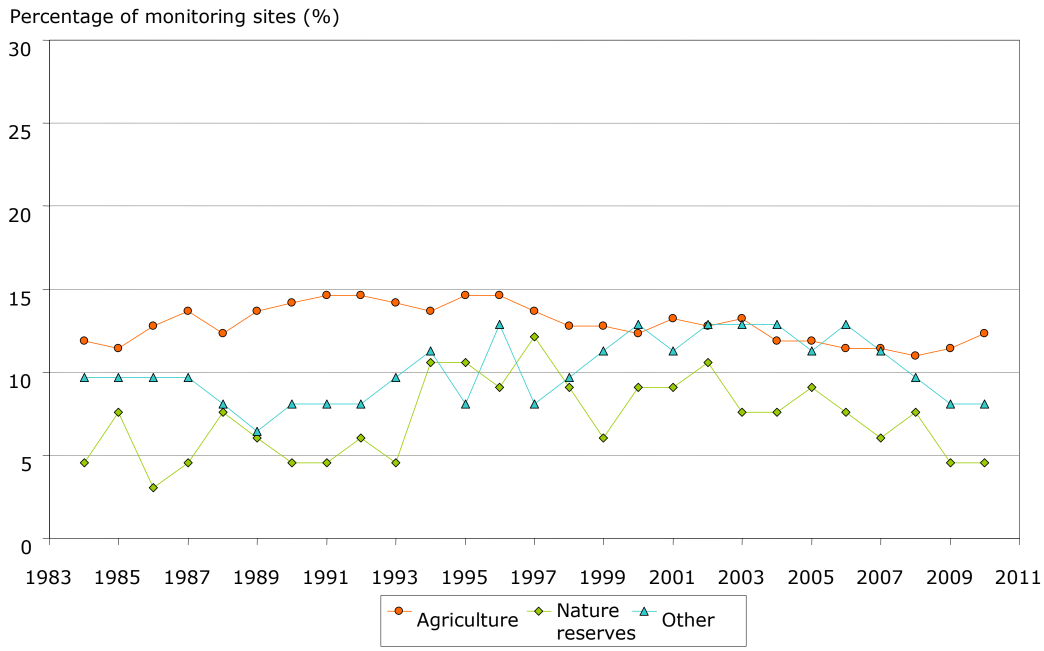



*Figure 5.3. Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at a depth of 5-15 metres below the surface by land use type for the period 1984-2010.*

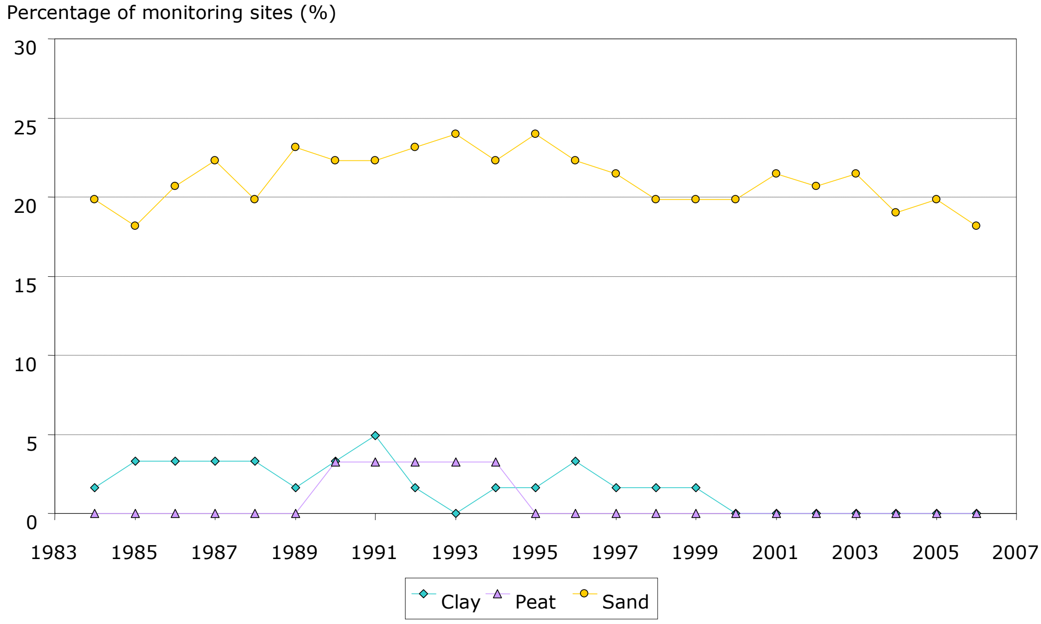



*Figure 5.4. Exceedance of the EU standard of 50 mg/l for nitrate in groundwater in agricultural areas at a depth of 5-15 metres below the surface for the period 1984-2010.*

*Table 5.1. Nitrate in groundwater at a depth of 5-15 metres for the period 1992-2010 (%)[1].*

| | All monitoring sites | | | Monitoring sites in agricultural areas | | |
|---|---|---|---|---|---|---|
| Concentration | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0 - 15 mg/l | 79.0 | 81.8 | 83.0 | 80.4 | 82.6 | 84.0 |
| 15 - 25 mg/l | 3.7 | 2.9 | 2.3 | 1.8 | 1.8 | 1.8 |
| 25 - 40 mg/l | 2.0 | 2.6 | 3.5 | 0.5 | 2.7 | 1.4 |
| 40 - 50 mg/l | 2.6 | 1.7 | 1.2 | 1.8 | 0.5 | 0.9 |
| > 50 mg/l | 12.7 | 11.0 | 10.1 | 15.5 | 12.3 | 11.9 |
| Number of monitoring sites | 347 | 347 | 347 | 219 | 219 | 219 |

[1] Percentage of monitoring sites with a period average within a given concentration range for all monitoring sites and for monitoring sites with water mainly affected by agriculture. The total percentage could exceed 100 because of rounding.

Most monitoring sites (about 70%) showed no change in nitrate concentration between reporting periods (1992-1995, 2004-2007 and 2008-2010;Table 5.2). The number of sites where a change occurred decreased slightly, mainly because of a reduction in the number of sites showing a fall. The pattern of differences between the first and fourth periods is comparable to that between the fourth and fifth, in that the percentage of sites showing a fall is greater than the percentage showing a rise.

*Table 5.2. Change in nitrate concentration in groundwater at a depth of 5-15 metres for the period 1992-2010 (%)*[1]

| Concentration | All monitoring sites 1992-1995/ 2004-2007 | All monitoring sites 2004-2007/ 2008-2010 | Monitoring sites in agricultural areas 1992-1995/ 2004-2007 | Monitoring sites in agricultural areas 2004-2007/ 2008-2010 |
|---|---|---|---|---|
| Large increase (% > 5 mg/l) | 8.9 | 4.9 | 7.8 | 5.5 |
| Small increase (% 1-5 mg/l) | 3.5 | 3.7 | 3.2 | 3.2 |
| Stable (% ± 1 mg/l) | 66.3 | 70.9 | 72.1 | 72.6 |
| Small decrease (% > 1-5 mg/l) | 4.3 | 6.9 | 1.8 | 6.4 |
| Large decrease (% > 5 mg/l) | 17.0 | 13.5 | 15.1 | 12.3 |
| Number of monitoring sites | 347 | 347 | 219 | 219 |

[1] Percentage of monitoring sites with given size of change in concentration between the first and fourth, and the fourth and fifth reporting periods. The table shows the data of all monitoring sites, as well of monitoring sites with water mainly affected by agriculture. The total percentage could exceed 100 because of rounding.

Of the three sand areas, North, Central and South (Figure 5.5, unbroken lines), the nitrate concentration is clearly the highest in Sand South (around 65 mg/l), lower in Sand Central (about 25 mg/l) and the lowest in Sand North (slightly over 10 mg/l). In these areas, other soil types also occur. If only the monitoring sites on sandy soil are considered (Figure 5.5, broken lines), the nitrate concentrations are slightly higher. Moreover, Sand South has the most wells where the EU standard is exceeded (Figure 5.6).

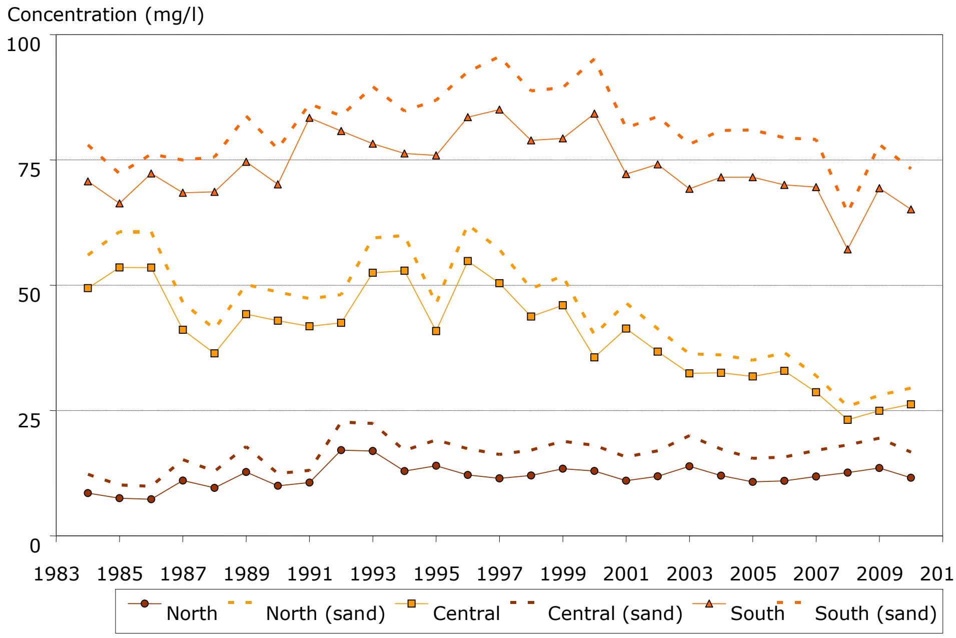



*Figure 5.5. Nitrate in groundwater at a depth of 5-15 metres below the surface in agricultural areas in Sand North, Sand Central and Sand South (unbroken lines) and from farming on sandy soil within these areas (dotted lines).*

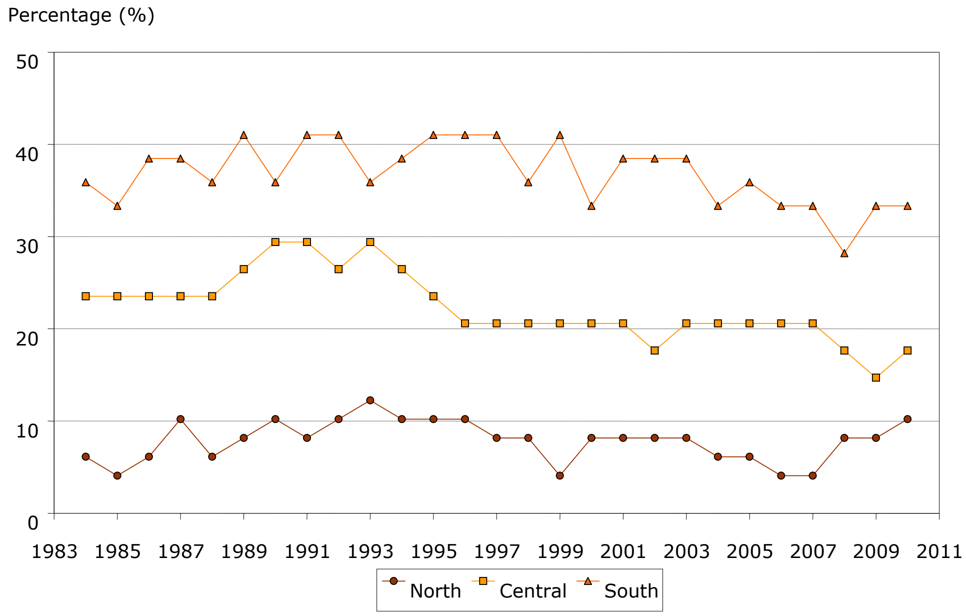
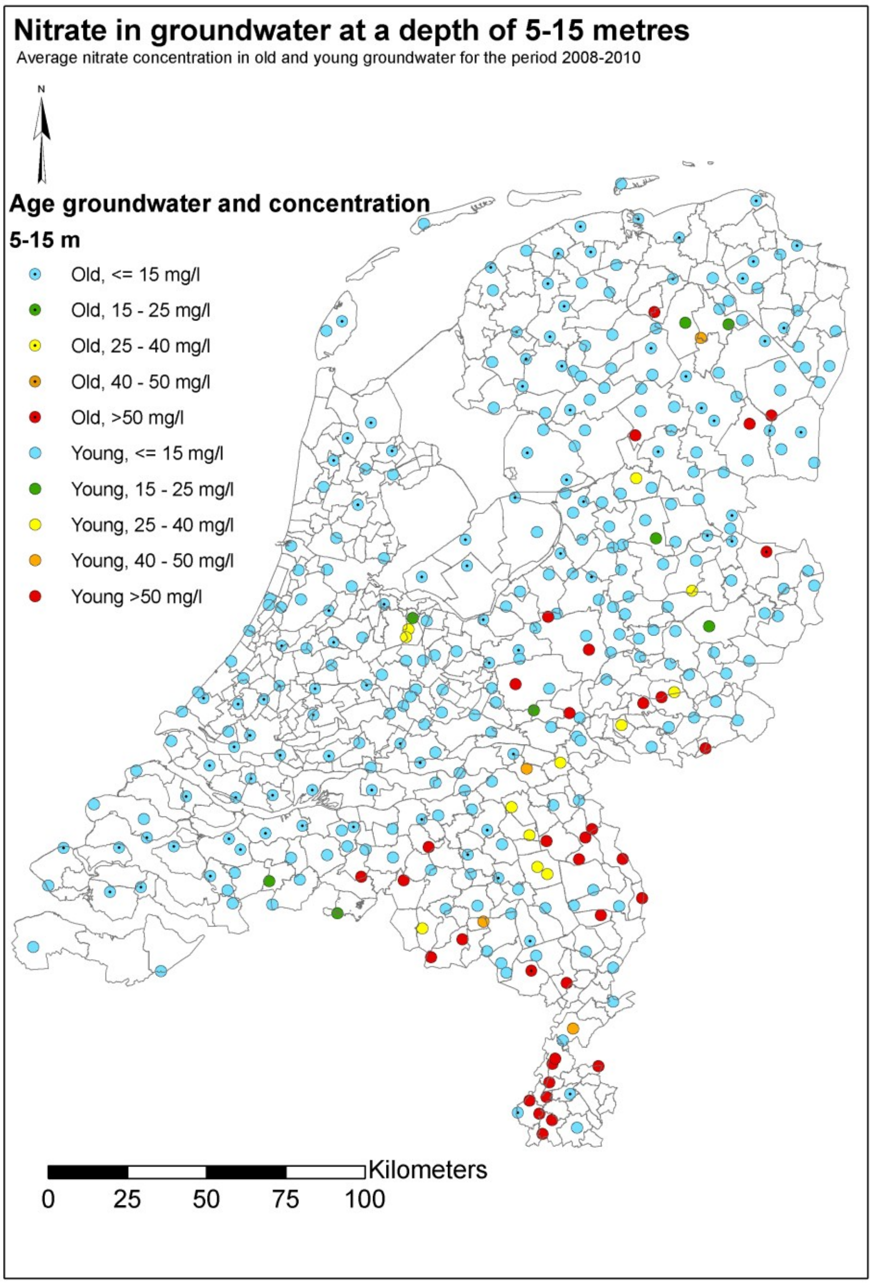



*Figure 5.6. Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at a depth of 5-15 metres below the surface in the areas Sand North, Sand Central and Sand South for the period 1984-2010.*

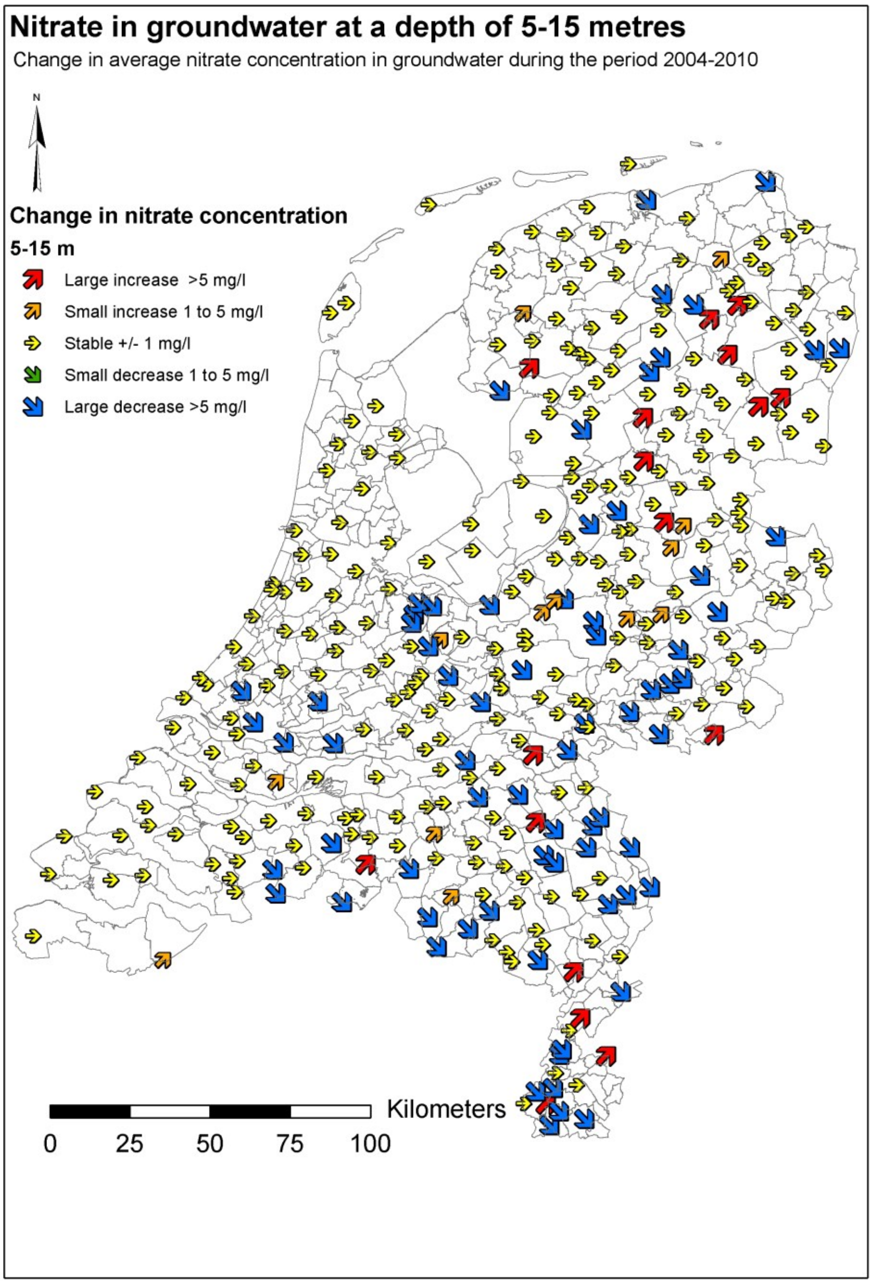
Starting in the mid-1990s, the nitrate concentration in groundwater between 5 and 15 metres below the surface in Sand South fell from about 85 mg/l to 65 mg/l. In Sand Central, the nitrate concentration fell from 55 mg/l to 25 mg/l. This decline also continued in the latest monitoring years, particularly in Sand South. Similar to the trend in nitrate in farming areas on sandy soil (Figure 5.2), nitrate concentration shows the same distinct dip in 2008. In Sand North, the nitrate concentration was reasonably stable during the monitoring period.

Map 5.1 shows the average nitrate concentration of all monitoring sites with monitoring depths of 5 to 15 m, for the period 2008-2010. The monitoring sites are divided into those with wells containing old groundwater (> 25 years) and young groundwater (< 25 years). In the wells containing old groundwater, this water is usually from confined or semi-confined aquifers, whereas in those containing young groundwater, it is from phreatic aquifers. High nitrate concentrations (> 50 mg/l) were found in young groundwater in the sand and loess regions (the eastern and southern parts of the Netherlands).

The change in nitrate concentration between the 2004-2007 and 2008-2010 periods is shown on Map 5.2. Most changes occurred in the sand and loess regions, with increases as well as decreases in nitrate concentrations being found.




*Map 5.1. Average nitrate concentration in groundwater at a depth of 5-15 metres for the period 2008-2010. “Young” refers to groundwater younger than 25 years; “Old” means older than 25 years.*




*Map 5.2. Change in average nitrate concentration in groundwater at a depth of 5-15 metres for the period 2004-2010. Change shown here is the difference between the averages for the 2004-2007 and 2008-2010 periods.*

## 5.3 Nitrate in groundwater at a depth of 15-30 metres

Until 1998, nitrate concentration at a depth of 15-30 metres was highest under agricultural land, followed by land used for other purposes and nature reserves (Figure 5.7). After 1998, the nitrate concentration in land used for other purposes rose substantially, so that it became more than in agricultural areas. This increase cannot be explained. Following a dip after 2002, the concentration in land used for other purposes seems to have stabilised in recent years, the average settling at 9 mg/l. In the case of agricultural areas, the average nitrate concentration is roughly 5 mg/l; for nature reserves, 3 mg/l.

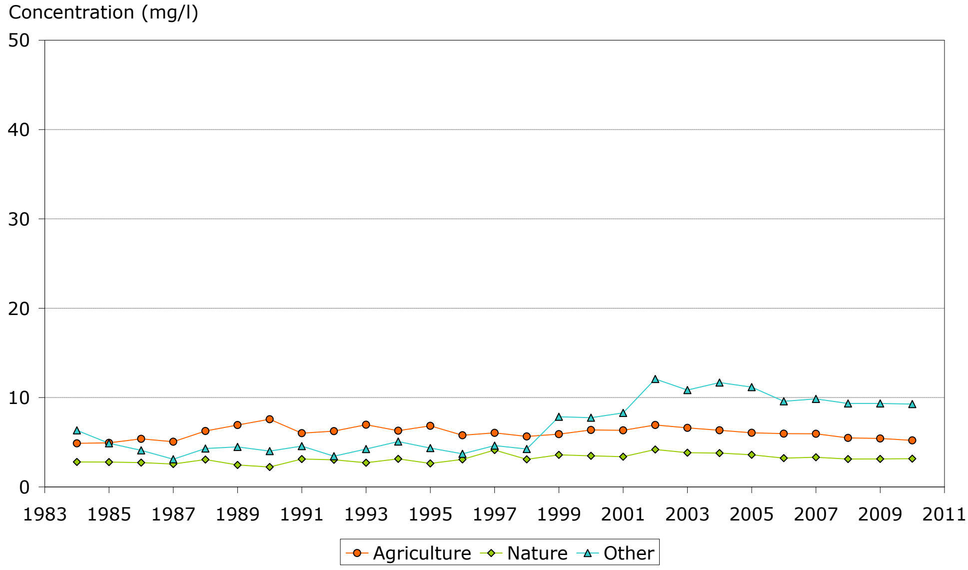



*Figure 5.7. Average annual nitrate concentration (mg/l) in groundwater at a depth of 15–30 metres by land use type for the period 1984-2010.*

The nitrate concentration in groundwater originating from farming on sandy soil is higher than the concentration under clay or peat soil, where virtually no nitrate is detected at a depth of 15-30 metres (Figure 5.8). After 2002, the nitrate concentration relating to agriculture on sandy soil fell from 11 mg/l to approximately 7 mg/l in 2010.

Between 2008 and 2010, the EU standard of 50 mg/l for nitrate was exceeded at 3% of the groundwater monitoring wells at a depth of 15 to 30 m. For agricultural areas, the figure was 3%; for nature reserves, 2%; and for other areas, 5% (Figure 5.9 and Table 5.3). There were slight variations from year to year.

The percentage of monitoring sites in agricultural areas on sandy soil where the EU standard for nitrate was exceeded shrank from 7% to 3%. During the same monitoring period, the percentage in the clay and peat regions was only 1% (Figure 5.10).

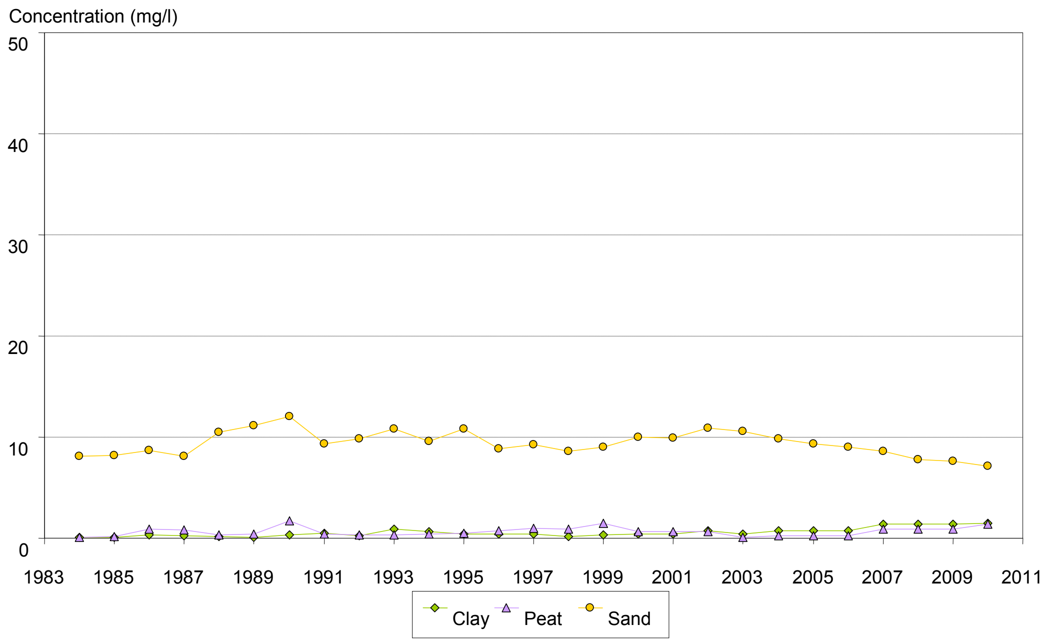



*Figure 5.8. Average annual nitrate concentration (mg/l) in groundwater at a depth of 15-30 metres in agricultural areas by soil type for the period 1984-2010.*

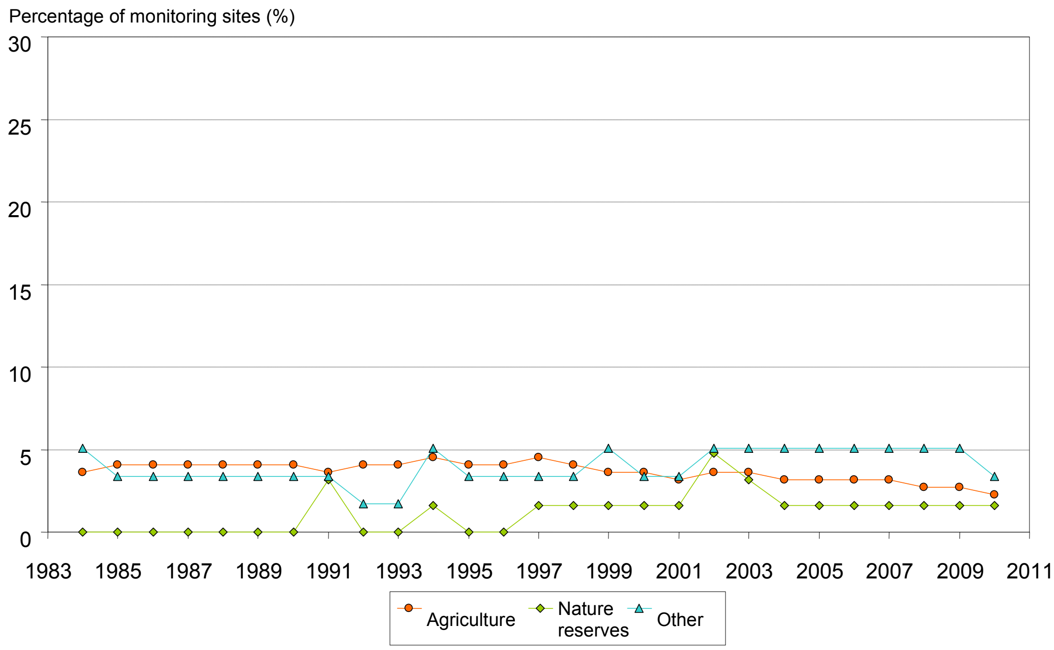



*Figure 5.9. Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at a depth of 15-30 metres by land use type for the period 1984-2010.*

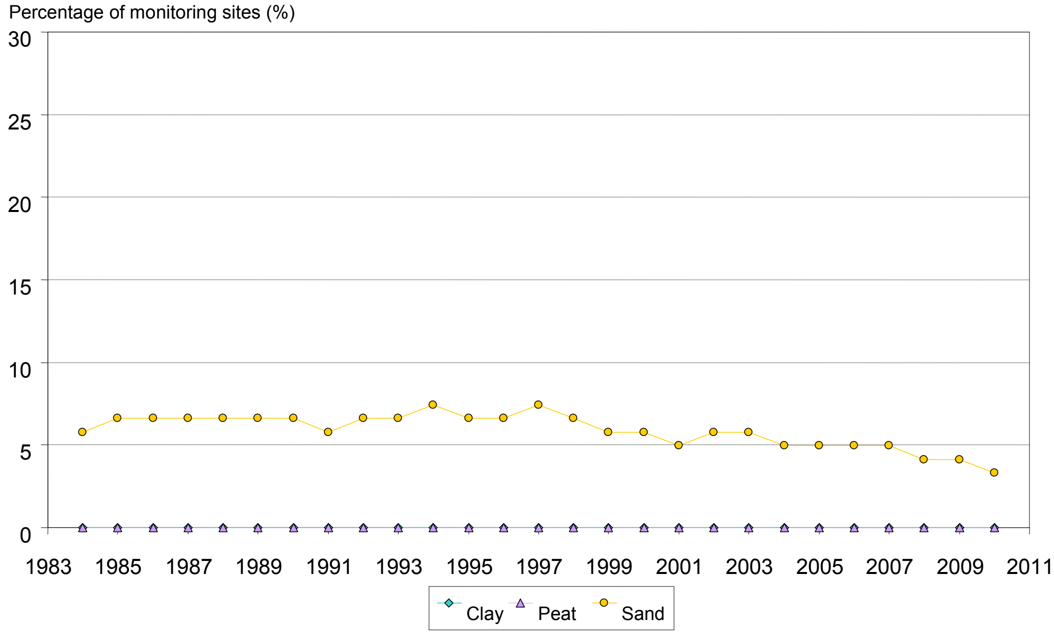



*Figure 5.10. Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at a depth of 15-30 metres below farming areas in the period 1984-2010.*

*Table 5.3. Nitrate in groundwater at a depth of 15-30 metres for the period 1992-2010 (%)[1].*

| Concentration | All monitoring sites | | | Monitoring sites in agricultural areas | | |
|---|---|---|---|---|---|---|
| | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0 - 15 mg/l | 94.3 | 93.5 | 92.9 | 93.8 | 93.8 | 92.8 |
| 15 - 25 mg/l | 0.9 | 1.2 | 2.1 | - | 1.0 | 1.9 |
| 25 - 40 mg/l | 0.9 | 1.5 | 1.8 | 1.4 | 1.4 | 1.9 |
| 40 - 50 mg/l | 0.6 | 0.9 | 0.9 | 0.5 | 1.0 | 1.4 |
| > 50 mg/l | 3.3 | 3.0 | 2.4 | 4.3 | 2.9 | 1.9 |
| Number of monitoring sites | 336 | 336 | 336 | 209 | 209 | 209 |

[1] Percentage of monitoring sites with a period average within a given concentration range for all monitoring sites and for monitoring sites with water mainly affected by agriculture. The total percentage could exceed 100 because of rounding.

Most monitoring sites (over 80%) showed no change in nitrate concentration between reporting periods (1992-1995, 2004-2008 and 2008-2010;Table 5.4). The number of sites with an increase was slightly higher than the number showing a decrease. The number of stable sites grew between periods, as the number showing an increase and the number showing a decrease both declined between periods.

*Table 5.4. Change in nitrate concentration in groundwater at a depth of 15-30 metres in the period 1992-2010 (%)[1].*

| Concentration | All monitoring sites | | Monitoring sites in agricultural areas | |
|---|---|---|---|---|
| | 1992-1995/ 2004-2007 | 2004-2007/ 2008-2010 | 1992-1995/ 2004-2007 | 2004-2007/ 2008-2010 |
| Large increase (% > 5 mg/l) | 6.3 | 2.4 | 4.8 | 2.9 |
| Small increase (% 1-5 mg/l) | 3.3 | 6.0 | 3.8 | 5.7 |
| Stable (% ± 1 mg/l) | 83.0 | 86.0 | 83.3 | 86.6 |
| Small decrease (% > 1-5 mg/l) | 4.8 | 1.2 | 5.3 | 1.0 |
| Large decrease (% > 5 mg/l) | 2.7 | 4.5 | 2.9 | 3.8 |
| Number of monitoring sites | 336 | 336 | 209 | 209 |

[1] Percentage of monitoring sites with given rate of change in concentration between the first and fourth, and between the fourth and fifth reporting periods. The table shows the data of all monitoring sites, as well of monitoring sites with water mainly affected by agriculture. The total percentage could exceed 100 because of rounding.

Nitrate concentrations were determined separately for each of the Sand North, Sand Central and Sand South sand areas (Figure 5.11). Something striking is that, in contrast to the measuring results for groundwater 5-15 m below the surface, the nitrate concentration in deeper water is highest in Sand Central. The average nitrate concentration at 15-30 metres in the sand areas is entirely determined by a limited number of wells with a high nitrate concentration (Table 5.5).

*Table 5.5. Number of wells at a depth of 15-30 metres below the surface in agricultural areas with sandy soil by nitrate concentration class.*

| Nitrate concentration class (nitrate in mg/l) | Sand North | Sand Central | Sand South |
|---|---|---|---|
| <1 mg/l | 41 | 25 | 32 |
| 1 to 10 mg/l | 3 | 4 | 5 |
| >10 mg/l | 4 | 5 | 1 |
| Total number of wells | 48 | 34 | 38 |

For the above reason, the average concentration can give a distorted impression, because it is largely dependent on chance. However, it certainly is the case that high nitrate concentrations were recorded at more locations in Sand Central than in Sand North or Sand South, as shown by Map 5.3. This map depicts all the deep screens of LMG, including those in areas designated as nature reserves or for other purposes, and for all soil types.

Map 5.3 shows the average nitrate concentration of all monitoring sites with monitoring depths of 15 to 30 m, for the period 2008-2010. The monitoring sites are divided into those with wells containing old groundwater (> 25 years) and young groundwater (< 25 years). In the wells containing old groundwater, the water is usually from confined or semi-confined aquifers, whereas in those containing young groundwater, it is from phreatic aquifers. High nitrate concentrations (> 50 mg/l) were found in young groundwater in the sand and loess regions (the eastern and southern parts of the Netherlands). The change in nitrate concentration between the 2004-2007 and 2008-2010 periods is shown in Map 5.4. Most changes occurred in the sand and loess regions, with increases as well as decreases in nitrate concentrations being found.

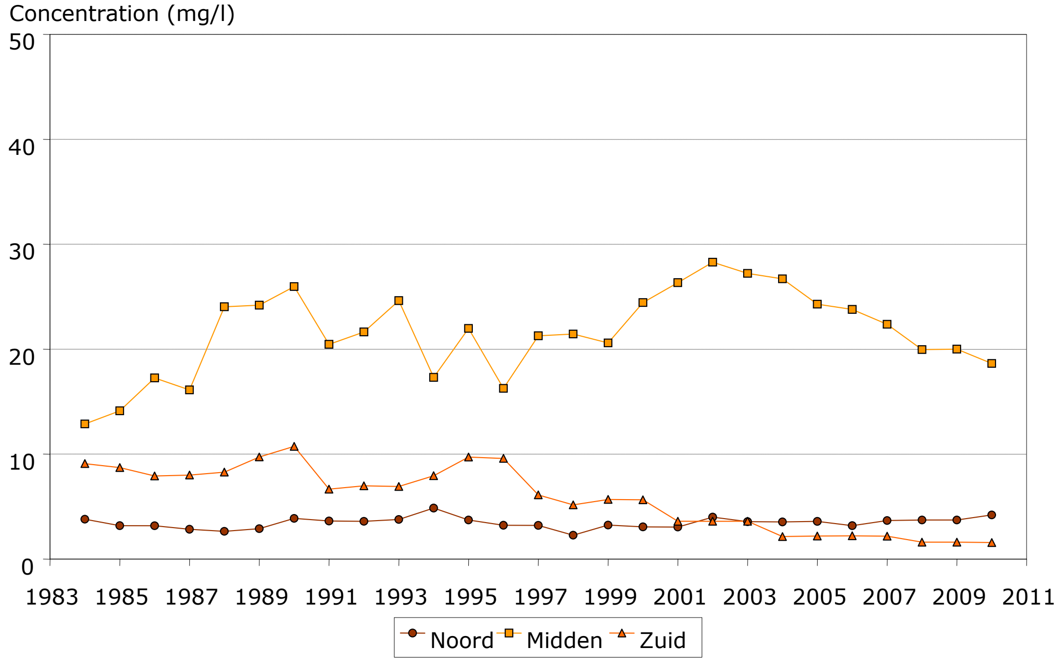



*Figure 5.11. Nitrate in groundwater at a depth of 15-30 metres under farming areas by sand area.*

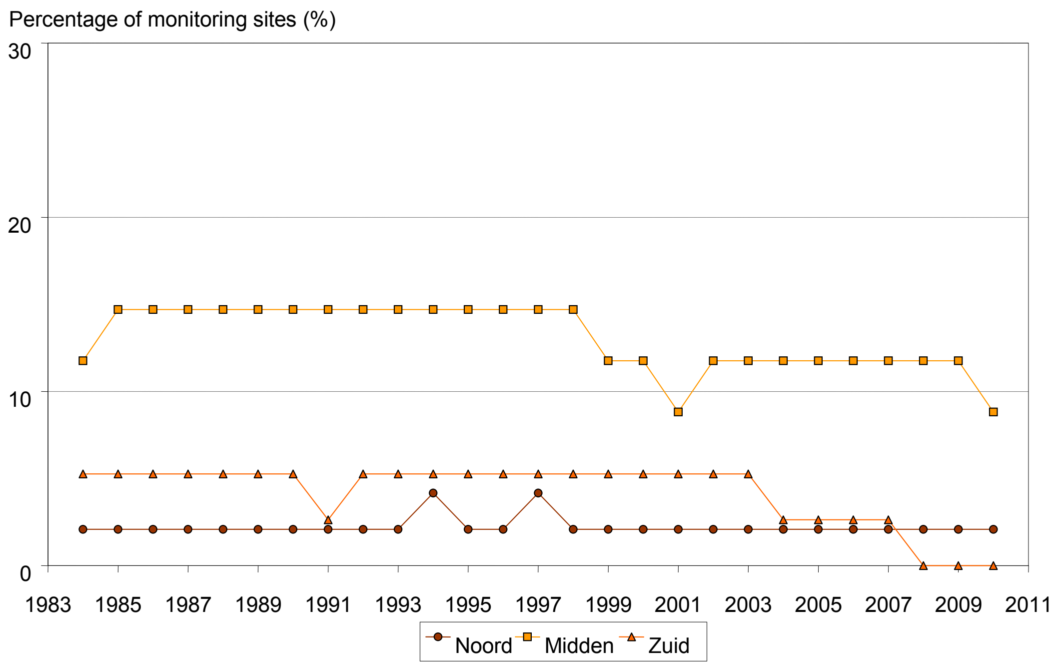
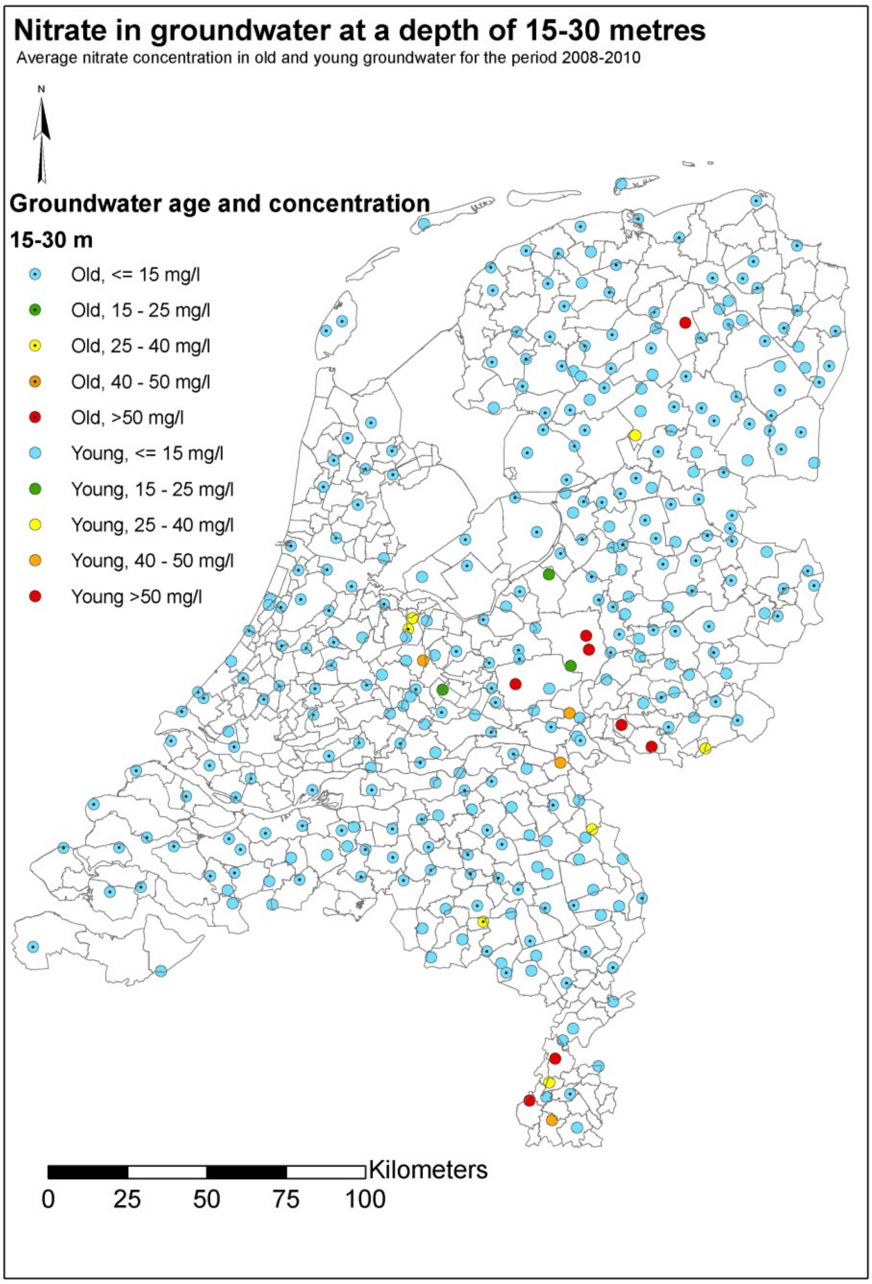
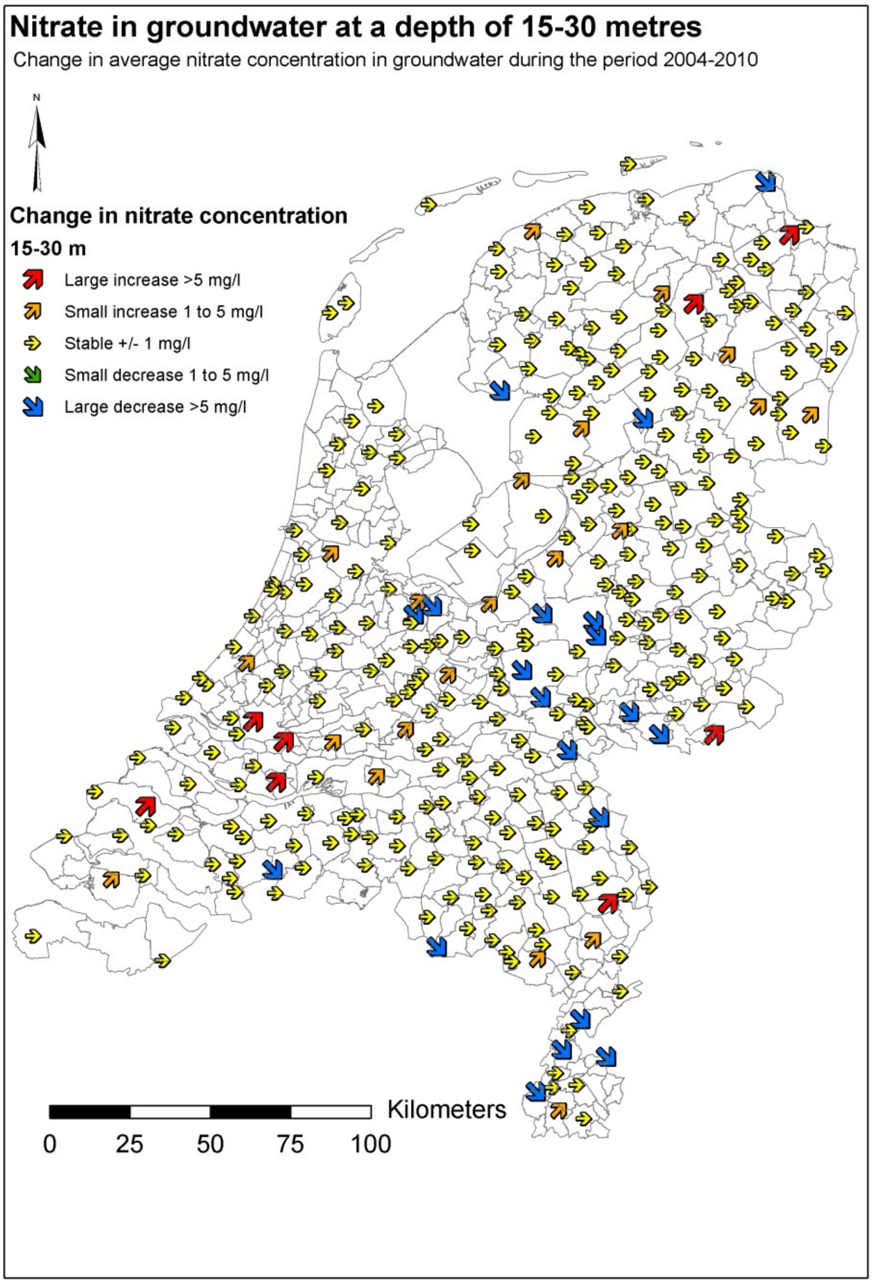



*Figure 5.12. Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at a depth of 15-30 metres by sand area for the period 1984-2010.*




*Map 5.3. Average nitrate concentration in groundwater at a depth of 15-30 metres in the Netherlands for the period 2008-2010. "Young" refers to groundwater younger than 25 years; "Old" means older than 25 years.*




*Map 5.4. Change in average nitrate concentration in groundwater at a depth of 15-30 metres for the period 2008-2010.*
*Change shown here is the difference between averages for the 2004-2007 and 2008-2010 periods.*

## 5.4 Nitrate in groundwater below 30 metres

In the period 2008-2010, the average nitrate concentration in groundwater used for drinking water production (raw water) was about 6.5 mg/l for phreatic aquifers and less than 1 mg/l for confined aquifers. The nitrate concentration in raw water from phreatic aquifers increased slightly until 2003, and then decreased until 2006. After 2006, the nitrate concentration remained stable (Figure 5.13).

The percentage of drinking water production sites with an average nitrate concentration in raw water above 50 mg/l was less than 2% (Figure 5.14 and Table 5.6).

The fairly constant nitrate concentration in raw water is also apparent fromTable 5.7. The 40-50 mg/l class increased slightly, whereas other classes decreased slightly again. The number of sites with an increase went down, whereas the number showing a large increase went up.

The EU standard of 50 mg/l was not exceeded in distributed drinking water. In 2010, none of the 227 drinking water production sites had a nitrate concentration exceeding 50 mg/l.

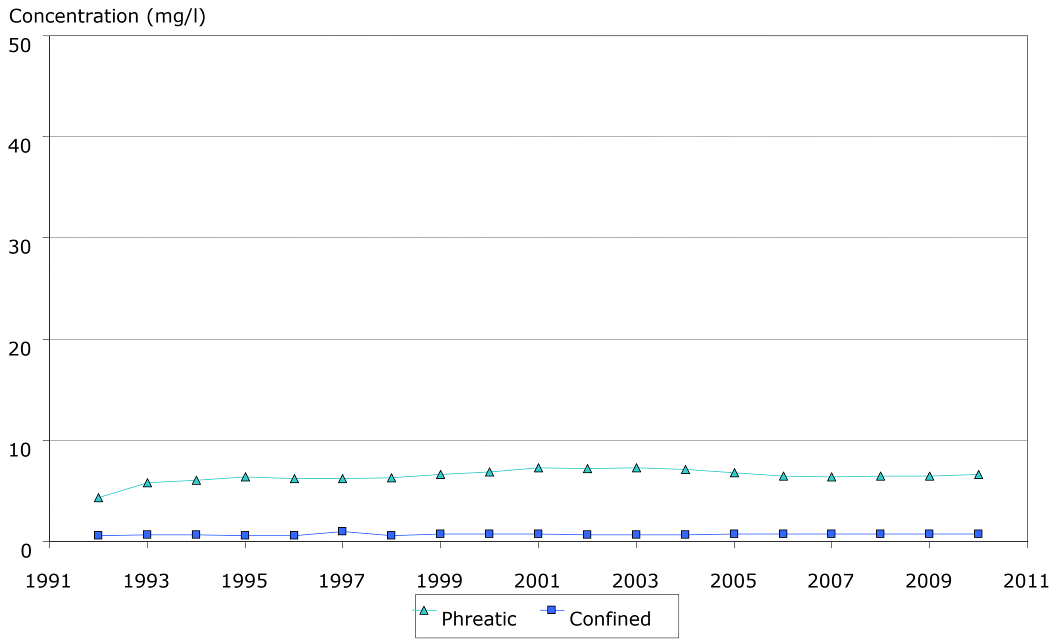



*Figure 5.13. Average annual nitrate concentration (mg/l) in groundwater in phreatic and confined aquifers at drinking water production sites in the period 1992–2010.*

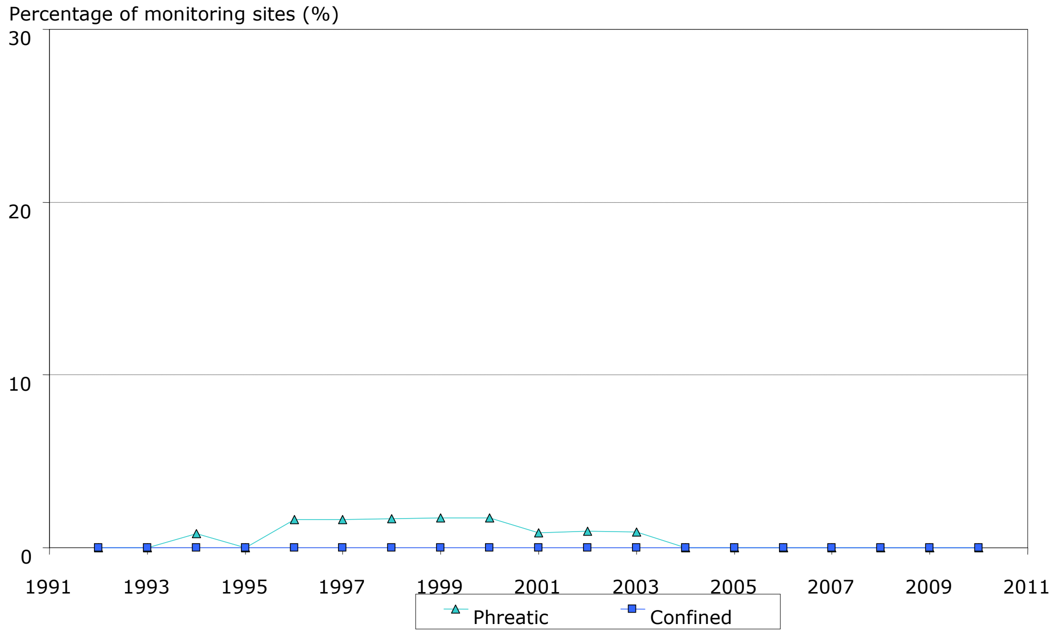



*Figure 5.14. Exceedance of the EU standard of 50 mg/l for average nitrate concentration in groundwater at drinking water production sites for phreatic groundwater and confined groundwater in the period 1992-2010. Exceedance is expressed as a percentage of all production sites.*

*Table 5.6. Average nitrate concentration in groundwater at a depth of more than 30 metres in the period 1992-2010 (%)[1].*

| | All production sites | | | Phreatic sites | | |
|---|---|---|---|---|---|---|
| Concentration | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0-15 mg/l | 91.2 | 90.0 | 90.9 | 85.3 | 82.4 | 83.8 |
| 15-25 mg/l | 5.1 | 6.3 | 4.5 | 8.5 | 11.1 | 8.1 |
| 25-40 mg/l | 3.2 | 3.2 | 2.8 | 5.4 | 5.6 | 5.1 |
| 40-50 mg/l | 0.5 | 0.5 | 1.7 | 0.8 | 0.9 | 3.0 |
| > 50 mg/l | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Number of sites | 217 | 190 | 176 | 129 | 108 | 99 |

[1] Percentage of drinking water production sites using groundwater with a period average within a given concentration range for all production sites and for sites with only phreatic groundwater. The total percentage could exceed 100 because of rounding.

In the period 2008-2010, the average maximum nitrate concentration in groundwater used for drinking water production was about 10 mg/l for phreatic aquifers and less than 1 mg/l for confined aquifers (Figure 5.15). The maximum nitrate concentration in raw water from phreatic aquifers remained constant over the last three years of the period. On average, 1% of the sites had a maximum nitrate concentration higher than the EU standard (Figure 5.16 and Table 5.8).

*Table 5.7. Change in average nitrate concentration in groundwater at a depth of more than 30 metres in the period 1992-2010 (%)[1].*

| Change | All production sites 1992-1995/ 2004-2007 | 2004-2007/ 2008-2010 | Phreatic sites 1992-1995/ 2004-2007 | 2004-2007/ 2008-2010 |
|---|---|---|---|---|
| Large increase (% > 5 mg/l) | 4.2 | 1.2 | 6.7 | 2.2 |
| Small increase (% 1-5 mg/l) | 7.3 | 3.6 | 13.3 | 6.7 |
| Stable (% ± 1 mg/l) | 86.7 | 86.7 | 65.6 | 76.7 |
| Small decrease (% > 1-5 mg/l) | 7.3 | 6.1 | 10.0 | 10.0 |
| Large decrease (% > 5 mg/l) | 1.8 | 2.4 | 2.2 | 4.4 |
| Number of sites | 165 | 165 | 90 | 90 |

[1] Percentage of drinking water production sites using groundwater with given size of change in concentration between the first and fourth, and the fourth and fifth reporting periods. The table shows the data of all production sites, as well as of sites with only phreatic groundwater. The total percentage could exceed 100 because of rounding.

Concerning the maximum nitrate concentration in groundwater used for drinking water extraction, the percentage of sources with a large increase went down, and the percentage of sources with a large decrease went up (Table 5.9).

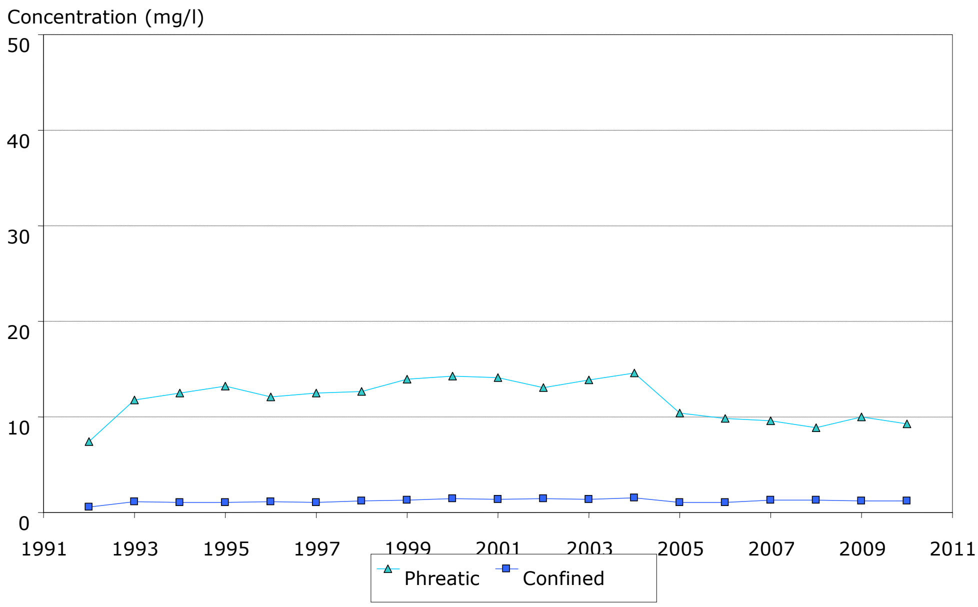



*Figure 5.15. Maximum nitrate concentration (mg/l) in groundwater at drinking water production sites for phreatic groundwater and confined groundwater in the period 1992–2010.*

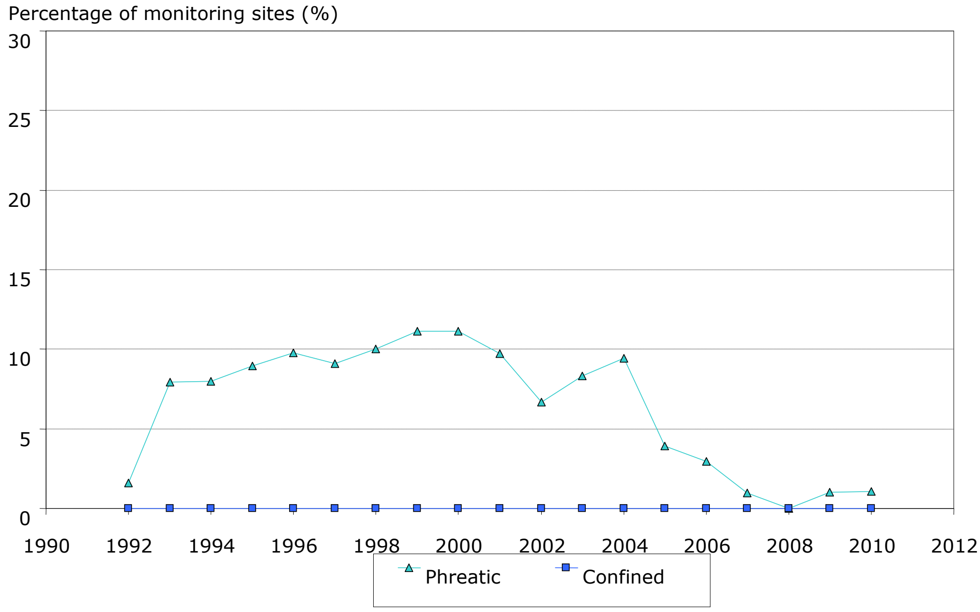



*Figure 5.16. Exceedance of the EU standard of 50 mg/l for average nitrate concentration in groundwater at drinking water production sites for phreatic groundwater and confined groundwater in the period 1992-2010. Exceedance is expressed as a percentage of all production sites.*

*Table 5.8. Maximum nitrate concentration in groundwater at a depth of more than 30 metres for the period 1992-2010 (%)[1].*

| | All production sites | | | Phreatic sites | | |
|---|---|---|---|---|---|---|
| Concentration | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0-15 mg/l | 84.3 | 83.2 | 85.8 | 75.2 | 71.3 | 74.7 |
| 15-25 mg/l | 5.5 | 6.3 | 4.5 | 7.8 | 10.2 | 8.1 |
| 25-40 mg/l | 5.1 | 3.7 | 4.5 | 8.5 | 6.5 | 8.1 |
| 40-50 mg/l | 0.5 | 3.7 | 4.5 | 0.8 | 6.5 | 8.1 |
| > 50 mg/l | 4.6 | 3.2 | 0.6 | 7.8 | 5.6 | 1.0 |
| Number of sites | 217 | 190 | 176 | 129 | 108 | 99 |

[1] Percentage of drinking water production sites using groundwater with a period average within a given concentration range for all production sites and for sites with only phreatic groundwater. The total percentage could exceed 100 because of rounding.

*Table 5.9. Change in maximum nitrate concentration in groundwater at a depth of more than 30 metres for the period 1992-2010 (%)[1].*

| | All production sites | | Phreatic sites | |
|---|---|---|---|---|
| Change | 1992-1995/ 2004-2007 | 2004-2007/ 2008-2010 | 1992-1995/ 2004-2007 | 2004-2007/ 2008-2010 |
| Large increase (% > 5 mg/l) | 4.2 | 0.6 | 7.8 | 1.1 |
| Small increase (% 1-5 mg/l) | 6.7 | 6.1 | 10.0 | 10.0 |
| Stable (% ± 1 mg/l) | 80.0 | 80.0 | 56.7 | 66.7 |
| Small decrease (% > 1-5 mg/l) | 10.3 | 4.8 | 6.7 | 6.7 |
| Large decrease (% > 5 mg/l) | 6.7 | 8.5 | 11.1 | 15.6 |
| Number of sites | 165 | 165 | 90 | 90 |

[1] Percentage of drinking water production sites using groundwater with given rate of change in concentration between the first and fourth, and between the fourth and fifth reporting periods. The table shows the data of all production sites, as well as of sites with only phreatic groundwater. The total percentage could exceed 100 because of rounding.

Map 5.5 shows the average concentration per drinking water production site in the period 2007-2009, while Map 5.6 shows the change between the 2004-2007 and 2007-2009 periods. The highest nitrate concentrations occur in the southern (mainly in the loess region) and eastern parts of the Netherlands near the German border (sand regions). These areas in particular showed decreasing trends.

Map 5.7 shows the maximum concentration per drinking water production site in the period 2007-2009, while Map 5.8 shows the change in maxima between the 2004-2007 and 2008-2010 periods. The highest maximum nitrate concentrations also occur in the southern and the eastern parts of the Netherlands.

## 5.5 References

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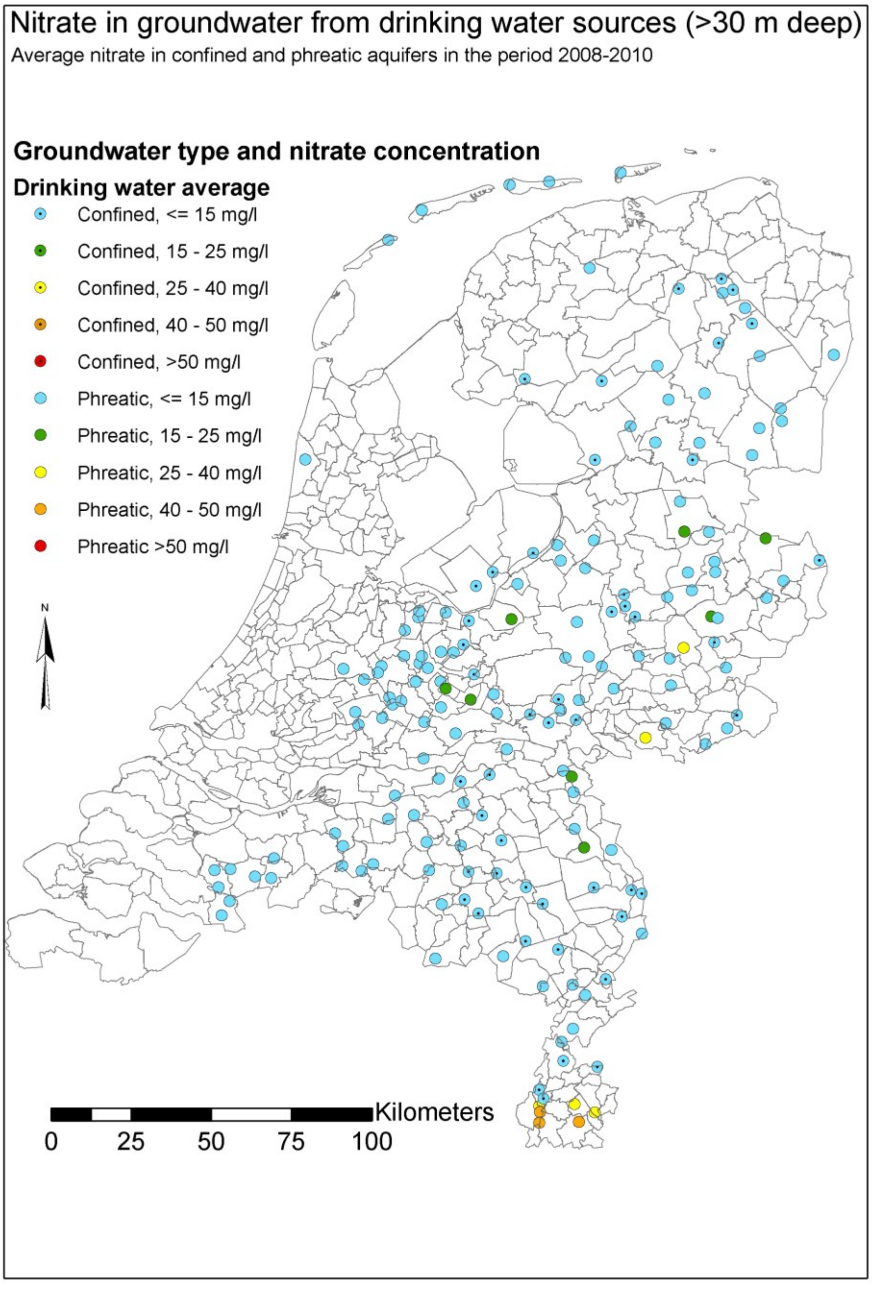
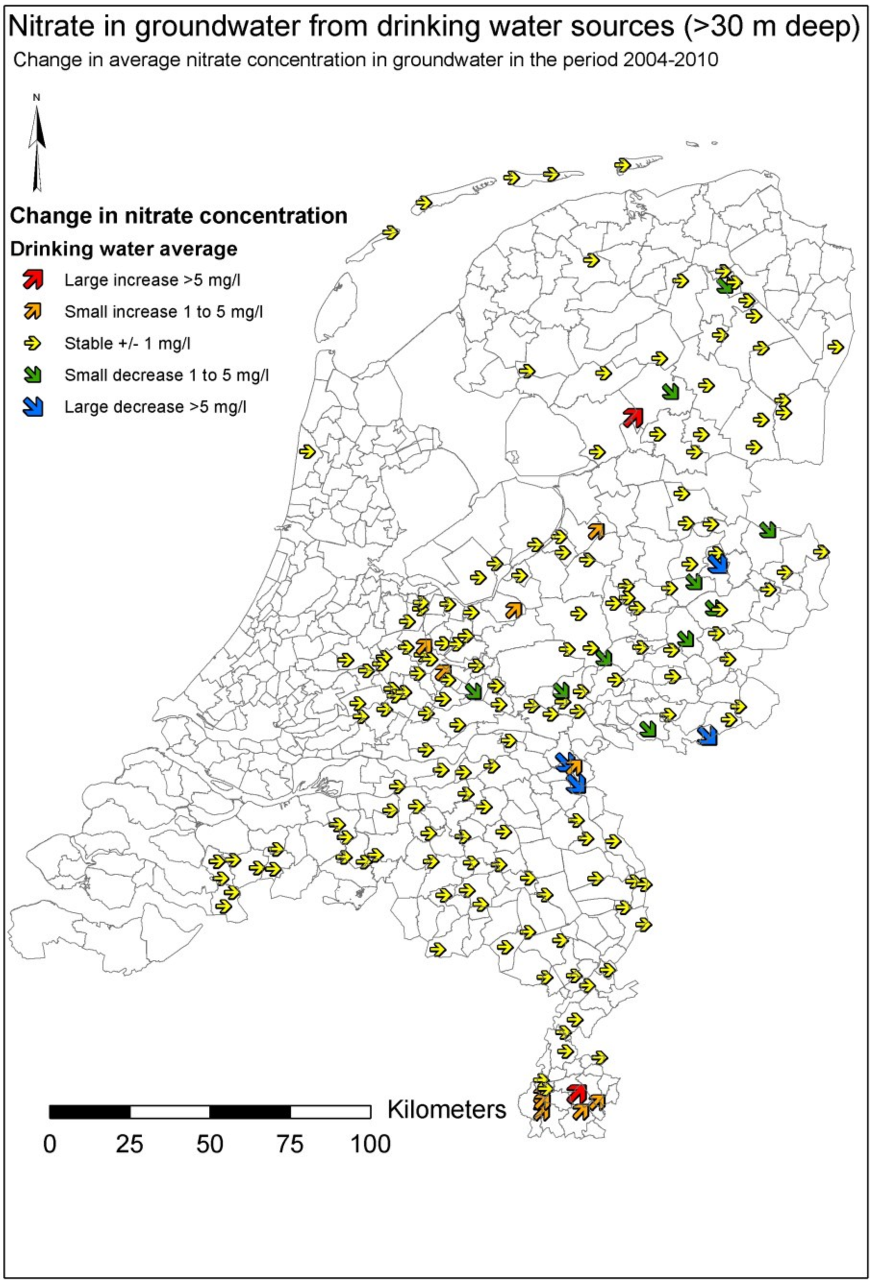
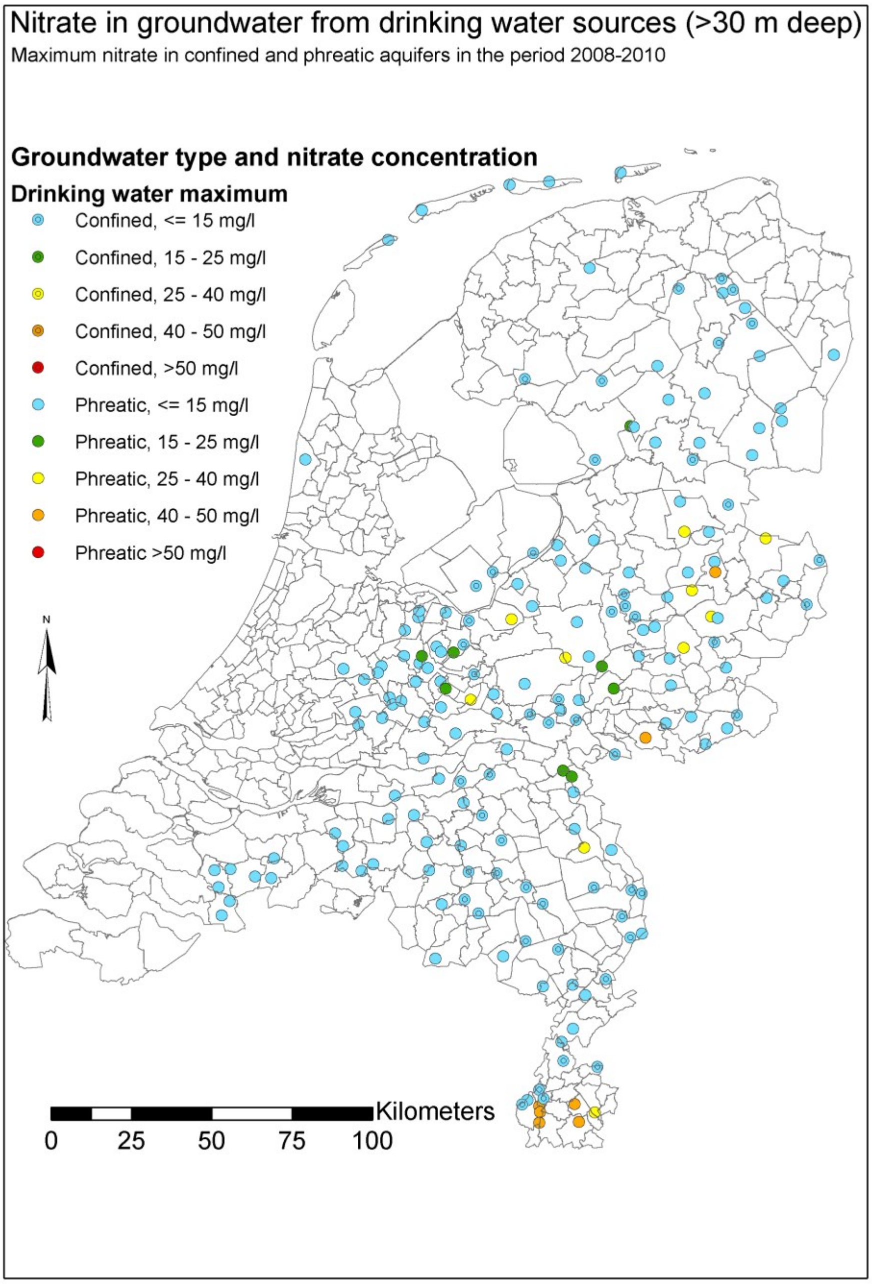
Van Vliet, M.E., Vrijhoef, A., Boumans, L.J.M., Wattel-Koekkoek, E.J.W. (2010). De kwaliteit van ondiep en middeldiep grondwater in Nederland in het jaar 2008 en de verandering daarvan in 1984-2008. RIVM Report 680721005.



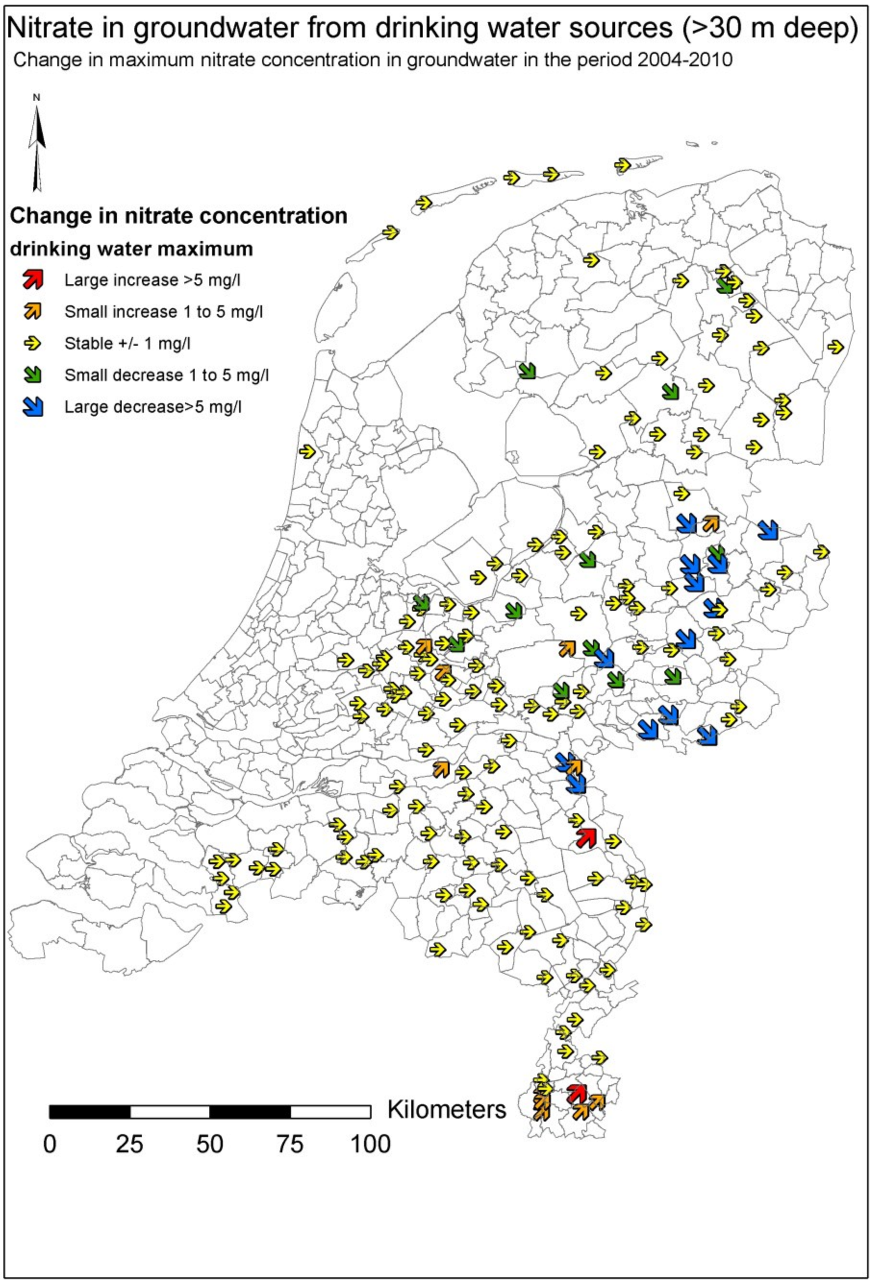

*Map 5.5. Average nitrate concentration in groundwater used for drinking water production in the period 2008-2010.*




*Map 5.6. Change in maximum nitrate concentration in groundwater used for drinking water production in the period 2008-2010. Change shown here is the difference between averages for the 2004-2007 and 2008-2010 periods.*




*Map 5.7. Maximum nitrate concentration in groundwater used for drinking water production in the period 2008-2010.*




*Map 5.8. Change in maximum nitrate concentration in groundwater used for drinking water production in the period 2004-2010. Change shown here is the difference between the averages for the 2004-2007 and 2008-2010 periods.*

# 6 Freshwater quality

## 6.1 Introduction

The first part (6.2) of this chapter deals briefly with the nutrient load on fresh surface waters. Section 6.3 presents an overview of the nutrient concentrations in the various fresh surface waters of the Netherlands, as well as the trend in nitrate concentration during three different periods. Section 6.4 deals with the various parameters that define the eutrophication status of freshwater. Nitrogen and phosphorus both affect the degree of eutrophication.

The data presented in this chapter originate from measurements of all the fresh surface waters, in particular, of those strongly affected by agriculture. In addition to these waters, main locations are also discussed in this chapter. It can be concluded in general that main locations are in the main water system, which comprises the large rivers and lakes. The remaining sites are those in regional waters.

Main locations are singled out as a separate category for two reasons. The first is that they show the impact on water quality of sources from outside the Netherlands. The second is that the effects of inland (non-agricultural) sources on water quality in the coastal zone are easy to identify by measuring the nitrate concentrations at main locations.

In conformity with EU standards, this report considers nitrate-nitrogen to be the most important variable for reflecting the effects of agriculture on surface water quality. In watercourses prone to eutrophication, nitrates disappear in varying degrees because algae absorb them in the summer months, which can result in the monitoring results presenting a distorted picture. The more eutrophicated a water body is, the lower the nitrate concentration during the summer. The winter average (October to March) is therefore more representative than the annual average. The winter period is also the time when leaching processes play a key role. In this report, the winter, summer and annual averages for nitrate are presented.

In the Netherlands, the degree of eutrophication is assessed from the chlorophyll-a concentration (algal biomass), total nitrogen concentration and total phosphorus concentration. Chlorophyll-a concentrations are at their highest during the summer months (April to October). For this reason, the summer average is used to determine the degree of eutrophication of the various water bodies during the designated periods. In accordance with Dutch standards, eutrophication is presented not only using the summer average of chlorophyll-a concentration, but also using the summer average of total phosphorus concentration and total nitrogen concentration (STOWA, 2007). Nitrogen concentration is an indicator of the quantity of nutrients present, as well as of the algal biomass.

## 6.2 Nutrient load on fresh surface waters

Water does not respect borders. As the Netherlands lies on the delta of several rivers, a large part of its water comes from other countries.

The greater part of the total quantity of nitrogen in the Dutch freshwater system originates from outside the country. Around 65% found in the Netherlands' freshwaters originates from abroad (Stroomgebiedbeheerplannen, 2009). The remainder in the Dutch water system originates from various other sources (Table 6.1).

Leaching and run-off are the leading domestic sources of both nitrogen (61%; Figure 6.1) and phosphorus (56%; Table 6.2). Their relative contributions have increased over time, mainly because the contributions from other sources, such as directly from agriculture, have decreased more steeply (Tables 6.1 and 6.2). In the case of nitrogen, between 89% and 94% of leaching and run-off amounts originate from farmlands. For phosphorus, the figure is between 92% and 94%. The ratio of nitrogen leaching to nitrogen run-off per ha from agriculture and natural sources varied between 1.6 and 2.8 in the period 1986-2000 (Schoumans et al., 2008). In the case of phosphorus, the ratio bracket was higher (1.8-7.8). The variations between soil types and between groups of groundwater steps were also significantly greater, with the reservation that the ratio for natural wetlands might be too low (Schoumans et al., 2008).

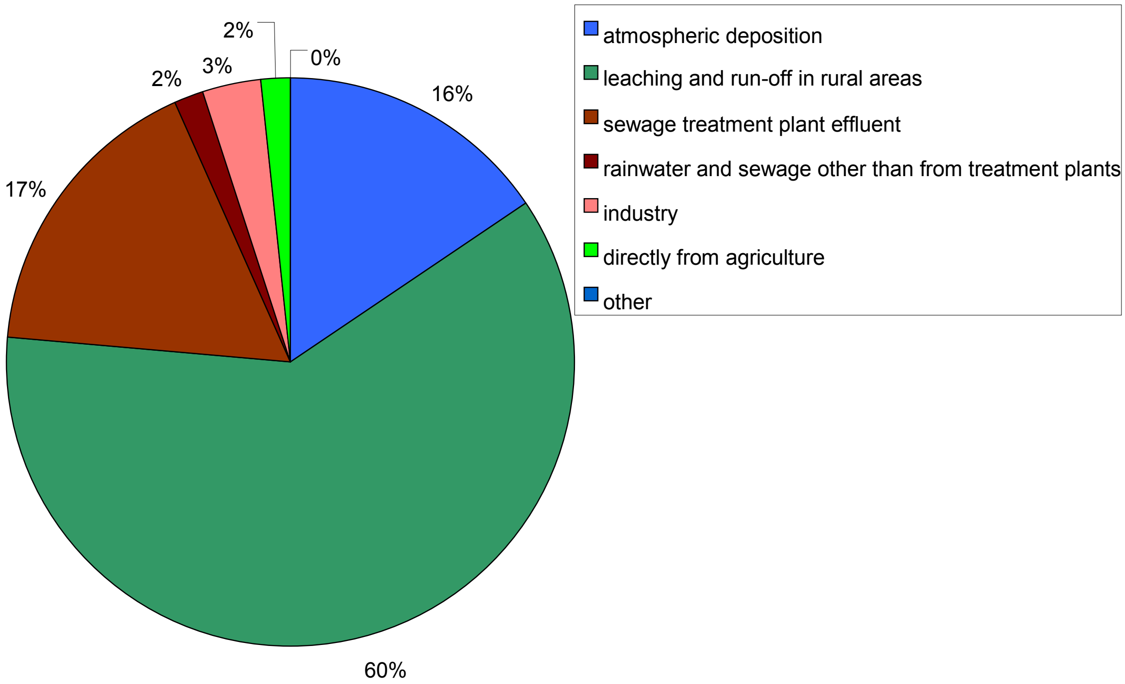



*Figure 6.1. Percentages of different sources of the nitrogen load on surface water in 2009.*
*Source: Pollutant Release and Transfer Register, 2012.*

For a detailed description of the different sources and an inventory of the quantities originating from abroad, refer to the various river basin management plans (SGBP, 2009).

*Table 6.1. Surface water nitrogen load from domestic sources (kg million).*

| Origin | 1990 | 1995 | 2000 | 2005 | 2008 | 2009 |
|---|---|---|---|---|---|---|
| Atmospheric deposition[1] | 24 | 20 | 17 | 16 | 15 | 14 |
| Leaching and run-off in rural areas | 55 | 83 | 83 | 43 | 54 | 54 |
| Sewage treatment plant effluent | 39 | 36 | 29 | 22 | 17 | 15 |
| Rainwater and sewage other than from treatment plants[2] | 5 | 4 | 3 | 2 | 2 | 1 |
| Industry | 13 | 7 | 5 | 4 | 3 | 3 |
| Directly from agriculture[3] | 6 | 5 | 2 | 2 | 1 | 1 |
| Other | 0.06 | 0.06 | 0.05 | 0.06 | 0.05 | 0.05 |
| Total | 143 | 154 | 138 | 89 | 92 | 89 |

1 Atmospheric deposition relates to fresh water and marine surface up to one mile from the coastal zone.
2 Sewage other than from treatment plants relates to overflowing, rainwater gullies, discharge from private wastewater treatment systems, and households not connected to sewer systems.
3 Directly from agriculture relates to greenhouse nurseries and unintended fertilisation of ditches.

*Source: Pollutant Release and Transfer Register, 2012 (new data not available until after 1 June).*

*Table 6.2. Surface water phosphorus load from domestic sources (kg million).*

| Origin | 1990 | 1995 | 2000 | 2005 | 2008 | 2009 |
|---|---|---|---|---|---|---|
| Leaching and run-off in rural areas | 2.75 | 3.78 | 4.26 | 3.02 | 3.51 | 3.51 |
| Sewage treatment plant effluent | 6.24 | 3.53 | 2.85 | 2.65 | 2.55 | 2.30 |
| Rainwater and sewage other than from treatment plants[1] | 0.63 | 0.42 | 0.27 | 0.19 | 0.11 | 0.11 |
| Industry | 10.99 | 3.47 | 1.87 | 0.38 | 0.36 | 0.24 |
| Directly from agriculture[2] | 0.50 | 0.33 | 0.15 | 0.12 | 0.06 | 0.06 |
| Other | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Total | 21.11 | 11.54 | 9.40 | 6.36 | 6.60 | 6.23 |

1 Rainwater and sewage other than from treatment plants relates to overflowing, rainwater gullies, discharge from private wastewater treatment systems, and households not connected to sewer systems.
2 Directly from agriculture relates to greenhouse nurseries and unintended fertilisation of ditches.

*Source: Pollutant Release and Transfer Register, 2012 (new data not available until after 1 June).*

For smaller water bodies, such as regional waters, the nitrogen content originates almost entirely from domestic sources. For larger water bodies, such as the major rivers, the greater part of the nitrogen content originates from foreign sources. The reduction in nitrogen emissions in other countries will mainly affect the nitrogen concentration in these water bodies.

It is necessary to conclude agreements with neighbouring countries to reduce the foreign emissions in the Dutch water system. Such agreements are already part of the river basin management plans, developed in accordance with the Water Framework Directive (first planning period), and will be updated in the second planning period (SGBP, 2009 and Note in Reply, 2009). The progress with measures within the Netherlands to reduce the nitrogen concentration is also set out in Water in Beeld, 2011.

## 6.3 Nitrate concentration in fresh water

### *6.3.1 Nitrate concentration – winter average*

In winter, the majority of freshwater sites (all waters) had an average nitrate concentration below the EU standard of 50 mg/l (Table 6.3 andMap 6.1). Comparing the first period with subsequent ones shows that the number of sites with an average greater than 50 mg/l was decreasing (Table 6.3). A comparison of the two latest periods shows that the nitrate concentration had stopped changing.

Water bodies where the EU standard of 50 mg/l was exceeded in winter during the latest period (2008-2010) are in Oost-Brabant, the southern part of Limburg, Westland, and the eastern part of the Netherlands (Map 6.1). A similar situation occurred in the preceding period (2004-2007; Zwart et al., 2008). During that period, however, water bodies in Oost-Brabant did not exceed the EU standard, unlike in West-Brabant, where this was the case. In the period 2008-2010, all sites in West-Brabant and Zeeland had a concentration less than 50 mg/l. Low concentrations were found during the latest period, in the area south of Friesland for example.

*Table 6.3. Nitrate concentration (winter average) in fresh surface waters in different periods (%).*

| | All waters | | | Waters strongly affected by agriculture | | |
|---|---|---|---|---|---|---|
| Concentration | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0-2 mg/l | 2 | 5 | 6 | 0 | 6 | 8 |
| 2-10 mg/l | 20 | 40 | 46 | 28 | 42 | 45 |
| 10-25 mg/l | 50 | 39 | 36 | 44 | 37 | 33 |
| 25-40 mg/l | 17 | 12 | 9 | 13 | 8 | 10 |
| 40-50 mg/l | 5 | 2 | 1 | 5 | 3 | 1 |
| >50 mg/l | 7 | 2 | 1 | 11 | 3 | 3 |
| Number of sites | 373 | 507 | 468 | 130 | 177 | 144 |

The winter average nitrate concentration remained stable or decreased at approximately 92% of sites (Table 6.4 and Map 6.2). At about 8% of the sites, there was an increase in nitrate concentration. If the first (1992-1995) and fourth (2004-2007) reporting periods are compared, then the winter average nitrate concentration remained stable or decreased at over 90% of sites (Table 6.4). In other words, the situation in the Netherlands was worse in the first period than in subsequent periods. The situation improved significantly in the fourth and fifth reporting periods. This was especially true in West-Brabant, which saw a reduction in the average nitrate concentration in the winter (Map 6.2). According to the previous report (Zwart et al., 2008), there had actually been an increase in average nitrate concentration in this region.

In the two latest periods, no appreciable difference existed between, on the one hand, sites strongly affected by agriculture and, on the other, main locations (Figure 6.2). The average nitrate concentrations in winter were almost halved between the first and fourth periods. Between the two latest periods, no significant change occurred. Something striking, though, is the higher winter average in 2007.

*Table 6.4. Change in nitrate concentration (winter average) in fresh waters in different periods (%).*

| | All waters | | Waters strongly affected by agriculture | |
|---|---|---|---|---|
| Change | 1992/1995-2004/2007 | 2004/2007-2008/2010 | 1992/1995-2004/2007 | 2004/2007-2008/2010 |
| Large increase (> 5 mg/l) | 4 | 2 | 6 | 4 |
| Small increase (1-5 mg/l) | 4 | 6 | 5 | 6 |
| Stable (± 1 mg/l) | 8 | 28 | 11 | 24 |
| Small decrease (1-5 mg/l) | 36 | 48 | 36 | 47 |
| Large decrease (> 5 mg/l) | 48 | 15 | 42 | 19 |
| | | | | |
| Number of sites | 326 | 431 | 118 | 125 |

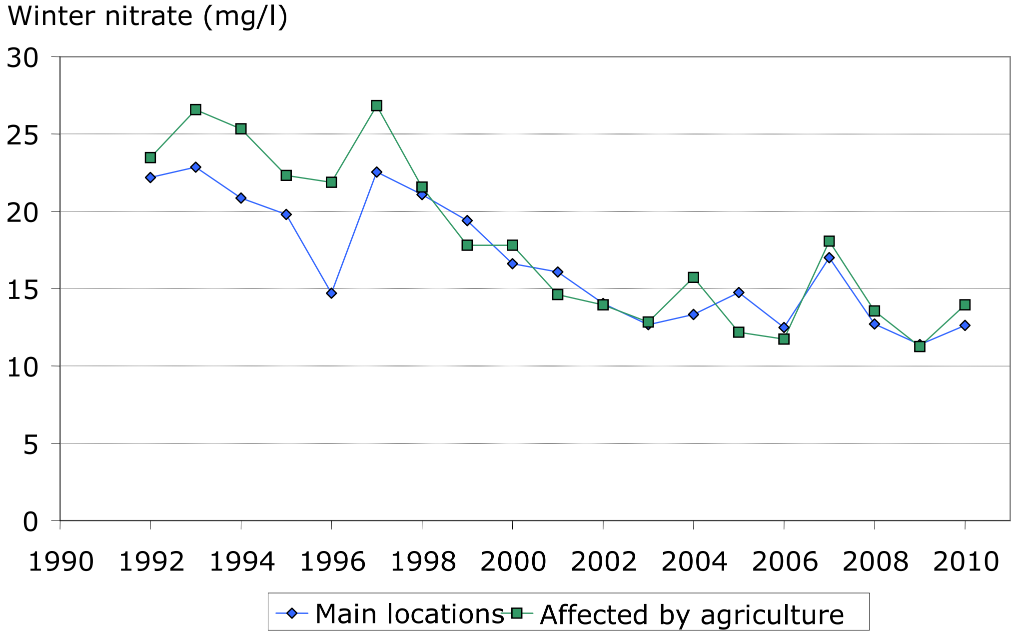



*Figure 6.2. Nitrate concentration (winter average) in fresh surface waters in the period 1992-2010.*

### 6.3.2 *Nitrate concentration – winter maximum*

For the vast majority of sites, the winter maximum nitrate concentration was below the EU standard of 50 mg/l, as shown in Table 6.5 and Map 6.3.

*Table 6.5. Nitrate concentration (winter maximum) in fresh surface waters for different periods (%).*

| Concentration | All waters 1992-1995 | All waters 2004-2007 | All waters 2008-2010 | Waters strongly affected by agriculture 1992-1995 | Waters strongly affected by agriculture 2004-2007 | Waters strongly affected by agriculture 2008-2010 |
|---|---|---|---|---|---|---|
| 0-2 mg/l | 1 | 3 | 3 | 0 | 2 | 1 |
| 2-10 mg/l | 10 | 22 | 28 | 13 | 25 | 30 |
| 10-25 mg/l | 39 | 48 | 43 | 38 | 43 | 42 |
| 25-40 mg/l | 26 | 13 | 15 | 24 | 15 | 13 |
| 40-50 mg/l | 7 | 5 | 5 | 5 | 2 | 6 |
| >50 mg/l | 17 | 10 | 5 | 20 | 12 | 8 |
| Number of sites | 373 | 507 | 468 | 130 | 177 | 144 |

As with winter average concentrations, winter maximum concentrations did not change much between the two latest periods. The largest change occurred between the first and fourth reporting periods, as shown in Table 6.6. The increase between the fourth (2004-2007) and fifth (2007-2010) periods was mainly in the eastern half of the country (Map 6.4).

*Table 6.6. Change in nitrate concentration (winter maximum) in fresh waters for different periods (%).*

| Change | All waters 1992/1995-2004/2007 | All waters 2004/2007-2008/2010 | Waters strongly affected by agriculture 1992/1995-2004/2007 | Waters strongly affected by agriculture 2004/2007-2008/2010 |
|---|---|---|---|---|
| Large increase (> 5 mg/l) | 9 | 5 | 18 | 6 |
| Small increase (1-5 mg/l) | 6 | 10 | 7 | 10 |
| Stable (± 1 mg/l) | 12 | 23 | 9 | 15 |
| Small decrease (1-5 mg/l) | 24 | 36 | 20 | 34 |
| Large decrease (> 5 mg/l) | 49 | 26 | 46 | 35 |
| Number of sites | 336 | 431 | 120 | 125 |

### 6.3.3 *Nitrate concentration – annual average*

As stated in the introduction, the annual average and the winter average nitrate concentration are both presented in this section.

It is explained in section 6.1 that nitrate sometimes disappears in the summer months owing to it being absorbed by algae. The average concentration in winter is therefore a better indicator of the nitrate concentration at different sites, a standpoint confirmed by comparing the results in Table 6.7 with those in Table 6.3.

*Table 6.7. Nitrate concentration (annual average) in fresh waters for different periods (%).*

| | All waters | | | Waters strongly affected by agriculture | | |
|---|---|---|---|---|---|---|
| Concentration | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0-2 mg/l | 3 | 9 | 11 | 3 | 8 | 14 |
| 2-10 mg/l | 33 | 52 | 55 | 44 | 59 | 54 |
| 10-25 mg/l | 46 | 31 | 29 | 34 | 23 | 24 |
| 25-40 mg/l | 9 | 5 | 4 | 5 | 4 | 5 |
| 40-50 mg/l | 4 | 1 | 0 | 4 | 1 | 1 |
| >50 mg/l | 5 | 2 | 1 | 10 | 4 | 2 |
| Number of sites | 374 | 511 | 472 | 128 | 178 | 147 |

Most sites had an annual average nitrate concentration of between 2-10 mg/l, which differs from the winter average concentrations. For all waters, 55% had an annual average nitrate concentration between 2 and 10 mg/l, as opposed to 46% if winter average concentrations are considered. For sites strongly affected by agriculture, the percentages are 54% and 45%, respectively.

## 6.4 Eutrophication of freshwater

### *6.4.1 Chlorophyll-a*

Eutrophication is defined in this section using the average chlorophyll-a concentration in the summer. However, the occurrence of eutrophication in the form of chlorophyll-a is not determined solely by nitrate concentrations in surface waters. Other nutrients, such as phosphorus, and physical and meteorological conditions, also play a role. Chlorophyll-a is related to the quantity of algae present in surface water and therefore the chlorophyll-a concentration is also an indicator of the degree of surface water eutrophication. According to proposed nutrient standards for ecological status (STOWA, 2007), the strictest standard will apply to moderately deep buffered lakes (water type M20), with a concentration of 10 µg chlorophyll-a/l as the line between the scores “adequate” and “good”. Higher cut-off scores apply to other water types (STOWA, 2007).

The chlorophyll-a concentration decreased between the first and fourth reporting periods (Tables 6.8 and 6.9). At sites affected by agriculture, the reduction was less pronounced. After that, the situation was virtually stable as regards the fourth and fifth reporting periods.

*Table 6.8. Chlorophyll-a concentration (summer average) in fresh waters in different periods (%).*

| | All waters | | | Waters strongly affected by agriculture | | |
|---|---|---|---|---|---|---|
| Concentration | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0-2.5 µg/l | 2 | 1 | 0 | 3 | 0 | 0 |
| 2.5-8 µg/l | 6 | 10 | 9 | 9 | 11 | 3 |
| 8.0-25 µg/l | 32 | 41 | 47 | 28 | 39 | 46 |
| 25-75 µg/l | 36 | 37 | 32 | 27 | 34 | 30 |
| >75 µg/l | 24 | 11 | 13 | 32 | 16 | 21 |
| Number of sites | 235 | 356 | 351 | 74 | 110 | 102 |

*Table 6.9. Change in chlorophyll-a concentration (summer average) in fresh waters in different periods (%).*

| | All waters | | Waters strongly affected by agriculture | |
|---|---|---|---|---|
| Change | 1992/1995-2004/2007 | 2004/2007-2008/2010 | 1992/1995-2004/2007 | 2004/2007-2008/2010 |
| Large increase (> 10 µg/l) | 11 | 18 | 19 | 26 |
| Small increase (5-10 µg/l) | 5 | 10 | 8 | 13 |
| Stable (± 5 µg/l) | 25 | 37 | 31 | 34 |
| Small decrease (5-10 µg/l) | 12 | 13 | 4 | 5 |
| Large decrease (> 10 µg/l) | 47 | 22 | 38 | 22 |
| Number of sites | 193 | 294 | 52 | 82 |

The largest decrease in chlorophyll-a concentration occurred between the first and fourth periods (59%), after which the largest group of sites (37%) was stable. At the same time, the number of sites that showed an increase was approximately the same as those that showed a decrease in chlorophyll-a concentration (about 28% and 35% respectively; Table 6.9).

A decline in chlorophyll-a concentration occurred over the years (Figure 6.3). Sites strongly affected by agriculture show the same trend as other sites, although the concentrations at the former are slightly higher and fluctuate more strongly from year to year.

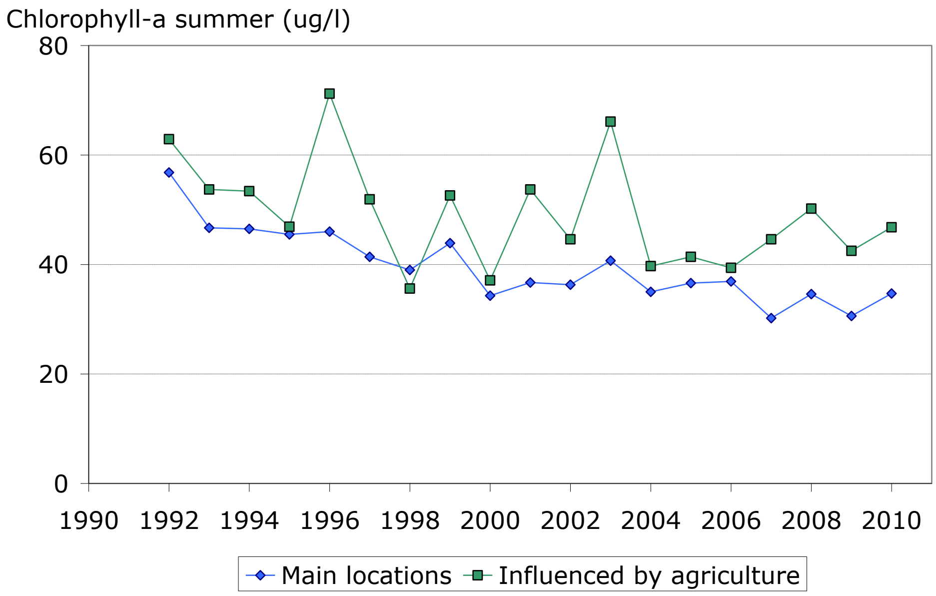



*Figure 6.3. Chlorophyll-a concentration (summer average) in fresh waters in the Netherlands in the period 1992-2010.*

### 6.4.2 *Other parameters indicating eutrophication*

Similar to chlorophyll-a in surface waters, the average of total nitrogen concentrations (Tables 6.10a and b, and Figure 6.4) in the summer and that of total phosphorus concentrations (Tables 6.11a and b, and Figure 6.5) show a falling trend over the years. In the Netherlands, separate standards for different water types have been derived for the summer average of total nitrogen (STOWA, 2007). Generally speaking, some 40% of Netherlands' waters met the relevant standard (State budget, 2011).

*Table 6.10a. Total nitrogen concentration (summer average) in different periods (%).*

| | All waters | | | Waters strongly affected by agriculture | | |
|---|---|---|---|---|---|---|
| Concentration | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| 0-2 mg/l | 5 | 23 | 27 | 4 | 23 | 29 |
| 2-5 mg/l | 64 | 61 | 59 | 65 | 59 | 52 |
| 5-7 mg/l | 12 | 9 | 9 | 10 | 7 | 10 |
| >7 mg/l | 19 | 8 | 5 | 21 | 11 | 9 |
| Number of sites | 350 | 510 | 422 | 113 | 177 | 157 |

For total nitrogen, the same situation existed as for chlorophyll-a (previous section), though less pronounced. Total nitrogen concentration in the summer showed a steep decline between the first and fourth periods, in common with all the other parameters discussed in this section.

*Table 6.10b. Change in total nitrogen concentration (summer average) in fresh waters between different periods (%).*

| Change | All waters | | Waters strongly affected by agriculture | |
|---|---|---|---|---|
| | 1992/1995-2004/2007 | 2004/2007-2008/2010 | 1992/1995-2004/2007 | 2004/2007-2008/2010 |
| Large increase (> 0.5 mg/l) | 9 | 6 | 13 | 7 |
| Small increase (0.25-0.50 mg/l) | 3 | 7 | 6 | 11 |
| Stable (± 0.25 mg/l) | 8 | 39 | 5 | 34 |
| Small decrease (0.25-0.50 mg/l) | 6 | 18 | 1 | 18 |
| Large decrease (> 0.5 mg/l) | 74 | 30 | 74 | 31 |
| Number of sites | 350 | 370 | 113 | 131 |

*Table 6.11a. Total phosphorus concentration (summer average) in different periods (%).*

| Concentration | All waters | | | Waters strongly affected by agriculture | | |
|---|---|---|---|---|---|---|
| | 1992-1995 | 2004-2007 | 2008-2010 | 1992-1995 | 2004-2007 | 2008-2010 |
| <0.05 mg/l | 0 | 4 | 2 | 0 | 2 | 2 |
| 0.05-0.10 mg/l | 8 | 15 | 21 | 15 | 14 | 20 |
| 0.10-0.20 mg/l | 38 | 38 | 33 | 31 | 33 | 25 |
| 0.20-0.50 mg/l | 31 | 24 | 23 | 18 | 14 | 20 |
| >0.50 mg/l | 23 | 20 | 20 | 36 | 37 | 34 |
| Number of sites | 331 | 507 | 503 | 102 | 175 | 179 |

*Table 6.11b. Change in total phosphorus concentration (summer average) between different periods (%).*

| Change | All waters | | Waters strongly affected by agriculture | |
|---|---|---|---|---|
| | 1992/1995-2004/2007 | 2004/2007-2008/2010 | 1992/1995-2004/2007 | 2004/2007-2008/2010 |
| Large increase (> 0.10 mg/l) | 5 | 6 | 11 | 11 |
| Small increase (0.05-0.10 mg/l) | 5 | 6 | 3 | 7 |
| Stable (± 0.05 mg/l) | 35 | 65 | 38 | 50 |
| Small decrease (0.05-0.10 mg/l) | 19 | 10 | 14 | 8 |
| Large decrease (> 0.10 mg/l) | 37 | 13 | 34 | 24 |
| Number of sites | 328 | 459 | 100 | 153 |

Of sites strongly affected by agriculture, there was an increase in average summer total phosphorus concentration at approximately 20% between 2004 and 2010, and a decrease at approximately 32% (Table 6.11b). For all waters, 12% showed an increase and 23 a decrease. In other words, the summer average concentration of total phosphorus decreases more slowly at sites strongly influenced by agriculture than at other sites (Figure 6.5). In the case of sites where the water is strongly affected by agriculture, the summer average concentration is above 0.50 mg/l at 34% of them, whereas for all sites together, the figure is 20% (Table 6.11a). The total phosphorus concentrations given in this report are some 0.2 mg/l higher than those reported in EMW 2012 (Klein et al., 2012b), the cause being a different selection of sites (see section 2.6.2).

Klein et al., (2012a) found there was a significant falling trend in median concentrations (50th percentile) in the period 1990-2010.

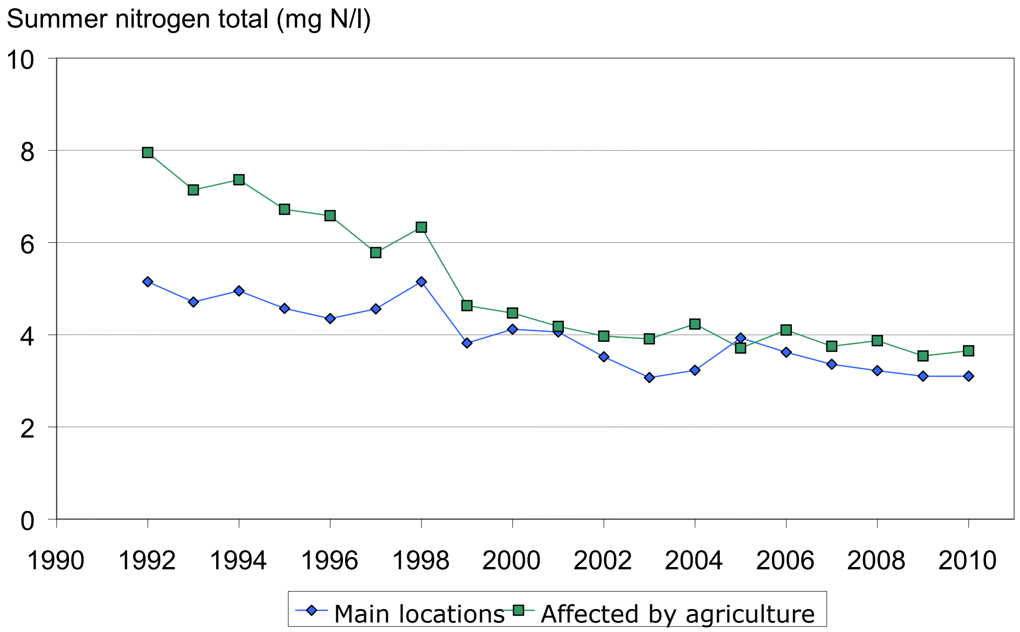



*Figure 6.4. Total nitrogen concentration (summer average) in fresh waters in the period 1992-2010.*

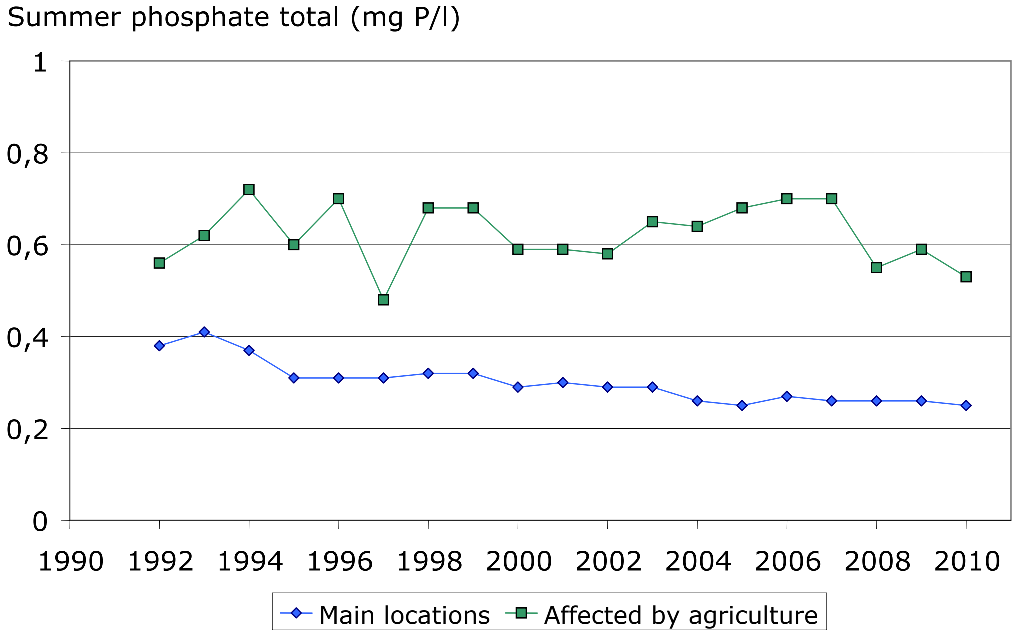



*Figure 6.5. Total phosphorus concentration (summer average) in fresh waters in the period 1992-2010.*

## 6.5 Trends

In general, more than 90% of all sites (main locations and sites strongly affected by agriculture) show a steady decrease in winter average nitrate concentration or a stable pattern for this concentration. This is clear from a comparison of the initial period with subsequent periods. In other words, the situation regarding nitrate in the water system has improved since 1992. The same applies to total phosphorus and chlorophyll-a, although the improvement in the case of the chlorophyll-a concentration is less pronounced.

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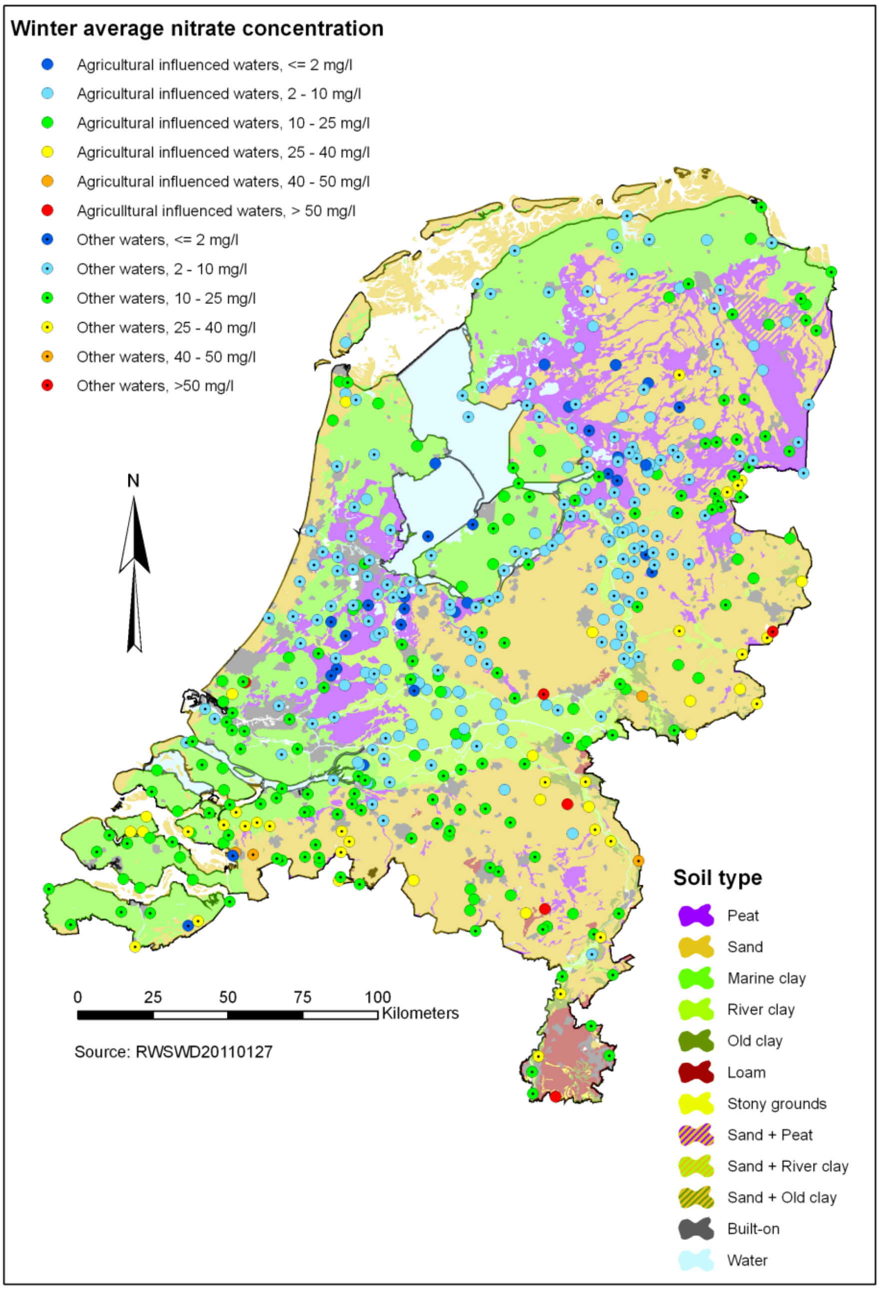
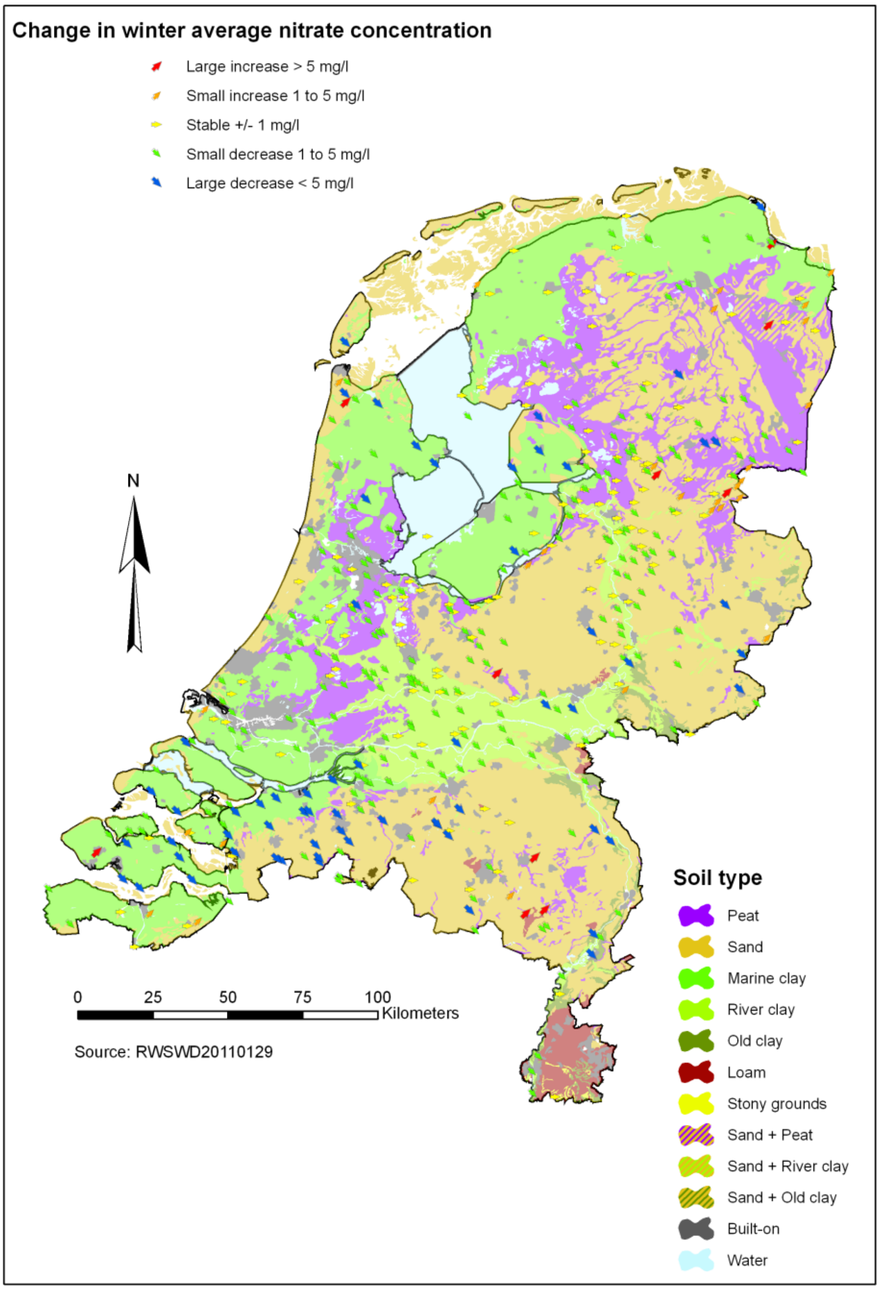
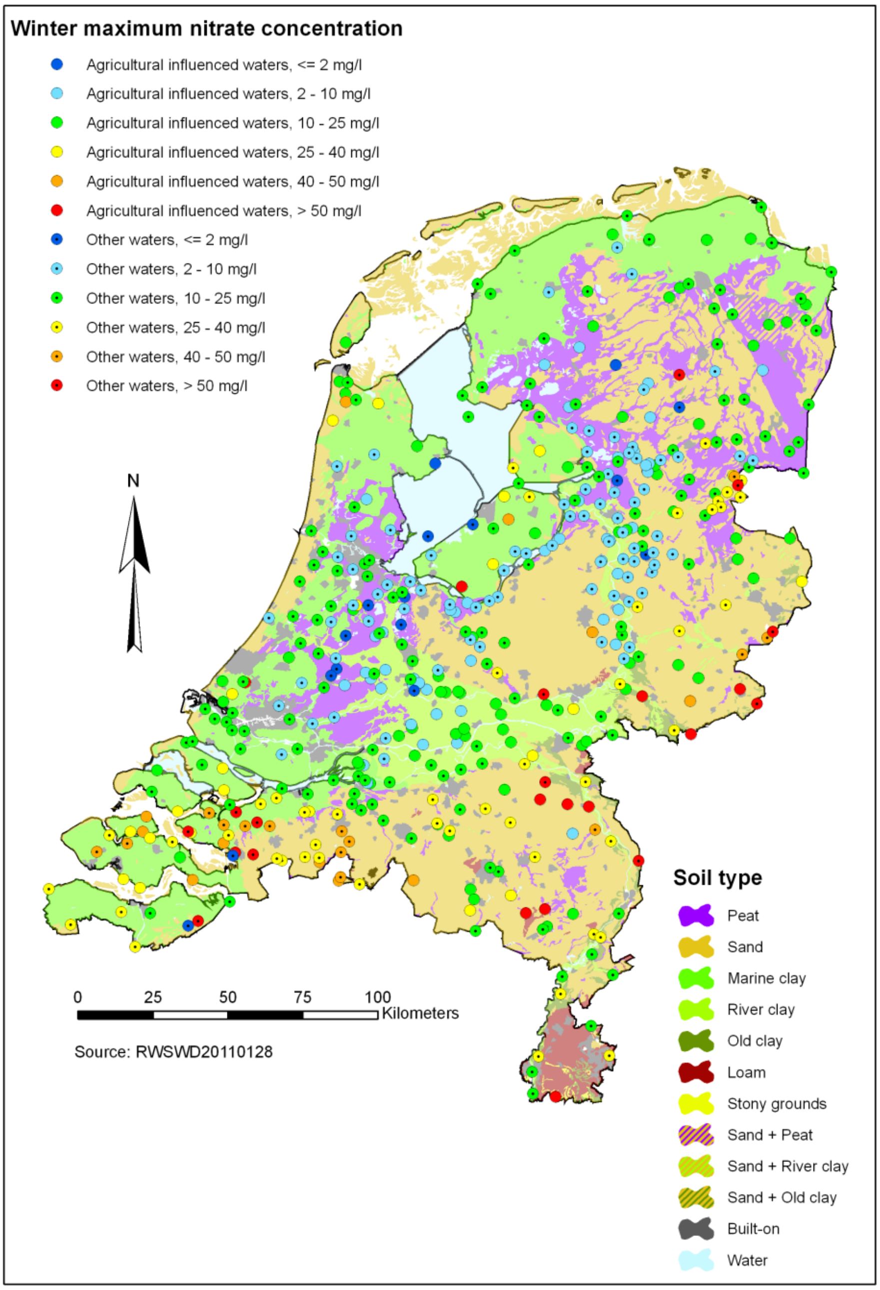


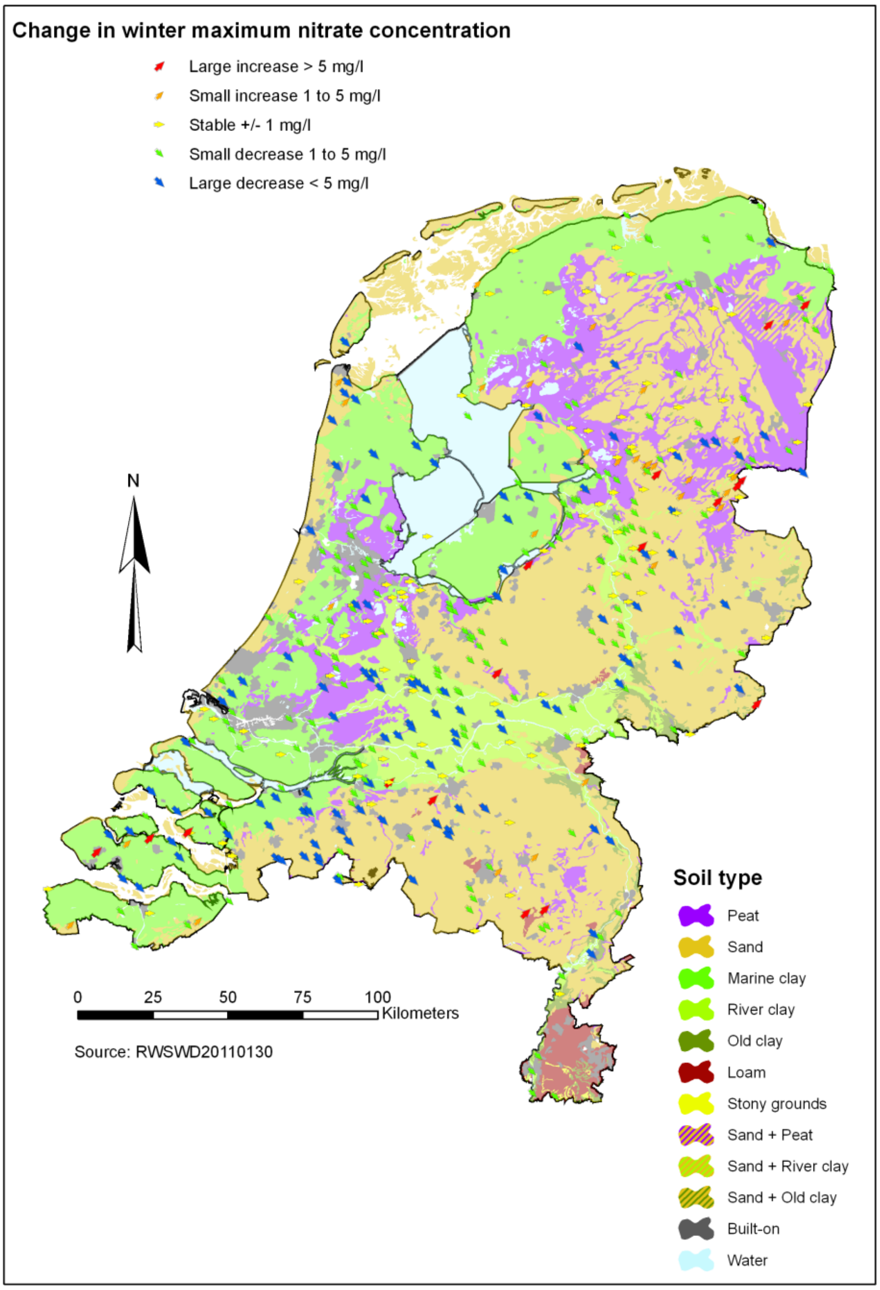

*Map 6.1. Winter average nitrate concentration by monitoring site in the period 2008-2010 (fifth period).*




*Map 6.2. Change in winter average nitrate concentration by monitoring site between the fourth (2004-2007) and fifth (2008-2010) periods.*
*Change shown here is the difference between the averages for the 2004-2007 and 2008-2010 periods.*




*Map 6.3. Winter maximum nitrate concentration by monitoring site in the period 2008-2010 (fifth period).*




*Map 6.4. Change in winter maximum nitrate concentration by monitoring site between the fourth (2004-2007) and fifth (2008-2010) periods.*
*Change shown here is the difference between the averages for the 2004-2007 and 2008-2010 periods.*

# 7 Marine and coastal water quality

## 7.1 Introduction

Chapter 7 discusses the results of the monitoring of nitrogen and phosphorus concentrations in marine surface waters.

The nitrate concentrations in the open sea and in coastal areas are described in section 7.2. The results in this section are based only on winter average concentrations (December to February), as the least biological activity occurs in this period. Accordingly, the nitrate concentrations measured in winter are a better indicator of changes in nutrient emissions than those measured in summer. Extensive studies of trends in inorganic nitrogen concentrations, corrected for saline content (salinity) are considered as well, meaning that the annual differences in output by rivers has been taken into account (section 2.6.3).

Eutrophication of marine waters is dealt with in section 7.3. Trends in eutrophication are presented in the form of changes in summer average and maximum average concentrations of chlorophyll-a.

## 7.2 Nitrate concentration in marine and coastal waters

In this section, winter average nitrate concentrations in marine waters are presented, expressed as milligrams of nitrate per litre. For the graphs, the winter period is defined as the period from 1 December to the last day of February (section 2.6.3).

At over 90% of the monitoring sites in marine and coastal waters during the period 2008-2010, the winter average nitrate concentration was below 10 mg/l, at none of the sites it was above 25 mg/l (Table 7.1). Nitrate concentrations remained stable during the three monitoring periods at all sites in the open sea (Table 7.2). Specifically, at none of the open sea sites was an absolute change measurement of more than 1 mg nitrate/l found. For coastal waters, changes during the two latest monitoring periods were found, however (Table 7.2). The decrease between the fourth and fifth periods is not as significant as that between the first and fourth periods. The nitrate concentration in coastal water is generally stable.

*Table 7.1. Winter average nitrate concentration in marine waters in the period 1992-2010 (%)[1].*

| Concentration | 1992-1995 | 2004-2007 | 2008-2010 |
|---|---|---|---|
| 0-10 mg/l | 87 | 95 | 92 |
| 10-25 mg/l | 13 | 5 | 8 |
| 25-40 mg/l | 0 | 0 | 0 |
| 40-50 mg/l | 0 | 0 | 0 |
| >50 mg/l | 0 | 0 | 0 |
| | | | |
| Number of sites | 39 | 40 | 39 |

[1] Percentage of monitoring sites with a winter average in a given concentration range.

*Table 7.2. Change in winter average nitrate concentration in marine waters in the period 1992-2010 (%)[1].*

| Change | Open sea | | Coastal water | |
|---|---|---|---|---|
| | 1992/1995-2004/2007 | 2004/2007-2008/2010 | 1992/1995-2004/2007 | 2004/2007-2008/2010 |
| Large increase (> 5 mg/l) | 0 | 0 | 0 | 0 |
| Small increase (1-5 mg/l) | 0 | 0 | 3 | 6 |
| Stable (± 1 mg/l) | 100 | 100 | 72 | 88 |
| Small decrease (1-5 mg/l) | 0 | 0 | 25 | 6 |
| Large decrease (> 5 mg/l) | 0 | 0 | 0 | 0 |
| Number of sites | 7 | 7 | 32 | 32 |

[1] Percentage of sites with a given change in concentration between the stated periods.

The winter average nitrate concentrations in coastal zones have decreased slightly over the past seven years, apart from the steep drop in the period 1995-1996 (Figure 7.1). In recent years, the average has fluctuated between 3 and 6 mg nitrate/l. Concentrations in open sea remained virtually stable at far lower concentrations (< 0.5 mg/l). The lower nitrate concentration in coastal water in 1996 was a result of limited precipitation in preceding years. Apart from the fall in 1996, the temporary increases in 2007 and 2008 also stood out.

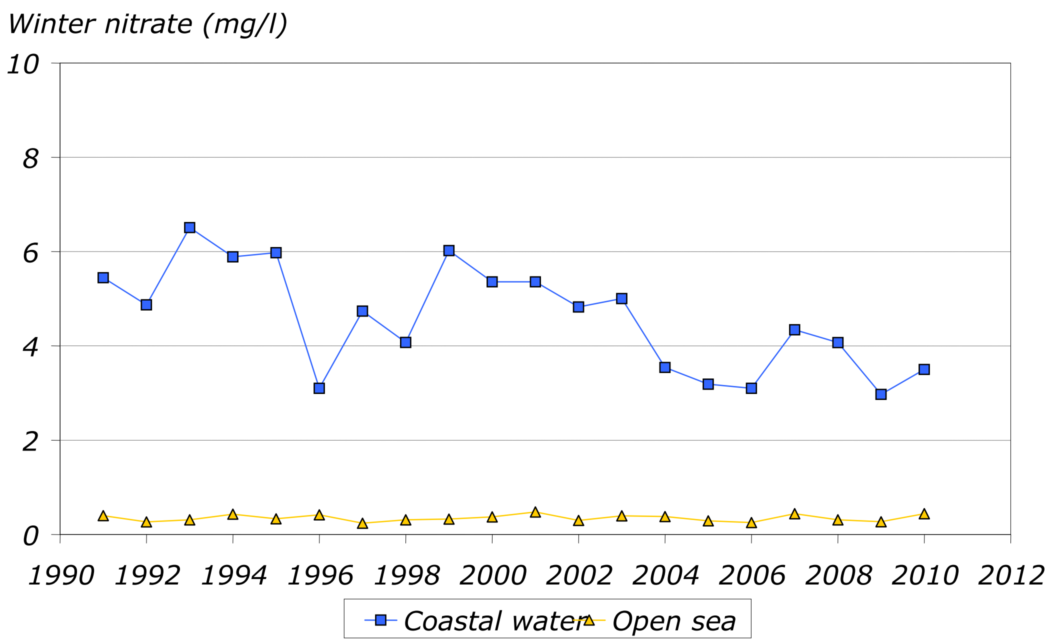



*Figure 7.1. Winter average nitrate concentration (mg/l) in open sea and Dutch coastal waters in the period 1991-2010.*

In the period 2008-2010, the winter average nitrate concentrations in open sea and Dutch coastal waters were almost everywhere below 10 mg/l (Map 7.1). They were only above this level in the Western Scheldt and the Eems-Dollard estuary. In open sea, the concentrations were less than 2 mg/l.

Compared with the period 2004-2007, from 2008 to 2010 there was a clearly discernible increase in winter average nitrate concentration in the Eems-Dollard estuary, and a decrease in the Western Scheldt (Map 7.2). At all other sites, concentrations remained essentially stable.

For the vast majority of sites, the maximum nitrate concentrations found ranged from 0 to 10 mg/l (Table 7.3). It seems that the number of sites with the lowest nitrate concentrations showed an increase between the first and second half of the 1990s.

*Table 7.3. Winter maximum nitrate concentration in marine waters for the period 1992-2010 (%)[1].*

| Concentration | 1992-1995 | 2004-2007 | 2008-2010 |
|---|---|---|---|
| 0-10 mg/l | 81 | 90 | 90 |
| 10-25 mg/l | 17 | 10 | 10 |
| 25-40 mg/l | 2 | 0 | 0 |
| 40-50 mg/l | 0 | 0 | 0 |
| > 50 mg/l | 0 | 0 | 0 |
| | | | |
| Number of sites | 39 | 40 | 39 |

[1] Percentage of monitoring sites with a maximum concentration in a given range. The total percentage could exceed 100 because of rounding.

Table 7.4 shows the percentages of monitored sites where an increasing, decreasing or stable winter maximum nitrate concentration was found. As in the previous section, only monitoring sites showing an absolute change of at least 1 mg of nitrate per litre were classified as having either an increasing or a decreasing concentration. Similar to the winter average nitrate concentrations (Table 7.2), all monitoring sites in open sea showed nitrate concentrations that remained stable during the reporting periods. The maximum nitrate concentration in coastal waters remained generally stable, with 16% of sites showing a decrease, and 6% an increase.

Figure 7.2 gives the trend in average winter maximum nitrate concentrations in open sea and coastal waters between 1991 and 2010. Apart from the drop in concentrations during the period 1996-1997, the graph shows that the winter maximum average in coastal zones fluctuated between 4 and 8 mg nitrate per litre, whereas concentrations in open sea remained fairly stable at significantly lower concentrations (< 0.5 mg/l). The text accompanying Figure 7.1 above explains why the maximum nitrate concentration was lower in 1996. For the maximum concentration, too, the increases in 2007 and 2008 are striking.

Map 7.3 shows the differences in winter maximum nitrate concentrations between open sea and Dutch coastal waters for the period 2008-2010. In the Western Scheldt and the Eems-Dollard estuary, the winter maximum nitrate concentrations exceeded 10 mg/l. At other sites in coastal areas, concentrations were generally less than 10 mg/l, whereas in open sea, they were below 2 mg/l.

*Table 7.4. Change in winter maximum nitrate concentration in marine waters in the period 1992-2010 (%)[1].*

| Change | Open sea | | Coastal water | |
|---|---|---|---|---|
| | 1992/1995-2004/2007 | 2004/2007-2008/2010 | 1992/1995-2004/2007 | 2004/2007-2008/2010 |
| Large increase (> 5 mg/l) | 0 | 0 | 0 | 0 |
| Small increase (1-5 mg/l) | 0 | 0 | 0 | 6 |
| Stable (± 1 mg/l) | 100 | 100 | 25 | 78 |
| Small decrease (1-5 mg/l) | 0 | 0 | 56 | 16 |
| Large decrease (> 5 mg/l) | 0 | 0 | 19 | 0 |
| Number of sites | 7 | 7 | 32 | 32 |

[1] Percentage of sites with given change in concentration between the reporting periods. The total percentage could exceed 100 because of rounding.

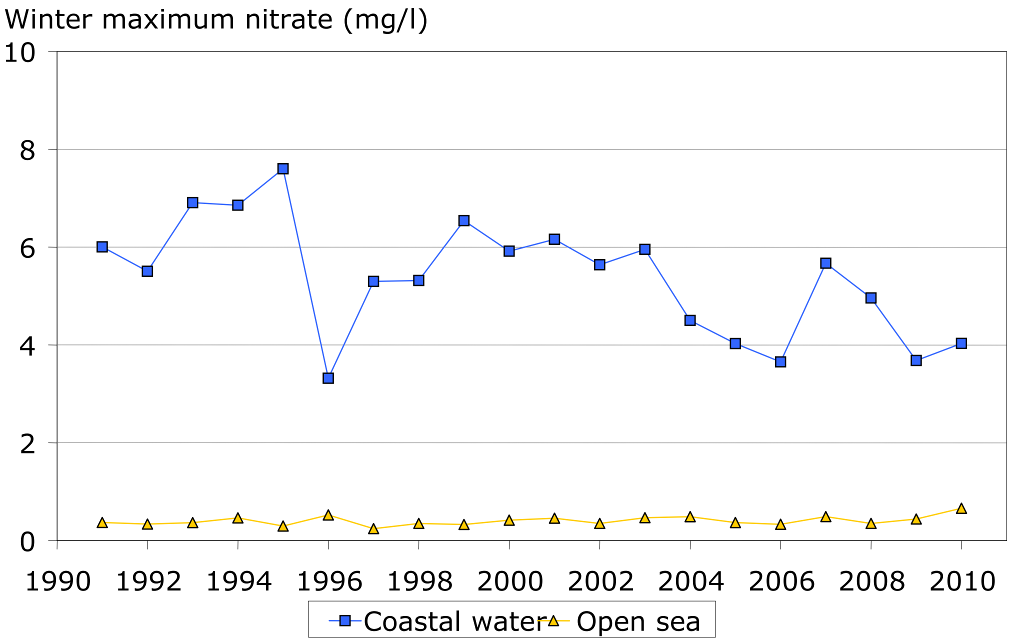



*Figure 7.2. Winter maximum nitrate concentration (mg/l) in open sea and Dutch coastal waters in the period 1991-2010.*

The trends in winter maximum nitrate concentrations at the different sites in the period 2008-2010 are the same as for winter average concentrations. The concentration in open sea remained fairly stable, while lower concentrations were found in estuaries (see Map 7.4).

The concentrations of nutrients in coastal waters are determined by natural background concentrations, direct discharge, and output from rivers. During winter, biological activity is low and inorganic nutrient concentrations remain fairly stable, showing negative linear correlation with salinity. For a long-term analysis of the relationship between changes in nutrient concentration and changes in nutrient emissions, the measured winter nutrient concentrations have to be corrected for changes in salinity at the selected monitoring sites (see section 2.6.3). Salinity is expressed in practical salinity units (PSUs), an international standard based on saline content in grams per litre.

Since 1991, the dissolved inorganic nitrogen concentrations (DINs) have been slowly but surely declining (Figure 7.3). The concentration in 2010 was approximately 30% lower than in 1991 (Figure 7.4). It seems that concentrations have remained stable since 2003.

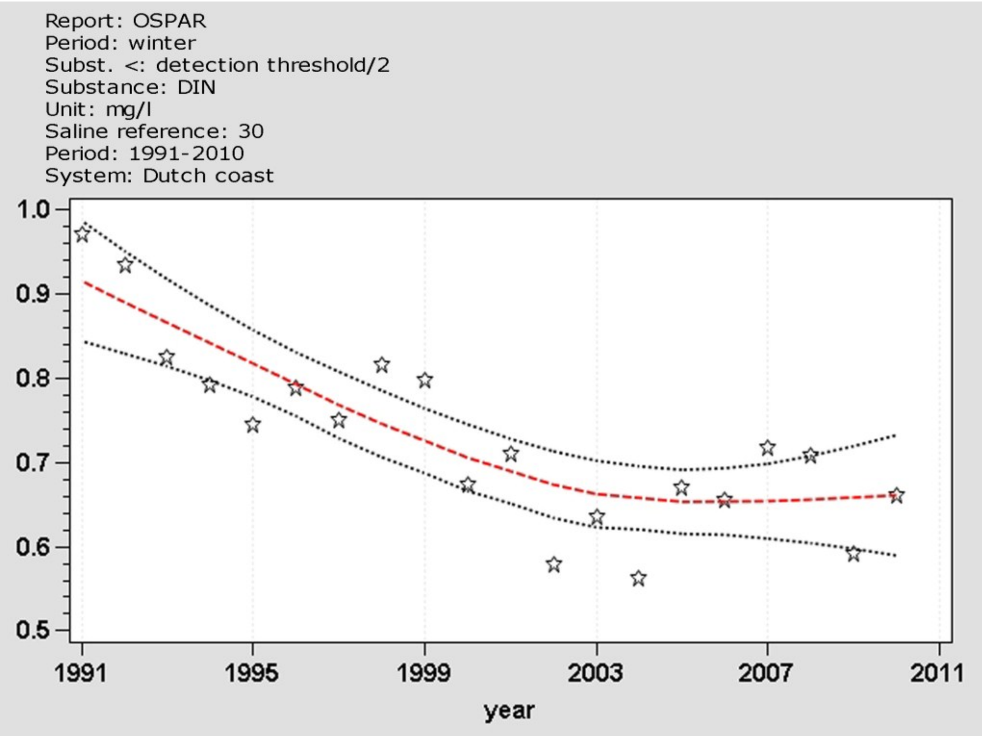



*Figure 7.3. Winter average dissolved inorganic nitrogen concentrations (DIN, mg N/l), standardised to a salinity of 30 PSU, in Dutch coastal waters at Noordwijk in the period 1991-2010. The red line is the smoothed trend line and the dashed lines show the 95% confidence interval for the trend line.*

## 7.3 Eutrophication of marine and coastal waters

Eutrophication is a major topic within OSPAR (Convention for the Protection of the Marine Environment of the Northeast Atlantic). A study of Dutch seawater in 2010 revealed that the entire Netherlands coastal zone and the open sea off the coast formed a problem area in terms of eutrophication (OSPAR, 2010). OSPAR specifically requires that DIN concentrations should be 50% below the 1985 level. This is not the case (OSPAR, 2010), so that action needs to be taken to reduce the nutrient load.

The percentage of sites in marine waters with a summer average chlorophyll-a concentration above 25 µg/l went up slightly in the latest period. Seemingly, this was at the expense of the number of sites with concentrations between 8.0 and 25 µg/l, which had apparently decreased (see Table 7.5). In general, though, conditions in marine waters remained fairly stable. It seems that, for open sea and coastal waters, the summer average chlorophyll concentrations were more or less stable (Table 7.6).

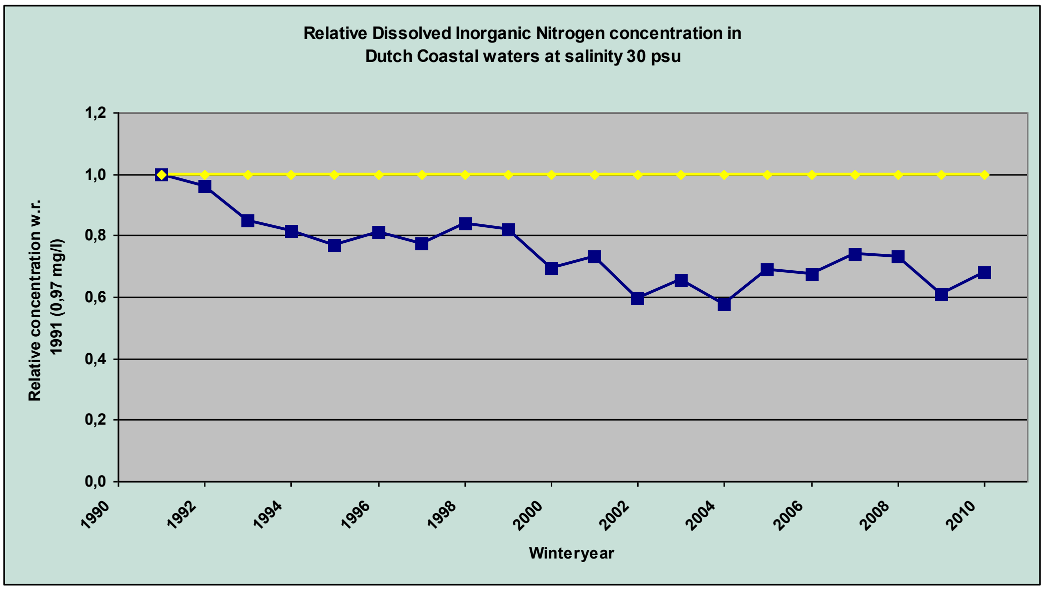



*Figure 7.4. Relative winter dissolved inorganic nitrogen (DIN) concentrations, standardised to a salinity of 30 PSU, in Dutch coastal waters at Noordwijk in the period 1991-2010.*
*DIN concentrations compared to concentration in 1991 (0.97 mg/l is set at 1).*

*Table 7.5. Summer average chlorophyll-a concentration in marine waters in the period 1992-2010 (%)[1].*

| Concentration | 1992-1995 | 2004-2007 | 2008-2010 |
|---|---|---|---|
| 0-2.5 µg/l | 15 | 18 | 21 |
| 2.5-8.0 µg/l | 17 | 32 | 29 |
| 8.0-25 µg/l | 62 | 50 | 44 |
| 25-75 µg/l | 6 | 0 | 6 |
| > 75 µg/l | 0 | 0 | 0 |
| Number of sites | 40 | 34 | 34 |

[1] Percentage of monitoring sites with a period average in a given concentration range. The total percentage could exceed 100 because of rounding.

*Table 7.6. Change in summer average chlorophyll-a concentration in marine waters in the period 1992-2010 (%)[1].*

| Change | Open sea | | Coastal water | |
|---|---|---|---|---|
| | 1992/1995-2004/2007 | 2004/2007-2008/2010 | 1992/1995-2004/2007 | 2004/2007-2008/2010 |
| Large increase (> 10 µg/l) | 0 | 0 | 0 | 0 |
| Small increase (5-10 µg/l) | 0 | 0 | 0 | 7 |
| Stable (± 5 mg/l) | 100 | 100 | 81 | 85 |
| Small decrease (5-10 µg/l) | 0 | 0 | 19 | 7 |
| Large decrease (> 10 µg/l) | 0 | 0 | 0 | 0 |
| Number of sites | 7 | 6 | 27 | 27 |

[1] Percentage of sites with a given change in concentration between reporting periods (1992-1995 and 2004-2007, and 2004-2007 and 2008-2010).

Although chlorophyll-a concentrations appear to have increased during the early 1990s, there seems to have been a decrease in summer average chlorophyll-a concentrations over the past few years (Figure 7.5), with the concentrations fluctuating between 10 and 17 µg/l in coastal water. During the past two years, the concentration in the coastal zone has been below 10 µg/l, while the concentrations in open sea have varied from 1 to 4 µg/l. In both cases, this is lower than OSPAR standards of 15 µg/l and 4.5 µg/l, respectively.

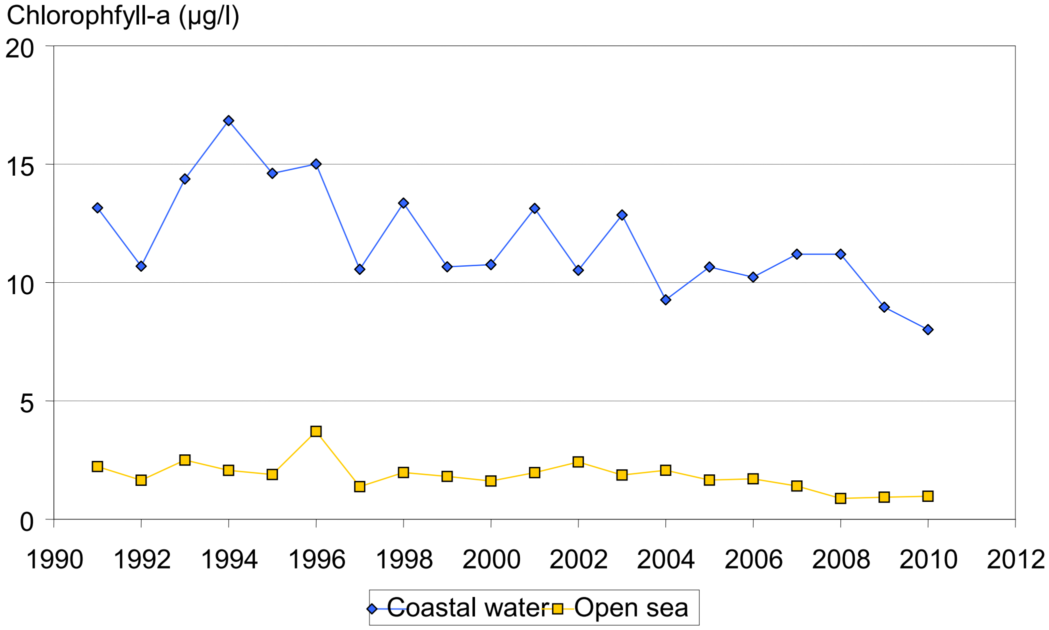



*Figure 7.5. Summer average chlorophyll-a concentration (µg/l) in open sea and Dutch coastal waters in the period 1991-2010.*

## 7.4 Conclusion

The marine waters of the Netherlands are characterised by elevated concentrations of nitrogen and chlorophyll-a. There is a slow but gradual decrease in dissolved inorganic nitrogen concentrations, the concentrations in 2010 being approximately 27% lower than those in 1991. Chlorophyll-a concentrations show a slight decreasing trend in coastal waters and remain stable in open sea.

It is necessary to reduce indirect and direct nutrient emissions further, that is, in order to achieve a healthy marine environment free of eutrophication.

## 7.5 References

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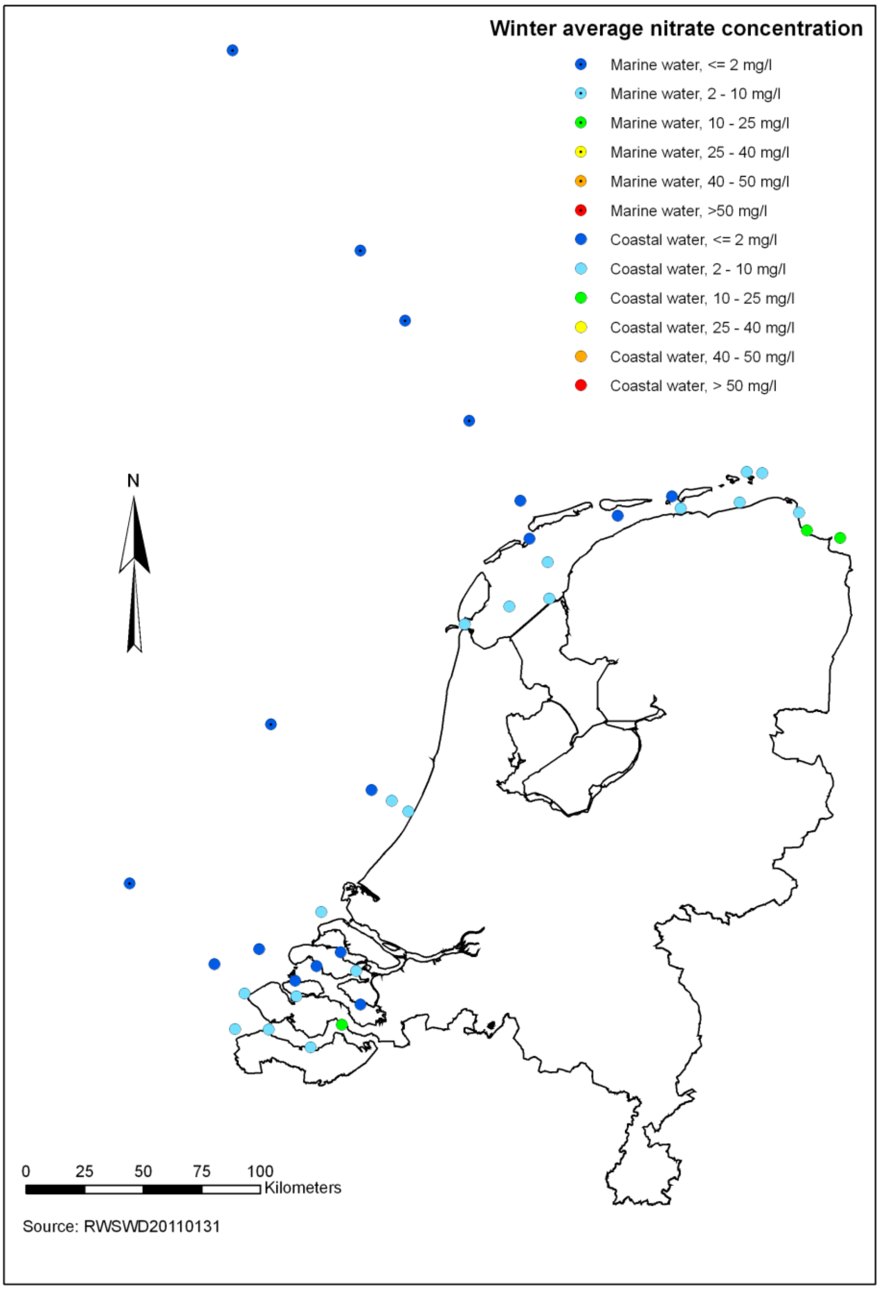
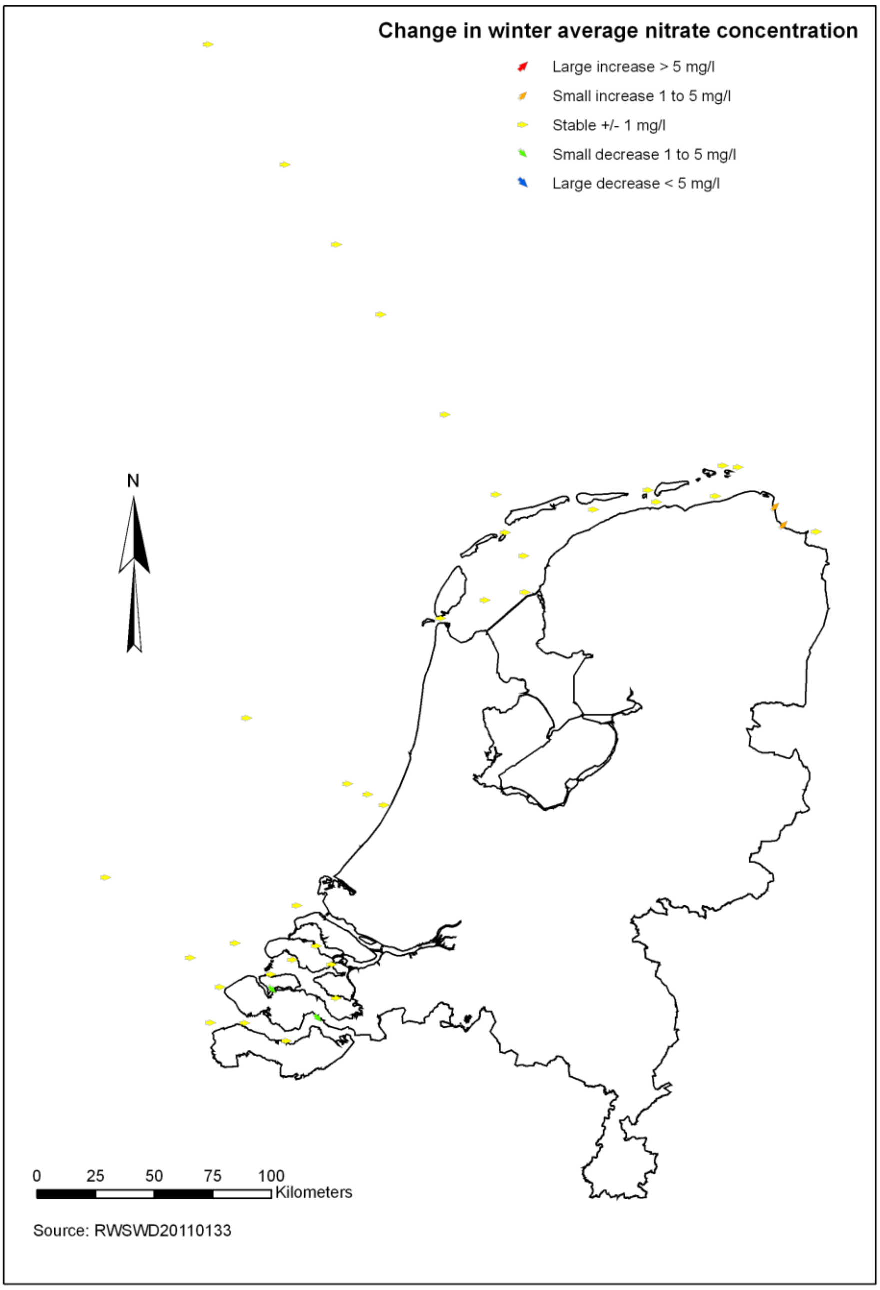
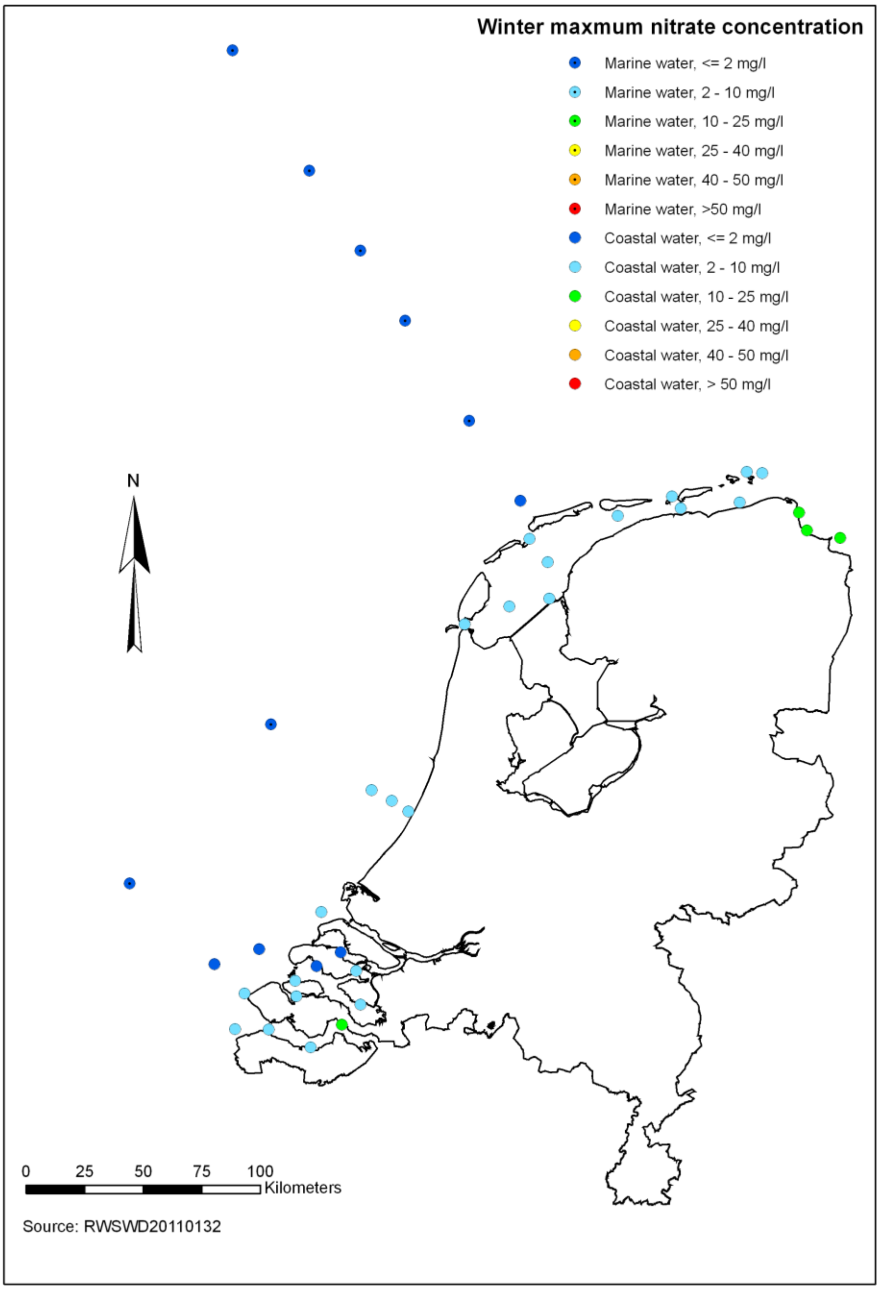


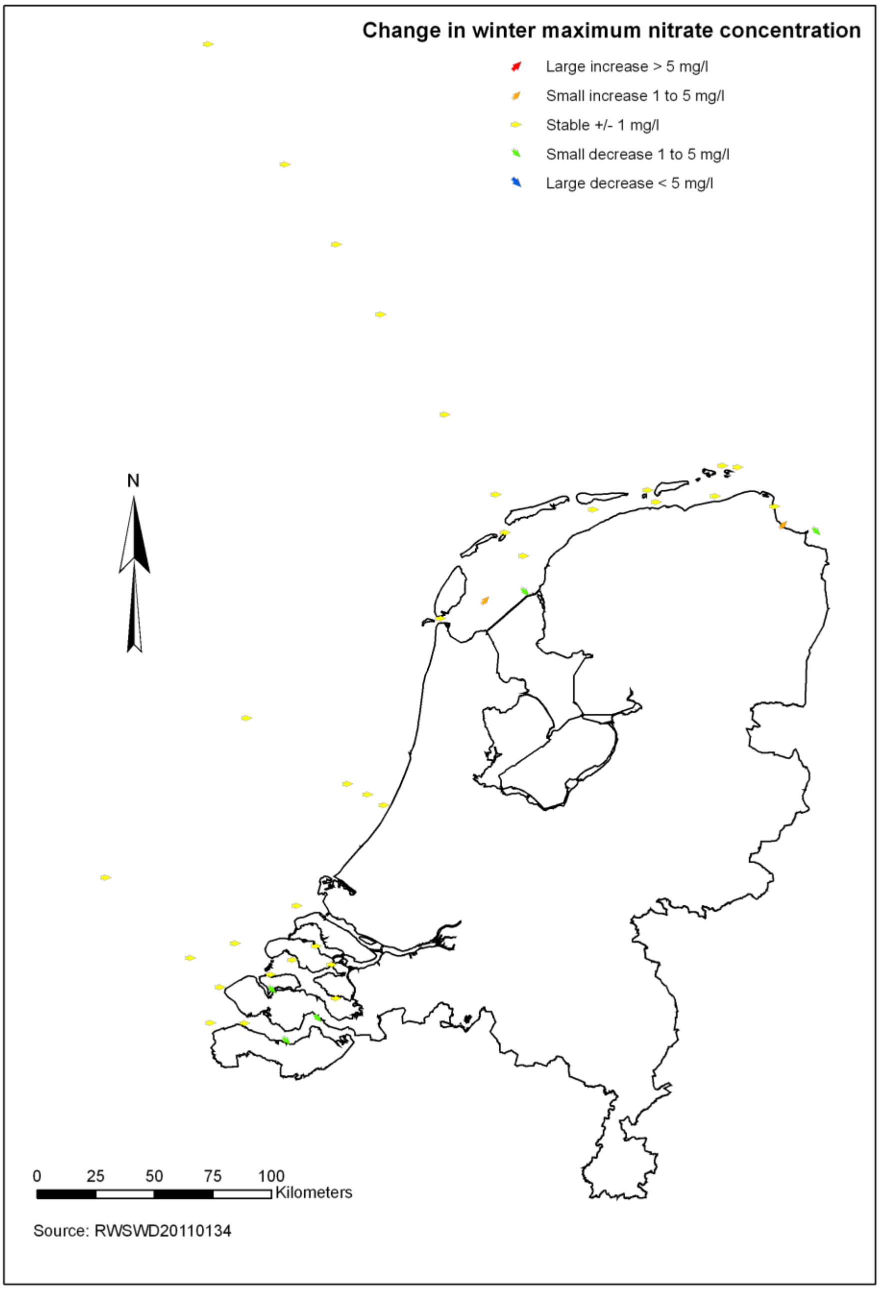

*Map 7.1. Winter average nitrate concentration in Dutch marine and coastal waters in the period 2008-2010.*




*Map 7.2. Change in winter average nitrate concentration in Dutch marine and coastal waters between the fourth (2004-2007) and fifth (2008-2010) periods. Change shown here is the difference between the averages for the 2004-2007 and 2008-2010 periods.*




*Map 7.3. Winter maximum nitrate concentration in Dutch marine and coastal waters in the period 2008-2010.*




*Map 7.4. Change in winter maximum nitrate concentration in Dutch marine and coastal waters between the fourth (2004-2007) and fifth (2008-2010) periods. Change shown here is the difference between the averages for the 2004-2007 and 2008-2010 periods.*

# 8 Future water quality development

## 8.1 Assessment of forecasting possibilities

It is exceptionally difficult to determine the time scale for changes in agricultural practice to result in changes in water quality. Groundwater travel times increase with the depth of the water, and as from a certain depth, these times exhibit enormous variation. Moreover, biological processes (e.g. denitrification and ammonification) and physical processes (e.g. dispersion, diffusion and dilution) lead to differences in water quality over time and from place to place, owing to the wide variety of physico-chemical characteristics of the saturated zones, aquifers and impermeable layers. Regional surface waters receive groundwater from different origins (agriculture, natural and urban areas) and of various ages. They are also fed by rainwater and sometimes waste water from, for example, farms, sewage treatment facilities or even industrial plants.

Travel times of water that leaches from root zones and that was studied under the LMM programmes are estimated to be less than five years (Meinardi and Schotten, 1999; Meinardi et al., 1998a, 1998b). It is therefore assumed that the effects of the fourth Action Programme (2010-2013) on the quality of the upper groundwater will become apparent between 2014 and 2019.

Travel times of groundwater at a depth of 5-15 metres in sand regions are on average 12 years, but range from less than 5 years to over 30 years (Meinardi, 1994). Travel times of groundwater at a depth of 15-30 metres are on average 36 years, but range from less than 25 years to over 80 years (Meinardi, 1994). In clay and peat regions, travel times are usually much longer, as the permeability of clay and peat aquifers is much lower than other types.

It will therefore be at least ten years before the effects of measures on nitrate concentrations in groundwater at a depth of 5-15 metres become apparent. Due to the large differences in travel times at any particular depth, nitrate concentrations will decrease slowly. In areas with confined aquifers and/or aquifers with a high denitrification capacity, nitrate concentrations are already low and will not change.

It will be at least several decades before the effects of measures to combat nitrate leaching at depths lower than 15 metres become apparent. This is certainly true concerning depths lower than 30 metres. Nitrate concentrations will change slowly due to the large variation in travel times at greater depths.

The effects of measures on nitrate concentrations in fresh surface waters strongly affected by agriculture will be discernible fairly quickly compared with their impact on nitrate concentrations in groundwater at a depth of more than 5 metres. Change in quality will probably be comparable to the effects on the upper groundwater of farms. Improvement in the quality of surface water in clay and peat regions will be comparable to that in the water that leaches from the root zones of farms, with the same improvement response as produced by the fourth Action Programme. The contribution of young groundwater (1-5 years old) to surface water in sand regions varies from less than 10% to more than 70%. It is therefore assumed that the effects of measures from the fourth Action Programme (2010-2013) on nitrate concentrations in fresh surface water will become apparent between 2014 and 2019. Because of mixing, it will probably be hard to distinguish the effects of the measures on nitrate concentrations from the effects of natural conditions on them. Examples of the latter are factors such as differences in precipitation.

Forecasting the future development of eutrophication due to agriculture is even more difficult than for nitrate concentrations, the main reasons being:
- the differences in surface waters with regard to their proneness to eutrophication;
- phosphorus concentrations and other factors such as hydromorphology, which also play an important part in the eutrophication process;
- contributions from other sources of nutrient input, such as urban wastewater and cross-border rivers;
- the extreme difficulty with predicting the response times of aquatic ecosystems to a substantial reduction in nutrient inputs and concentrations.

As well as source-oriented measures, regional effect-oriented measures, such as fish stock management, have been taken in situations offering good prospects for restoration and will be implemented further in the future. In some cases, the ecological restoration process was accelerated substantially (for example, the Veluwe border lakes). However, as the chlorophyll measurements reported in the previous sections reveal (Figures 6.3 and 7.5), the ecological restoration process in Dutch surface waters is generally progressing only slowly. An overall, clearly visible acceleration of this process is not expected in the short term.

## 8.2 Future water quality development

The report Evaluation of the Fertilisers Act 2012 (PBL, 2012) and the sub-report with the prognosis for the environment (Groenendijk et al., 2012) use simulation models to assess future development. Figure 8.1 presents the prognosis for the nitrate concentration in the upper metre of groundwater under farmland in sand regions (the most vulnerable). The prognosis includes corrections for variations in weather conditions.

PBL (2012) concludes that, for upper groundwater, tightening the nitrogen application standard for a number of crops, mainly on sandy soil, will lead to an overall reduction in average nitrate concentration from 2010 until the end of 2013. For the sand regions as a whole, the average nitrate concentration is predicted to fall to 50 mg/l (Figure 8.1; corrected results). The calculations also indicate that the nitrate targets for Sand North and Sand Central will easily be reached on average. After correcting for weather conditions, the groundwater quality should improve in Sand South and the loess region to an average of 70 and 60 mg/l respectively. Achieving the nitrate target is not yet in sight, however.

PBL (2012) states that the results from the model are uncertain, however, as they depend heavily on the assumptions for the further input of nitrate, as well as on the impact of weather. Concentrations calculated for the sand regions are slightly higher than the actual measurements. A reliable comparison between measurements and calculations from a model is difficult to make, though. First, not all farm types are monitored in all parts of the Netherlands. Second, land used for highly intensive or extensive farming is not included separately in the model, only the average being factored into the calculations.

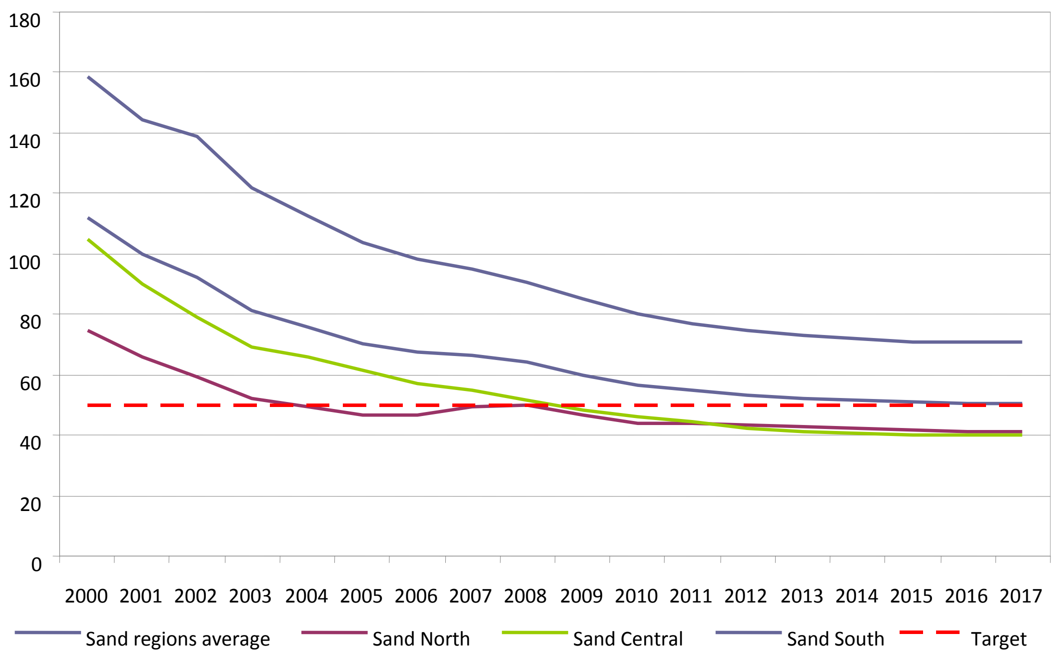



*Figure 8.1. Calculated nitrate concentration in upper groundwater in sand regions, taking into account measures of the fourth Action Programme. Source: PBL (2012) / Alterra (2012).*

Based on the calculated results from the model, the expectation for surface-water load from the run-off and leaching of nutrients is that it will reduce by 4% in the case of nitrogen and 2% in the case of phosphorus, compared with the levels for the 2010 application standards (PBL, 2012).

## 8.3 References

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PBL (2012) Summary report on the Evaluation of the Fertilisers Act 2012. PBL report number 500252.

# Appendix 1. Agricultural areas by sector and region

*Table B1. Agricultural areas (in 1,000 ha) for clay and sand regions by farmland category in LMM for the period 1992-2011.*

| Clay regions | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy | 236 | 237 | 235 | 235 | 233 | 233 | 232 | 233 | 227 | 226 | 229 | 226 | 227 | 227 | 226 | 227 | 234 | 234 | 231 | 242 |
| Arable | 328 | 320 | 312 | 315 | 315 | 312 | 306 | 295 | 297 | 290 | 296 | 292 | 292 | 293 | 284 | 288 | 288 | 291 | 286 | 302 |
| Other | 64 | 71 | 71 | 73 | 73 | 72 | 76 | 81 | 86 | 87 | 94 | 93 | 94 | 94 | 99 | 103 | 102 | 96 | 83 | 85 |

| Sandy regions | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy | 484 | 484 | 479 | 477 | 470 | 470 | 469 | 457 | 445 | 443 | 450 | 447 | 442 | 434 | 427 | 415 | 420 | 425 | 407 | 408 |
| Arable | 130 | 125 | 121 | 126 | 128 | 128 | 129 | 124 | 125 | 117 | 121 | 127 | 131 | 127 | 123 | 120 | 119 | 119 | 116 | 124 |
| Factory farm animals | 44 | 46 | 45 | 45 | 46 | 49 | 48 | 49 | 50 | 49 | 50 | 41 | 43 | 47 | 46 | 50 | 50 | 50 | 65 | 71 |
| Other | 139 | 146 | 147 | 149 | 150 | 156 | 158 | 155 | 167 | 158 | 167 | 157 | 157 | 161 | 166 | 169 | 168 | 157 | 140 | 125 |

*Source: LEI, May census data processed by Statistics Netherlands.*

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