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Report 680716003/2008
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RIVM Report 680716003/2008

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This investigation has been performed by order and for the account of the Ministries of Housing, Spatial Planning and the Environment (VROM), Agriculture, Nature Management and Food Quality (LNV) and Transport, Public Works and Water Management (V&W).

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Abstract

Agricultural practice and water quality in the Netherlands in the 1992-2006 period.

As a result of the European Nitrate Directive, the nitrogen surplus in Dutch agriculture decreased by almost 40 percent between 1992 and 2007. This is one of the conclusions. This report provides a summary of developments in water quality as far as measures taken in Dutch agriculture to improve the quality of groundwater and surface water are concerned.

The nitrate content in groundwater below agricultural land showed a strong decrease during the 1992 to 2007 period, in sandy areas especially, where the average concentration decreased from 140 mg/l to 75 mg/l. Nitrate content also decreased in clay areas, and was well below the standard of 50 mg/l for this period. There has always been very little nitrate present in groundwater in peat regions.

The chlorophyll-a concentration (an indicator for the extent of water eutrophication) in agriculturally-influenced regional surface waters showed a constant decrease following 1992. The average nitrate concentration during the winter period in fresh surface waters has been decreasing since 1998.

Both nitrate content and eutrophication are decreasing. However, it takes several years before the effects of policy measures taken by farmers are seen in the water quality. It is therefore expected that it will be some years before the effects of recent policy measures from the current action programme (2004-2009) are seen in the water quality and that water quality will therefore only show further improvement in the 2010-2015 period.

Key words:
Nitrate Directive, agricultural practice, groundwater and surface water quality

Rapport in het kort

Landbouwpraktijk en waterkwaliteit in Nederland, periode 1992-2006.

Als gevolg van de Europese Nitraatrichtlijn is het stikstofoverschot in de Nederlandse landbouw tussen 1992 en 2007 afgenomen met bijna 40 procent. Dit is een van de conclusies. Dit rapport geeft een overzicht van de ontwikkelingen in de waterkwaliteit ten opzichte van Nederlandse maatregelen in de landbouw om de kwaliteit van het grond- en oppervlaktewater te verbeteren.

Het nitraatgehalte in het grondwater onder landbouwpercelen is in de periode van 1992 tot 2007 sterk gedaald, vooral in de zandregio's. Daar daalde de gemiddelde concentratie van 140 mg/l naar 75 mg/l. Ook in de kleiregio's zijn de gehaltes gedaald en lagen ze in deze periode ruim onder de norm van 50 mg/l. In de veenregio's is altijd weinig nitraat in het grondwater aanwezig geweest.

Sinds 1992 is de chlorofyl-a concentratie (een indicator voor mate waarin het water eutrofieert) in regionale oppervlaktewateren die door de landbouw worden beïnvloed constant gedaald. De gemiddelde nitraatconcentratie in de winterperiode in het zoete oppervlaktewater vertoont een afname sinds 1998.

Zowel nitraatgehaltes in, als de eutrofiëring van het water neemt af. Het duurt echter enkele jaren voordat effecten van beleidsmaatregelen door boeren in de waterkwaliteit waarneembaar zijn. Verwacht wordt dat de effecten van de recente beleidsmaatregelen uit het huidige actieprogramma (2004-2009) pas over een aantal jaren te zien zullen zijn in de waterkwaliteit. Het is daarom te verwachten dat de waterkwaliteit pas in de periode 2010-2015 verder verbeterd.

Trefwoorden / Key words:
Nitraatrichtlijn, landbouwpraktijk, grondwater en oppervlaktewaterkwaliteit

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Summary, synthesis and conclusions

Introduction

This report provides the background information for the Netherlands Member State report, 'Nitrates Directive, status and trends of aquatic environment and agricultural practice', to be submitted to the European Commission in mid-2008. It 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 as a consequence of changes in farm practice. The report deals with the evaluation of the implementation and impact of the measures in the Action Programmes and forecasts the future evolution of water body quality. The period reported is 1992-2006; data for 2007 is also presented whenever available.

The data presented in this background document refers to the period preceding the first Action Programme (before December 1995) as well as the period of the first (1995-1999), second (1999-2003) and, partly, third Action Programme (2004-2009). This third Action Programme has a longer time span due to extended measures following the derogation granted to the Netherlands. New measures were added to the third Action Programme in 2006, dividing the programme into part a and part b.

In general, water quality reacts slowly to changes in agricultural practice. Changes in water quality in the 1992-2002 period were therefore also a result of policy measures and changes in agricultural practice before 1992. In addition, expected improvements in water quality as a consequence of the second Dutch Action Programme are only partly noticeable in this period.

Agricultural policy measures and practice

<u>*Policy measures*</u>

A new system was introduced and developed in the 1998-2003 period. The system of manure bookkeeping was replaced in 1998 by the system of minerals accounting at farm level, based on the mineral balance of nitrogen (N) and phosphorus (P) (farm gate balance). In this system, limits are set on the level of the N and P surplus on farms (MINAS loss standards). The loss standards have gradually been tightened. On 1 January 2002, the Manure Transfer Contracts (MAO) system became effective in order to comply with the application standards for manure stipulated by 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 manure policy based on application standards instead of mineral loss standards. The new manure policy, including application limits for nitrogen in manure and fertilisers as required by the Nitrate Directive, sets tighter limits on the use of nitrogen and phosphorus compared with the previous MINAS. It is not possible to evaluate the effect of this new policy in this report as the effects can only be seen in farm management data from 2006. The period of effectuation has been too short to detect any effects on water quality.

<u>*Agriculture in the 2004-2007 period*</u>

In 2006, the cultivated area in the Netherlands totalled 1.88 million ha, amounting to 55.8% of the total land surface. Of the cultivated area, 52% comprised grassland (79% permanent), 12% silage maize and 30% other arable crops. The remaining area (6.1%) was used for horticulture. There were about 81,700 farms, of which 50% consisted of farms with grazing animals, 15% arable farms, 18% horticultural and 16% pig and poultry and mixed farms.

Livestock included 3.8 million heads of cattle, 11.4 million pigs, 91 million heads of poultry and 1.6 million sheep and goats. The livestock produced manure containing about 463 million kg of nitrogen (N) and 72 million kg of phosphorus (P). Cattle manure was responsible for 60% of the nitrogen and 51% of the phosphorus production. Nitrogen (N) input to soil was on average 377 kg/ha, of which 177 kg/ha was via manure, 148 kg/ha via artificial fertiliser and 52 kg/ha via atmospheric deposition and other sources. The nitrogen surplus in the soil surface balance was on average about 172 kg/ha. Phosphorus (P) input to soil was on average 47 kg/ha, of which 34 kg/ha was via manure, 11 kg/ha via artificial fertiliser and 3 kg/ha via atmospheric deposition and other sources. The phosphorus surplus in the soil surface balance was on average about 19 kg/ha.

Trends in agricultural practice in the 1992-2006 period
The area of land used for agriculture in the 1992-2006 period decreased by 4.3% and the number of farms by 30%. The number of cattle and pigs both decreased by 21% and the number of poultry by 3.6%.

Manure nitrogen and phosphorus production by livestock decreased by 31% and 26% respectively, due to a combination of decreases in number of livestock and excretion per head as a consequence of lower nitrogen and phosphorus content in fodder and improved fodder conversion. As a result, the nitrogen and phosphorus surplus in Dutch agriculture decreased by 37% and 47% respectively.

The transport of manure between regions decreased even further. The emission of ammonia from agricultural sources into the atmosphere has stabilised in the last reporting period.

The storage capacity of manure has increased. In 2007, 97% of the dairy farms, 95% of the pig farms and 86% of the intensive veal calf farms had storage facilities sufficient for at least five months of manure production.

Nitrogen and phosphorus load to surface waters

In 2005, the communal contribution to the total nitrogen load of fresh surface waters in the Netherlands was 25%. The foreign contribution was 58%. Agriculture is the main contributor to the national nitrogen load, at 52%.

The nitrogen load to fresh surface waters decreased between 1985 and 2005 by almost half. The nitrogen load from agriculture decreased by 21%.

Quality of groundwater and surface waters

Nitrate concentrations in the 2004-2006 period
Average nitrate concentrations in groundwater and surface waters for the 2004-2006 period are shown in Table S2. In the Netherlands, groundwater occurs on average at depths of 1 to 1.5 m. For this reason, it has been decided to monitor the effects of the Action Programme in the upper metre of groundwater or tile drain water.

Table S1: Average measured nitrate concentration (in mg/l) and exceedance of the EU-target (%) in groundwater and surface waters for the 2004-2006 period[1].

Water type	Sand	Clay	Peat	Loess	All
Groundwater					
at a depth of < 5 m (agriculture)	75 (60%)	50 (40%)	9 (2%)	97 (90%)	65 (53%)
at a depth of 5-15 m (agriculture)	37 (19%)	< 1 (0%)	< 1 (0%)		-
at a depth of 15-30 m (agriculture)	10 (5%)	< 1 (0%)	< 1 (0%)		-
at a depth of > 30 m (phreatic groundwater abstraction ells)	7 (2%)	-	-		-
Fresh surface waters[2]					
Agriculturally influenced	17.1 (7%)	13.5 (1%)	4.3 (0%)	-	13 (3%)
Other regional water	15.2 (2%)	14.1 (1%)	8.3 (0%)	-	13 (2%)
Marine waters[2]					
Coastal waters					5 (0%)
Open sea					< 1 (0%)

1 Percentages showing exceedance of the EU target value of 50 mg/l in the 2004-2006 period are given in parentheses. For groundwater at about < 5 m the percentage of farms showing exceedance is given. For groundwater at depth > 5 m it refers to the percentage of wells and for surface waters to the percentage of monitoring locations.

2 Winter average nitrate concentrations, the period in which leaching plays a significant role in surface water quality.

Nitrate concentrations in groundwater and surface waters decrease with increasing distance to the agricultural nitrogen source, both in depth and spatially. Nitrate concentrations in groundwater decrease with depth as shown in Table S1. Nitrate concentrations in surface waters decrease spatially in the following order of importance: agriculturally influenced regional waters > other regional waters > national fresh surface waters > coastal water > open sea.

Two factors contribute to this decrease in concentration. The first is the conversion of nitrate into elementary nitrogen (denitrification) during transport, and the second is the mixing that occurs with water from non-agricultural areas (dilution). For groundwater, two other factors also play a role, namely time and hydrological conditions. Groundwater at a depth of less than 5 m is young water (1-5 years old). In the sandy areas, groundwater at a depth of 5-15 m has a travel time of about 10 years, and groundwater at 15-30 m a travel time of about 40 years. On average, groundwater at a depth of 15-30 m therefore reflects the agriculture of 40 years ago. In clay and peat regions, groundwater at depths of 5-15 and 15-30 m is usually even older. Here hydrological factors (groundwater pathways) are important, as groundwater in clay and peat regions at a depth of 5-15 m, as well as 15-30 m, is usually confined or semi-confined. In these regions the precipitation surplus drains superficially to surface waters. Confined and semi-confined aquifers also occur locally in sandy regions.

Nitrate concentrations in groundwater in peat regions are lower than in clay regions which, in turn, are lower than in sandy regions. This is caused by an increase in denitrification in ascending order, from sand to clay to peat.

Eutrophication of surface waters in the 2004-2006 period

The chlorophyll-*a* concentration is an effect indicator for eutrophication. Total nitrogen and total phosphorus concentrations are state indicators for eutrophication. Summer average concentrations for the 2004-2006 period are shown in Table S2. As with nitrate, concentrations of the eutrophication indicators decrease spatially in the following order of importance: agriculturally influenced regional waters > other regional waters > national fresh surface waters > coastal water > open sea. Chlorophyll-*a* concentrations are higher than 75 µg/l in 17% of the agriculturally influenced regional water stations and 12% of the other regional water stations.

Table S2: Eutrophication parameters (chlorophyll-*a* in µg/l and total nitrogen and phosphorus in mg/l), summer average values[1] for several types of surface waters in the 2000-2002 period.

Water type	Chlorophyll-*a*	Total nitrogen	Total phosphorus
Agriculturally influenced regional waters	40 (17%)[a]	4.0	0.67
All waters	36 (12%)[a]	3.6	0.26
Coastal waters	9 (0%)[a]	0.3[b]	-
Open sea	1 (0%)[a]	< 0.5[b]	-

[1] Summer average values are reported, since summer is the most critical period with respect to eutrophication.
[a] Percentage of locations with concentration > 75 µg/l in parentheses.
[b] Total dissolved inorganic nitrogen.

Trends in nitrate concentrations in the 1992-2006 period

Nitrate concentrations in on-farm water decreased in the 1992-2006 period, along with the number of farms exceeding the EU target value of 50 mg/l, even when accounting for confounding factors such as variation in net precipitation (see Figures S1 and S2). Nitrate concentrations decreased, especially in the sandy regions, where the average concentration decreased from 140 mg/l (both measured and standardised) to about 75 mg/l (measured and standardised).

Nitrate concentrations in groundwater at depths of 5-30 m did not show a clear trend, with the exception of groundwater at a depth of 5-15 m in agricultural areas of the sand regions. Both nitrate concentration and target value exceedance were lower in the 2000-2003 period than in the 2004-2006 period. Nitrate concentrations in phreatic groundwater at drinking water production sites (at a depth > 30 m in sand regions) showed a slightly increasing trend in the 1992-2006 period. Trends in nitrate concentration in groundwater in clay and peat regions are not expected, because the concentrations are low and the aquifers usually confined, with little or no impact from agricultural practice.

Winter average and maximum nitrate concentrations in fresh surface waters decreased after 1998. There was no trend in winter average nitrate concentration in marine and coastal water. The winter average dissolved inorganic nitrogen concentrations, corrected for riverine discharge (precipitation), showed a decrease in the early 1990s, then stabilised and since the end of the 1990s the concentration seems to have decreased again.

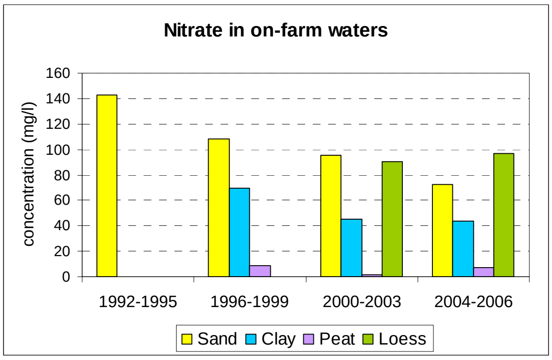

Figure S1: Nitrate concentration in upper metre of groundwater (sand, peat) and tile drain water (clay) on farms in the Netherlands for the 1992-1995, 1996-1999, 2000-2003 and 2004-2006 periods.

Nitrate concentrations in the sand region have been corrected for confounding factors.

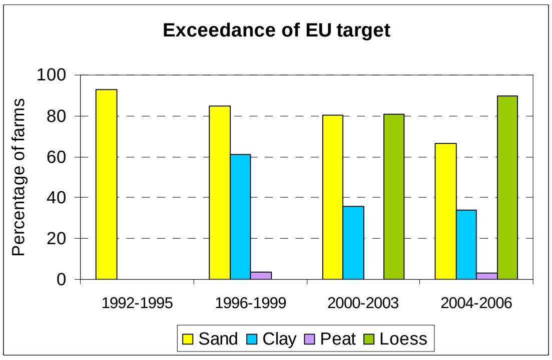

Figure S2: Exceedance of the EU target value of 50 mg/l in on-farm waters (see text Figure S1) in the Netherlands for the 1992-1995, 1996-1999, 2000-2003 and 2004-2006 periods.

Nitrate concentrations in the sand region have been corrected for confounding factors.

Trends in eutrophication in the 1992-2006 period
Since 1992, the chlorophyll-*a* concentration in fresh waters in the summer has decreased continuously in agriculturally influenced regional waters. Similar trends are shown for total nitrogen and total phosphorus concentrations in fresh waters in summer. The decrease in phosphorus concentration is not as significant as it is for nitrogen.

All Dutch marine waters are characterised as eutrophication problem areas (OSPAR Convention). The average summer chlorophyll concentrations did not show any clear trend in marine and coastal waters in the 1992-2006 period, except for the last three years, which show a stable lower average concentration than in previous years.

Effect of the Action Programmes and estimation of future evolution of water quality

In general, several years pass before policy measures are fully implemented by farmers. Measures taken by farms are not immediately revealed in a change in water quality due to factors such as processes in the soil and water environment and confounding factors such as year-to-year variation in the precipitation surplus.

On-farm water quality (upper metre of groundwater, tile drain water, etc.) will show the clearest and quickest response to the Action Programme measures. The effect of measures from the third Action Programme (2004-2007) is estimated to become apparent in on-farm water quality between 2008 and 2013.

Groundwater quality of phreatic aquifers at a depth of more than 5 m will only show the effects of the measures after one or more decades. Moreover, these effects will be hard to detect due to the mixing of groundwater of different ages and origins as well as soil physico-chemical processes. The effect of measures of the third Action Programme on surface water quality will also be evident between 2008 and 2013 although these effects will be masked, particularly in the case of national waters and coastal and marine waters, due to mixing effects (influence of foreign contribution via main rivers) and chemical processes in groundwater and surface water bodies.

Estimating future evolution in relation to agricultural practice is even more difficult for eutrophication than for nitrate concentrations. The main reasons for this are:

(i) the differences in surface waters with regard to their sensitivity to eutrophication
(ii) phosphorus levels and other factors such as hydro morphology, which also play an important part in the eutrophication process
(iii) the contribution made by other sources of nutrient input, notably urban wastewater and transboundary rivers
(iv) the very poor predictability of the response lag of aquatic ecosystems to a substantial reduction in nutrient inputs and nutrient concentrations

In addition to source-oriented measures, regional effect-oriented measures such as fish stock management have been taken in several cases where prospects were good. Expectations are that such measures will be pursued further. In some cases, the ecological restoration process was accelerated substantially as a result of such measures (for example in the Veluwe border lakes area). However, as Chapters 6 and 7 show, the ecological restoration process in Dutch surface waters is seen to take place at a relatively slow pace and a general, clearly observable acceleration of this restoration process is not expected in the short term.

Conclusions

Since 1987, the Netherlands has turned the increase in nitrogen and phosphorus surpluses in Dutch agriculture into a decrease. After the implementation of MINAS in 1998, the nitrogen surplus, which had been stable for about seven years, decreased again.

In the reporting period (1992-2006), water quality, both with respect to nitrate concentration and eutrophication, improved due to measures taken since 1987. That nitrate concentrations in on-farm water were significantly lower in the 2004-2006 period than in the previous periods is due to the reduction in nitrogen use since 1998. Nitrate concentrations in deep groundwater (> 30 m depth) are still increasing as a consequence of increased nitrogen loads in the period before 1987.

Water quality is expected to continue to improve in the period (2010-2015) as a result of measures taken during the third Action Programme (2004-2007). With respect to nitrate concentration in deep groundwater, a reversal of the increasing trend is estimated to take several decades. With respect to eutrophication, clearly observable acceleration of the restoration process is not expected.

The nitrate concentration in groundwater and the frequency with which the EU target value of 50 mg/l is exceeded depends not only on human activities but also on weather conditions, soil type and sampling depths. The last factor is the result of local hydrological and geochemical conditions in the sediments.

1 Introduction

1.1 General

This report provides the background information for the Netherlands Member State report, 'Nitrates Directive, status and trends of aquatic environment and agricultural practice', to be submitted to the European Commission in mid-2008. It 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 as a consequence of changes in farm practice. The report deals with the evaluation of the implementation and impact of the measures in the Action Programmes and forecasts the future evolution of water body quality. The period reported is 1992-2006; data for 2007 is also presented whenever available.

This introductory chapter summarises the goal of the Nitrates Directive and the main obligations arising from it (§1.2). The two obligations relevant for this report, i.e. reporting (§1.3) and monitoring (§1.4), are discussed in more detail. The 2008 Member State report represents the fourth reporting phase. A review of the first three reports is given in §1.5, with a more detailed, substantial description of the fourth report given in §1.6. References (§1.7) are found at the end of each chapter.

1.2 The Nitrates Directive

The European Nitrates Directive (EU, 1991) is aimed at reducing water pollution caused or induced by nitrate from agricultural sources and, further, at preventing such pollution. The Directive obliges Member States to take several actions to realise this objective.

First, Member States are obliged to designate areas in their territory (Nitrate Vulnerable Zones or NVZ) that drain into fresh surface waters and/or groundwater (Article 3, Annex 1) that contain, or could contain, more than 50 mg/l nitrate if actions prescribed in the Directive are not taken. This is valid for freshwater bodies, estuaries, coastal waters and marine waters that are now eutrophic or that may become eutrophic in the near future if actions prescribed in the Directive are not taken. Second, the Directive compels Member States to establish Action Programmes with respect to designated NVZ so that the objective of the Directive can be realised (Article 5). Third, Member States are obliged to implement suitable monitoring programmes to establish the extent of nitrate pollution in waters from agricultural sources and to assess the effectiveness of Action Programmes (Article 5, sub 6; see §1.4 for more details). Member States are to submit a report on the preventive actions taken, and the results and expected results of the Action Programme measures, to the European Commission (Article 10, see for more details §1.3).

The Netherlands has not designated Nitrate Vulnerable Zones, but informed the European Commission in 1994 that they would establish an Action Programme, as laid down in the Nitrates Directive, which they would apply throughout their national territory. According to a study in 1994 (Working Group Designating NVZ, 1994), agriculture is a relevant source of nitrate emission to groundwater and/or fresh surface waters and/or coastal waters. The working group concluded therefore that an Action Programme should be applied to the whole country.

1.3 Reporting liability

The obligation of reporting to the Commission on preventive actions taken and the results and expected results of the Action Programme measures are elaborated in Annex 1 of the Directive. This Annex stipulates the information for inclusion in a report brought out every four years, which in the Netherlands is the responsibility of the Ministries of Housing, Spatial Planning and the Environment (VROM), Agriculture, Nature and Food Quality (LNV) and Transport, Public Works and Water Management (V&W).

Reporting obligations:
1) A statement of the preventive action taken pursuant to Article 4. This article states that within two years following the notification of the Directive, a code of Good Agricultural Practice (GAP) has to be established and a programme promoting the code has to be set up.
2) A map showing the following:
   a) waters identified as being affected or capable of being affected by pollution
   b) the location of the Nitrate Vulnerable Zones, distinguishing between the existing zones 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 which led to the designation and to any revision.
4) A summary of the Action Programmes drawn up, in particular:
   a) the measures required with respect to the application of fertiliser, storage capacity for manure and other restrictions on the use of fertilisers, and measures prescribed in the GAP code
   b) the implementation of a maximum amount of nitrogen per ha for application, along with manure, amounting to 170 kg/ha[1]
   c) any additional measures or reinforced actions taken to overcome inadequate measures for achieving the Directive objective
   d) a summary of the results of the monitoring programmes to assess the effectiveness of the Action Programmes
   e) the assumption made by the Member States about the likely time scale within which the waters identified are expected to respond to the measures in the Action Programmes, along with an indication of the level of uncertainty inherent in these assumptions

This report focuses on points 4d and 4e of the reporting obligations.

1.4 Monitoring liability

Member States who have designated NVZ have different obligations from Member States who apply their Action Programmes to their entire territory.

Member States who have designated NVZ shall, for the purpose of designation and revising the designation of NVZ, monitor nitrate concentrations in fresh waters and groundwater for at least one year within two years of notification of the Directive, i.e. the end of 1993, and repeat the monitoring programme at least every four years.

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[1] Since 8 December 2005 Dutch dairy farms with more than 70% pasture have been granted a derogation for the use of manure of 250 kg/ha per annum. Concerning the reporting obligations following this derogation we refer to Fraters et al, 2008.

Member States applying their Action Programme to their entire territory, e.g. the Netherlands, will monitor the nitrate concentrations in fresh waters and groundwater to establish the extent of nitrate pollution in waters from agricultural sources. The Directive does not provide a time limit in this case. Given that the first Action Programme took effect on 20 December 1995, monitoring has to be performed before that date to be able to record the starting point. The monitor for designation does not have to coincide with the monitor assessing the effectiveness.

The Nitrates Directive provides limited guidance on how monitoring is to be implemented. As a matter of fact, only a few monitoring guidelines are given for the purpose of designation (Article 6, Annex IV).

The European Commission published draft monitoring guidelines according to Article 7 of the Directive in 1998 (EC/DG XI, 1998). Revisions were published in 1999 (EC/DG XI, 1999) and in 2003 (EC/DG XI, 2003), but these are still draft versions. The guidelines do not refer to any statutory obligation. The objective of the guidelines is to define the aim of each type of monitoring and suggest ways in which Member States might achieve this. In addition, the Commission aims at ensuring that it will be possible to compare monitoring regimes between Member States.

1.5 The first, second and third Member States reports on the Netherlands

The first Member States report on the Netherlands was submitted to the Commission in 1996 (LNV, 1996). This report refers to the period between 20 December 1991 and 20 December 1995. With respect to the obligation to report on the results of the monitoring programmes to assess the effectiveness of the Action Programme, it was thought too early to be able to show any effect, since the first Action Programme had only been introduced on 20 December 1995. The report provides an overview of the operational monitoring programmes and the following remarks were made with respect to the results:

> 'The effectiveness of the Action Programme can't be properly assessed when the results of monitoring groundwater and surface waters only are considered. Measures aimed at a decrease of emissions of nutrients will have a delayed effect on nitrate concentration, especially in surface waters. Therefore the estimation of the surplus on the national agricultural nitrogen balance is an appropriate tool when assessing the effectiveness of the measures. This tool provides an opportunity to follow the achieved progress due to reduction measures in agriculture in a more direct manner.'

This report also states that the effectiveness of the Action Programme will be reported on in four years' time.

The second Member States report of the Netherlands was submitted to the Commission in 2001 (LNV, 2001). This report refers to the period from 20 December 1995 to 20 December 1999. It contains the results of the monitoring programmes to assess 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 remarks were made in the Member States report with respect to the results of these programmes:

‘The report (of the Working Group - Monitoring Nitrates Directive) indicates that there is a stabilisation, but not yet a substantial amelioration, of the environmental quality. This lack of amelioration was foreseen because:

1. During the reporting period (1995-1999) only the use of manure was regulated, the use of artificial fertiliser was not. The decrease in the amount of nitrogen used by manure application was often compensated by fertiliser application. Since 1998, the Netherlands has rules that include the regulation of the use of artificial fertiliser nitrogen, the Mineral Accounting System (MINAS). As a consequence, the effects of MINAS fall beyond the reporting period. In addition, expectations are that tightening of the mineral policy (September 1999) will show results in 2002 and 2003. That means that an amelioration of the environmental quality as a consequence of the mineral policy will become apparent in the third reporting period.
2. Due to transport processes and decomposition and conversion processes in soil and groundwater, effects of measures are lagging, and it will take some time before they show in a decrease in nitrate concentration. However, the extent of the lag time cannot be specified. The results of monitoring particularly reflect the stabilisation in agricultural practice in the 1980s and early 1990s, when the development of an increase in environmental pressure was brought to a halt.’

The third Member States report of the Netherlands was submitted to the Commission in 2004 (VROM, 2004). This report refers to the period from 20 December 1999 to 20 December 2003. It contains the results of the monitoring programmes to assess 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 remarks were made in the Member States report with respect to the results of these programmes:

1. In Dutch agriculture the rising nitrogen and phosphate surpluses have changed to a tendency to decline since 1987. After the introduction of the MINAS registration system in 1998 the nitrogen surplus, which remained stable between 1990 and 1998, showed a further decline.
2. As a consequence of policy measures taken since 1987, the water quality in the reporting period has improved, both for nitrate concentrations as well as for eutrophication. The nitrate concentration in the upper meter of groundwater on farms has clearly decreased in the period 2000-2002 compared to previous periods. This is connected with the decrease in nitrogen use since 1998. Nitrate concentrations in the deeper groundwater (>30 meters) still show an increase, probably connected with the increase in nitrogen surpluses in the period before 1987.
3. The expectation is that the water quality will continue to improve during the next reporting period, thanks to measures taken during the second Action Program (1999-2003). Before these effects reach the deeper groundwater it is expected that a longer period of time is needed (some decennia). Despite the initial improvement in water quality, a clearly visible increase in the ecological improvement of surface water, meaning a decrease of eutrophication symptoms, is not expected in the following reporting period.
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 are also dependent on weather conditions, soil type and sampling depth. This last factor is connected to the hydrological and geochemical characteristics of the subsoil.

1.6 The Member States fourth report and this report

1.6.1 Delineation and account

In mid-2008 the Member States have to submit their Nitrates Directive Member States report to the European Commission. The fourth Member States report deals with the period from 20 December 2003 to 20 December 2006 and should also contain the results of the monitoring programmes assessing the effectiveness of the Action Programme (point 4d in Section 1.3) and the assumption made by the Member States about the likely time scale within which the waters identified are expected to respond to the measures in the Action Programme (point 4e in Section 1.3).

The ministries responsible for the reportage by the Netherlands (see §1.3) requested the Working Group - Monitoring Nitrates Directive to report on the two above-mentioned topics. This report represents the result of this working group's efforts.

The point of departure for drawing up this report was formed by the reporting guidelines published by the Commission in 2000 (EC/DGXI, 2000). In November 2007 and January 2008 the Commission published a draft reporting guideline which became definitive in March 2008; EC/DGXI (2008). As far as is possible, changes from the reporting guidelines dated 2000 have been integrated within this report. These guidelines contained a request that the results for the monitoring periods be published using an average of three years of monitoring for each period. Because the guidelines have not been updated, it is not clear whether results for only two monitoring periods should be given or for all the periods, in this case four. It is also not clear which periods should be used for comparison of results, as prescribed in the guidelines.

The working group has recommended (Fraters, 2007) that in order to show a comprehensive overview of the status and trends of agricultural practice and the aquatic environment, the first and two last periods should be presented in tables. The monitoring periods 1992-1995, 2000-2003 and 2004-2006 are therefore presented in tables. In addition, figures are given showing yearly averages for the 1992-2006 period at a minimum. However, if earlier data is available, often going as far back as the mid-1980s, this is presented as well. To limit the number of maps presented, only the maps showing the water quality status for 2004-2006 and the change in water quality between 2000 and 2006 (third and fourth periods) should be included. The ministries have agreed with this recommendation.

1.6.2 Structure of report

This report consists of an introduction and written account (Chapters 1 and 2), the results of the monitoring programmes to assess the effectiveness of the Action Programmes (Chapters 3 - 7), a forecast of how the quality of water bodies will evolve in the future (Chapter 8) and a chapter on synthesis of the results from the foregoing chapters and conclusions. For the convenience of the reader, this chapter is at the beginning of the report. To allow the chapters containing the results of the monitoring programmes to be read independently, references are provided at the end of each chapter.

After the general introduction to the report in Chapter 1, Chapter 2 goes on to describe the nationwide monitoring programme and the aim and design of the respective sub-programmes that contribute the results for this report.

The status of and trends in agricultural practice are described in Chapter 3. The effect of both agricultural practice and changes in practice on the on-farm water quality is illustrated in Chapter 4. In the remaining three chapters, the status of and trends in the aquatic environment are depicted for groundwater (Chapter 5), fresh surface waters (Chapter 6) and coastal and marine waters (Chapter 7).

Groundwater nitrate concentrations are shown for three depths: 5-15 m, 15-30 m and > 30 m below surface level; different depths are used since nitrate concentrations vary considerably with depth. Other important environmental factors considered when reviewing nitrate in groundwater are land use, soil type and aquifer type. These factors have been accounted for in Chapters 4 and 5.

Nitrogen and phosphorus loads are given for surface waters, along with a description of water quality. Water quality is described by nitrate concentrations for the winter period and by eutrophication parameters for the summer period. Four water types are distinguished for fresh surface waters: agriculturally influenced regional waters, other regional waters, national waters and drinking water stations. These show a decreasing influence of agriculture on water quality. Other sources influencing water quality are, for example, effluent from wastewater and sewerage treatment plants, sewerage overflow during storms (excessive rainfall) and atmospheric deposition. For marine waters, we make a distinction between coastal water and the open sea, illustrating the difference in the influence of nutrient loads, mainly by rivers and not by direct discharge.

The forecast of the future evolution of the quality of water bodies is addressed in Chapter 8. The estimations are mainly based on extrapolations of the evolution of water quality derived from current monitoring. For a more detailed forecast we refer to Klijne, 2007 and MNP, 2007.

The synthesis of the results from the preceding chapters and any conclusions that could be drawn are incorporated in the 'Summary, synthesis and conclusions' at the beginning of the report.

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2 National monitoring programmes

2.1 Introduction

Several monitoring programmes exist for the monitoring of agricultural practice and the aquatic environment in the Netherlands: agricultural practice (§2.2), the effectiveness of the minerals policy (§2.3), groundwater (§2.4), fresh surface waters (§2.5) and water used for drinking water production (§2.6). These programmes are carried out under the responsibility of various institutes and organisations.

This chapter provides a brief description of each of these programmes. In addition to a general account on the data collection, information is provided on data processing – used for the summaries to illustrate the status of and trend in agricultural practice and the aquatic environment. Details of data collection and processing are given in referenced literature sources.

2.2 Monitoring agricultural practice

2.2.1 General

Agricultural practice is monitored intensively in the Netherlands. The monitoring programmes are discussed in the next sub-section, followed in §2.2.3 by details on the calculation of mineral balances and manure and nutrient excretion and production and manure storage capacity.

2.2.2 Data collection

There are two agricultural monitoring programmes in the Netherlands: the Agricultural Census and the Farm Accountancy Data Network (FADN).

Agricultural Census
Statistics Netherlands collects general information on such topics as acreage and number of farm animals for all farms larger than three ‘Dutch Magnitude Units’ (NGEs) (CBS Statline, 2007). These NGEs represent units of gross balance corrected for price fluctuations; NGEs are also used as the basis of levies and issuing rules. More information about the NGE’s can be found at: http://www.lei.wur.nl/NL/nieuwsagenda/archief/nieuws/2005/RekenenmetNederlandsegrootteeenheden.htm. In 2007, one NGE was equivalent to about one cow, four sows or 400 laying hens. The annual data collection is called the ‘Agricultural Census’.

Farm Accountancy Data Network
The Dutch Agricultural Economics Research Institute (LEI) collects more specific information on farm economics and technical management through the Farm Accountancy Data Network (FADN) (Vrolijk, 2002; Poppe, 1993; Lodder and De Veer, 1985). This farm management information includes environmental relevant data such as mineral balances (inputs and outputs of minerals), the use of pesticides, water and energy consumption, fertiliser, import and export of minerals and grazing frequency. The FADN represents 1500 farms from the Agricultural Census, selected through stratified

random sampling and so forming a representative sample of Dutch agriculture. The FADN network is a participant in the EU networks (EU Council Regulation 79/65/EEG). Farms participate for a five to six year period and are visited annually. 15-20% of the farms were replaced every year, so that the FADN network could remain representative of Dutch agriculture. Recent research shows that the replacement of farms after five or six years doesn't make the data any more representative, as it did in the past. Therefore, the replacement of farms is reduced to farms which leave the business, move to another region, etc. 3-5% of the farms are currently replaced every year. The FADN represents about 75% of the total number of farms and about 91% (in NGEs) of registered agricultural production in the Netherlands. For reasons of representativeness, farms of less than 16 NGEs, on which farming is generally not the main occupation of the farmer, are excluded in the FADN. Farms (mostly greenhouse nurseries) of greater than 1200 NGEs are less appropriate for data collection and therefore also excluded from the survey. Today, the FADN covers more than 90% of the agricultural area (Vrolijk, 2006). Other recent years show similar results.

Surveillance of compliance to the code of Good Agricultural Practice and the observance of regulations occur mainly by way of a check on the minerals return that each farmer has to complete and return to the Levies Office, and generally not on an individual measures level. From 2006 onwards, the policy changed so that there is more focus on manure and fertiliser and less on total mineral flows, in order to better agree with EU directives. Information collected by the General Inspection Service (AID) provides insight into the level of observance of regulations as far as related administrative obligations like manure application (amount, timing and application method) and manure disposal contracts are concerned.

The National Reference Centre of the Ministry of Agriculture, Nature and Food Quality (LNV, Dienst Regelingen) has produced an overview of the activities around fertilisation recommendations, promotion of the code and demonstration projects.

2.2.3 Data processing

Nitrogen and phosphorus balances

Nitrogen and phosphorus balances of the agricultural system are calculated annually by Statistics Netherlands. All balance items are based on statistical data, except for atmospheric deposition, which is based on model calculations made by the RIVM (Erisman et al., 1998; Van Jaarsveld, 1995) using statistical data on emissions to air (Van Amstel et al., 2000). The surplus is the difference between supply and removal items. The destiny of the surplus on the balance is not specified because leaching, run-off, denitrification and accumulation can only be estimated through 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 in calculation methods have occurred; until 2000 these are published in every fourth issue of the quarterly bulletin of Statistics Netherlands, together with the definitive version of the balances from the previous two years and the draft version of the balance for the previous year (see, for example, Fong, 2000 and earlier issues). From 2000 onwards, this information is published on the Internet (see for example CBS, 2007a and earlier years).

Nutrient excretion and production

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

1. nutrient excretion factors, calculated for each element on the basis of the balance sheet: excretion = intake via feed minus retention in animal products.
2. statistics and technical administration of a certain year used in place of expert knowledge and feeding standards as a source material for basic figures on quality and content. This makes it possible to follow not only changes in feed composition, but also zoo-technical developments such as more efficient milk and meat production from year to year in the calculations. Statistics are preferably used as source material since they show continuity in method, outcome and time of publication. Basic information is used from animal feed statistics (compound feed and its nutrient content, concentrates and their nutrient content, use and production of roughage, kg of feed per animal, etc.) and from animal production statistics (milk production per cow, protein content of milk, egg production per hen, meat growth per animal, delivery weight of piglets, etc.).
3. actual emission factors are calculated per year per animal category as defined in the Agricultural Census. This means that the outcome of technical administration and statistics has to be harmonised in this respect. Care should be taken to check whether basic information refers to a counted animal, a housing animal or a delivered animal.

The two calculations of nitrogen in manure are not completely independent of one another. Differences between nitrogen excretion (484 million kg N in Figure 2) and the sum of manure nitrogen production and ammonia volatilisation (387 + 73 million kg N in Figure 2) are mainly due to the use of species-specific data on animal cycles, animal production, etc. for the calculation of the manure production.

Manure storage capacity
Manure storage capacity on livestock farms has been a subject of the Agricultural Census in only some years in the monitoring periods (1993, 1997, 2003 and 2007). Part of the form deals with the manure storage capacity of animal manure on the farm site. The question is classified into storage capacity in time (months) for different types of manure. The data is presented in Table 15.

Data on the production and storage capacity of manure at farm level can also be obtained from the Farm Accountancy Data Network (FADN), see §2.2.2, which is a representative sample of Dutch farms. In the FADN, the storage capacity concerns only liquid manure and not solid manure. This data is used in this report (Chapter 4).

2.3 Monitoring effectiveness of the mineral policy

2.3.1 General

Monitoring of the effects of the Action Programme consists of the regular agricultural, groundwater, and surface-water monitoring programmes and a specialised monitoring programme, the National Monitoring Programme for the effectiveness of the Minerals Policy Monitoring Programme (LMM). The LMM was developed to assess the contribution of nitrate from agriculture to receiving waters and the effects of changing agricultural practice on these losses. It would thus monitor the effect of policy measures on water quality.

The LMM monitors both water quality and farm management, i.e. agricultural practice. Policy measures aim to change farm management in such a way that water quality will improve. The water quality of groundwater and surface waters is generally not only influenced by farm practice, but also by other sources of pollution and environmental factors such as weather. To exclude other sources of pollution as far as possible, water quality of on-farm waters (such as the upper metre of groundwater or soil moisture within 5 metres of the soil surface, tile drain water or ditch water) is monitored. This type of water also reflects the effect of recent management (less than 4 years ago). To be able to distinguish between the effects of measures on water quality and the effects of confounding factors, such as weather, these confounding factors are monitored as well (see Fraters et al.,2004) The next sub-section (§2.3.2) provides more details on the LMM data collection, followed by §2.3.3 with details of data processing.

2.3.2 Data collection

LMM and FADN

When the LMM monitoring programme started up in the sandy regions in 1992, it was decided that linking LMM and FADN (see §2.2.2) would have many advantages. Linking these two would make both farm management and water quality data available to all farms. In 1996, after the evaluation of the first four-year period, it was decided to continue this cooperation. Because of the characteristics of Dutch agriculture and the high level of dynamics, the advantages of linking the FADN and the LMM were obvious. The decision to use a changing group for the FADN was taken in the second half of the 1960s. Monitoring a fixed group independent of the FADN would implicate a duplication of the activities of the FADN, while the regular replacement of farms would still occur due to the high level of dynamics (Fraters, 2005). It should be noted that both the FADN and LMM exclude some farms from participation. For reasons of representiveness, farms of less than 16 ‘Dutch Magnitude Units’ (NGEs) and greater than 1200 NGEs are excluded in the FADN (see §2.2.2). In addition to these FADN thresholds, the LMM also includes a minimum participation criterion of 10 hectares of land per farm.

The monitoring network expanded in 2006 due to obligations resulting from the granted EU derogation on the application of 250 kg/ha of manure. The monitoring group is now fixed, except for changes due to dynamics.

Main soil type areas

The Netherlands applies the Nitrates Directive Action Programme to the entire territory; nevertheless, legislation distinguishes between soil types, and measures are based on soil vulnerability to nitrate leaching. The effect monitoring programmes therefore focus on the level of the main soil type regions in the Netherlands, i.e. sand, loess, clay and peat. The different vulnerability situations, such as dry or wet soils (Groundwater Regime Class[1], GRC) are taken into account in the sand and loess areas. Each of these areas can be considered as a group of similar groundwater bodies. The state of affairs with respect to the aquatic environment on farms is described for each main soil type area. Each main soil type area consists of one or more regions.

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[1] In total, 11 groundwater regime classes are identified on the basis of average highest groundwater level (AHG) and average lowest groundwater level (ALG) in a hydrological year (April – April). The three highest/lowest values in a hydrological year are averaged. Subsequently, the average of a succession of years is calculated. Mapping the GRC is largely based on field estimations using soil characteristics in combination with measurements. The influence of GRC on nitrate concentration in the upper metre of groundwater was studied by Boumans et al. (1989), who expressed this influence in a ‘Relative Nitrate Concentration’ factor (RNC), where the nitrate concentration found in soil with GWR VII* (lowest AHG and ALG) has an RNC of 1.

Main farm types
Within each main soil type area, the LMM focuses on the main farm types with respect to acreage (i.e. arable farms and dairy farms) and sometimes includes a group of other farm types. The reason for this restriction of the sample population is to decrease the variation in farm practice and water quality within the sample and, in this way, increase the ability to observe a change in farm practice and water quality.

Sampling and other data collection
The water quality on farms is monitored by sampling soil water in the unsaturated zone below the root zone, shallow phreatic groundwater (within 5 m of the soil surface), tile drain water and/or ditch water. Environmental data, e.g. precipitation and evapotranspiration, fraction of soil types and GRCs, is collected, and the influence of the data on the monitoring results is accounted for using modelling approaches (see §2.3.3 and Fraters et al., 2004).

Sampling unit
The unit used for the sample location in the LMM is the farm. This is because Dutch legislation regulates agricultural practices at the farm scale, because farm management can be monitored more easily at the farm level than at any other scale level (e.g. parcel level) and because farm management was already monitored at the farm level in the FADN (§ 2.2.2.).

Sampling frequency
The sampling frequency varies between programmes and main soil type areas. The sampling frequency is the key to the expected change in quality in time and the variation in quality in time and space. For groundwater and surface waters, changes in nitrate concentrations in time should be relatively large if target values are to be reached. The current design of the LMM, i.e. the sampling strategy, is based on statistical analysis of the results of the research performed in the 1992-2002 period. This comprises research in the sand regions in the 1992-1995 period (Fraters et al., 1998) and in the clay (Fraters et al., 2001) and peat regions (Fraters et al., 2002a) in the 1995-2002 period. Farms were sampled each year in these periods.

This research showed three major sources of variation in nitrate concentration (in decreasing order of magnitude):

1. differences in nitrate concentration between farms,
2. differences in nitrate concentrations between years on a single farm,
3. differences in nitrate concentrations between sampling points on a farm in a certain year.

Differences in nitrate concentration between farm types were to a lesser extent a source of variation as well. The statistical analysis of the data points to increased effectiveness by the sampling of more farms (and each farm) only a limited number of times in the FADN participation period compared with sampling a smaller number of farms each year. The difference in nitrate concentration between farms as the most important source of variation justifies this approach.

The sampling strategy during the participation period of the farms is determined by both the importance of the sources of variation and the organisational and financial aspects of sampling e.g. travel time between farms and number of samples that could be taken on a farm in a day. On the basis of the importance of the sources of variation for nitrate concentration, the first aim should be to maximise the number of farms in the sample population. This should be followed by maximising the number of years of monitoring on a certain farm and, finally, the number of sampling points per farm.

The potential number of farms in the FADN eligible for participation in the LMM evaluation monitoring programme is large. For this reason, the most cost-effective method was to sample farms in the sand and peat regions, where the upper metre of groundwater is sampled, but only in years 1, 4 and 7. However, in the clay regions, where tile drains artificially drain most of the farms and tile drain water is sampled, it is more cost-effective to sample farms each year.

A change took place in 2006 due to the obligations resulting from the granted EU derogation on the application of 250 kg/ha of manure. The monitoring group is now sampled every year.

Relevant farming practice information, an essential part of the FADN, is recorded each year for all participating farms in the LMM evaluation monitoring programme.

Loess region

The Loess region has been part of the LMM since the FADN year 2001, and first groundwater results date from 2002. The data from the Provincial Soil Moisture Network of Limburg is added to the LMM data to gain a view over a longer period of time. The design of the Provincial Network for the sampling unit, the parcel instead of the farm, differs from that of the LMM (IWACO, 1999; Voortman et al., 1994).

Sample size

The total number of representative farms for all main soil type regions varied according to year in the 1992-2006 period (see Table 1). In total, about 1730 farm samplings were performed for evaluation purposes on representative farms. The number of different farms sampled per sub-period and the number of years they are sampled in that sub-period is given in Table 2.

Table 1: Number of representative farms where on-farm water quality was measured per farm type per year in the 1992-2007 period[1].

	Sand regions			Clay regions			Peat regions	Loess regions		
Year	Dairy farms	Arable farms	Other farms	Dairy farms	Arable farms	Other farms	Dairy farms	Dairy farms	Arable farms	Other farms
1992	67 (67)	18 (18)	7 (7)							
1993	64 (63)	19 (19)	5 (5)							
1994	32 (31)		3 (3)							
1995	61 (51)	18 (16)	5 (4)							
1996							16 (16)			
1997	14 (13)	10 (10)	3 (3)	2 (2)	4 (4)					
1998	18 (18)	11 (11)	13 (7)	16 (16)	11 (11)	1 (1)				
1999	18 (18)	8 (8)	17 (6)	23 (22)	26 (26)	4 (4)	14 (10)			
2000	23 (22)	8 (8)	9 (6)	27 (26)	27 (25)	4 (4)				
2001	28 (*)	10 (*)	7 (*)	26 (*)	25 (*)	5 (*)	8 (*)			
2002	29 (26)	10 (9)	14 (7)	24 (11)	22 (17)	6 (4)	17 (5)	7 (6)	9 (1)	3 (2)
2003	40 (33)	17 (16)	23 (12)	32 (16)	17 (8)	2 ()	3 (3)	5 (5)	5 (4)	4 (3)
2004	67 (63)	15 (15)	22 (11)	28 (18)	36 (28)	5 (2)	11 (9)	5 (4)	7 (3)	2 (1)
2005	67 (67)	13 (11)	31 (13)	22 (22)	28 (27)	6 (5)	20 (20)	6 (6)	5 (3)	3 (1)
2006	119 (^)	14 (^)	21 (^)	19 (^)	25 (^)	5 (^)	12 (^)	8 (^)	1 (^)	2 (^)
2007	#	#	#	74 (^)	24 (^)	21 (^)	65 (^)	#	#	#

[1] The number of farms for which data on farming practices is available for the previous year is shown in parentheses.
* No data available for the related FADN year 2000.
^ No comparison with corresponding previous FADN year available (2005 and 2006).
# Data collected after spring 2007 were not available in time for this report.

Table 2: Number of different representative farms where on-farm water quality was measured per farm type per sub-period in the 1992-2006 period[1].

	Sand regions			Clay regions			Peat regions	Loess regions		
Year	Dairy farms	Arable farms	Other farms	Dairy farms	Arable farms	Other farms	Dairy farms	Dairy farms	Arable farms	Other farms
1992-95	70 (3.2)	19 (2.9)	8 (2.5)							
1996-99	49 (1.0)	28 (1.0)	33 (1.0)	25 (1.7)	29 (1.4)	4 (1.3)	16 (1.9)			
2000-03	88 (1.4)	34 (1.3)	40 (1.4)	51 (1.9)	39 (2.0)	8 (1.8)	19 (1.5)	6 (2.0)	6 (2.3)	4 (1.8)
2004-06	148 (1.7)	39 (1.1)	66 (1.1)	38 (1.8)	40 (2.2)	9 (1.6)	29 (1.5)	7 (2.7)	7 (1.9)	3 (2.3)

[1] The average number of years the farms were sampled in the sub-period is shown in parentheses.

2.3.3 Data processing

Calculating annual averages

Annual average concentrations and other parameters are calculated by averaging farm annual means. Period average values are calculated by averaging farm period averages. An exception are the loess data from the Province of Limburg (BVM loess), these are based on average values per parcel instead of farm; this is due to the different design of this monitoring programme (§2.3.2). Loess data from the LMM is, like the other soil types, based on farm averages.

Statistical analyses and perceived effects

The residual maximum likelihood method is used to statistically analyse the relationships between farm management and nitrate concentration in recently formed groundwater (Payne, 2000). A statistical method is used to discern the effect of the Minerals policy and filter out effects of differences in weather and sample population between years (Boumans et al., 2001; 1997). This method is currently available for the programmes in the sand and clay regions. A detailed description of the method is given in Fraters et al., 2004. Recent figures used for these calculations are given in Annex 1.

2.4 Monitoring status and trends in groundwater

2.4.1 General

Groundwater monitoring in the Netherlands is carried out similarly to that in many other countries (Koreimann et al., 1996) using permanent wells specially placed for the purpose of monitoring. Permanent wells are placed outside the fields, so that groundwater sampled in the Dutch Monitoring Programme ‘Landelijk Meetnet Grondwater’ (LMG) is from a minimum depth of 5 m (usually between 8 and 10 m), to ensure: (a) that the well screen is not in the vadose zone and (b) that groundwater sampled originated from the field. As a consequence, the quality of the groundwater at this depth reflects the effect of management practices of about a decade ago. More details are given about the data collection in the LMG in the next sub-section. Details of data processing are given in the following sub-section.

2.4.2 Data collection

LMG set-up

The National Groundwater Quality Monitoring Network (LMG), established between 1979 and 1984, comprises about 360 locations spread over the whole of the Netherlands (Van Duijvenbooden, 1987). The main criteria for site selection were type of soil, land use and hydrogeological state. At each location groundwater is sampled at depths of 5-15 m and 15-30 m below surface level. The number of well screens used for this study is given for each combination of soil type, land use and depth of sampling in Table 3.

Table 3: Number of well screens for which complete[1] data series are available for the 1984-2006 period, for each combination of soil type, land use and depth of sampling.

Land use	Depth	Sand	Clay	Peat	Other
Agriculture	5-15	119	61	31	5
	15-30	119	62	31	4
Nature	5-15	55	4	4	3
	15-30	53	4	4	2
Other	5-15	36	18	2	6
	15-30	38	16	2	3

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

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 decreased for certain combinations of soil type and depths. Shallow well screens in sandy regions are still sampled every year; while shallow well screens in other regions (clay and peat) are sampled every two years. Deep well screens are sampled every four years; shallow well screens with high chloride concentrations (more than 1000 mg/l due to marine influence) are also measured every four years. Finally, well screens dominated by local conditions, for example, near rivers and local sources of pollution, are eliminated. In this way, the number of well screens to be sampled each year has been reduced from 756 to about 350. The National Institute for Public Health and the Environment is responsible for the network and data interpretation and reporting.

2.4.3 Data processing

Because of the design of the LMG there are locations (well screens) that are not sampled each year. In order to avoid apparent trends that are a consequence of the design, an estimate is made for all missing data, calculated by interpolating the available data. For data missing at the beginning and end of the series, the first (beginning) or the last (end) available value is used as an estimation of the missing data. Annual average concentrations are calculated by simply averaging measured concentrations. Period average concentrations are calculated by averaging period averages per location. More details on the data processing are given in Fraters et at., 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 wells screens were used for analysis for this study due to the application of less strict criteria with respect to missing data in the 1984-2006 period.

2.5 Monitoring status and trends in surface water quality

2.5.1 General

The surface water monitoring networks comprise the monitoring networks for regional and large freshwater bodies and coastal and marine waters. Even a regional water station is representative of an area larger than a farm, thus distinguishing it from the LMM (see §2.3). As a consequence, the influence of other sources of pollution and the time between measurement and effect increase in the following order of importance: regional waters > large fresh surface waters > coastal waters > open sea. Details of the data collection are given in the next sub-section (§2.5.2), followed by details of data processing in §2.5.3.

2.5.2 Data collection

Both national and local authorities perform surface water quality monitoring. The national authorities are responsible for the Monitoring Water Status of the Country (MWTL) and the local authorities for the Regional Water Status Networks (RWSN).

Monitoring the Water Status of the Country (MWTL)
The Department of Public Works of the Ministry of Transport, Public Works and Water Management collects data from 39 stations in marine waters (including the Zeeland estuary) and at around 30 stations in large (national) fresh surface waters, such as larger rivers, canals and lakes. The frequency of sampling in marine waters is once a month in winter and once every two weeks in summer. The sampling depth for marine waters is about 1.5 m below water level, and 3.5 m below water level for North Sea locations. For most locations (23), nutrients, common parameters (temperature, oxygen, etc) and phytoplankton (species composition and chlorophyll) are determined, while for the other marine stations only nutrients and common parameters are determined. The sampling frequency at most large freshwater stations is once every four weeks; for stations bordering with Germany and Belgium it is once every two weeks. The sampling depth is about 0.5 – 1.0 m below water level. Samples are analysed for nutrients, common parameters and chlorophyll.

The Centre for Water Management is responsible for the interpretation of the marine water data and for the fresh surface water data.

Regional Water Status Networks
The 27 regional Water Boards and some of the regional departments of public works all have their own Regional Water Status Networks (RWSNs). These RWSNs comprise several thousands of freshwater monitoring locations in regional waters. The frequency of sampling varies but is usually once every four weeks. Depth of sampling depends on local conditions but is normally about 0.5 – 1.0 m below water level.

The Centre for Water Management conducts an annual survey of water quality data of the main RWSN stations. In 2006 this survey comprised about 450 freshwater locations, representative of the larger regional water systems, while in 1992 the number was around 250. The water quality of these stations is not only influenced by agriculture but also by other sources, and in summer also by incoming water from the main water system.

The data presented in this report might deviate slightly from the data presented in the 2004 report (Fraters et al., 2004). The 2006 locations are used in the current report. For all these locations, historical data is collected in such a way that the last two periods, i.e. the 2000-2003 and 2004-2006 periods, have the same amount of locations.

Regional Water Boards have determined whether or not a monitoring location is strongly influenced by agriculture or not. Two types of locations will be discussed in this report; ‘strongly influenced by agriculture’ locations and ‘main locations’. The latter are stations used by the Ministry of Transport, Public Works and Water Management.

2.5.3 Data processing

Nitrate concentration

For freshwater, nitrate data actually concerns ‘nitrate + nitrite’. Only data on ‘nitrate + nitrite’ was available for most stations and only data on nitrate was available for one or more years for a few stations. Because nitrite concentrations in freshwater are very low compared with nitrate concentrations, the sum of nitrate and nitrite is here presented as nitrate.

Annual average values

Figures showing winter and summer averages and maxima in the last period are based on the various data collected at different locations. The winter and summer averages and maxima are calculated as the average of the winter and summer averages, and the respective averages of winter and summer maxima for all surface water stations.

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. Here the winter months, the period in which leaching plays a significant role, are of particular importance. In marine waters however, there is still high biological activity in the months October and November. These months are therefore not taken into account in the calculation of the winter average. For the marine environment, the data also indicates that biological growth and therefore interference already occurs in March. The March data is therefore not suitable for nutrient trend analyses and the winter period for marine waters is therefore defined as the period December up to and including February. The winter period for fresh surface waters runs from October up to and including March. To make interannual comparisons of N for marine waters as a measure of water quality (eutrophication) meaningful, the data is analysed for the months where biological activity is close to zero. The summer period runs from April up to and including September.

Variation in salinity

During the winter period, nutrients show a more or less conservative behaviour and a clear linear relationship with salinity; an increase in concentration with decreasing salinity (i.e. an increase with increasing distance from the river mouth). In order to compensate for differences in salinity at the various locations from one year to another (due to differences in yearly river discharges), nutrient concentrations are usually normalised for salinity (Bovelander and Langenberg, 2004).

For the present study on nutrient trends, no salinity correction was carried out for the results presented within the framework of the reporting guidelines. Consequently, the conclusions drawn from interannual in-depth studies on trends in nutrients presented in this way are affected by interannual differences in riverine water discharges (as a consequence of differences in rainfall etc.) and should be treated with care. Additional figures are therefore presented showing inorganic nitrogen concentrations after salinity correction for a number of locations 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). DIN is standardised to a salinity of 30 psu (Practical Salinity Units). The Dutch zone of the North Sea contains on average about 3.5% sodium chloride (NaCl) or about 35 psu. This presentation of data is in accordance with the OSPAR Comprehensive Procedure, and shows the long-term trend in inorganic nitrogen concentrations corrected for the effects of rainfall.

2.6 Monitoring status and trends in water used for drinking water production

2.6.1 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. Companies report results annually to the national Inspectorate for the Environment, which is a statutory obligation. Data management and reporting are carried out by RIVM. This report uses data on the quality of water resources and not the quality of the end product (tap water). The lag between measurement and effect on the water quality of water resources used for drinking water production is usually large. Details of the data collection are given in the next sub-section (§2.6.2), followed by a sub-section giving details of data processing (§2.6.3).

2.6.2 Data collection

Drinking water production in the Netherlands was carried out by 21 companies in 2001 (VROM, 2003). About 65% of the drinking water originates from groundwater (Joosten et al., 1998). There are about 200 groundwater production sites, of which 120 deliver from phreatic (unconfined) groundwater and 80 from confined groundwater. There are about another 30 sites where drinking water is produced from riverbank groundwater, dune infiltration groundwater and surface water (see Table 4). The average depth of the groundwater used for drinking water production for phreatic aquifers is 45 m, with an average depth for the upper part of the well screen of 30 m and for the lower part, 65 m.

2.6.3 Data processing

As for the processing of data for fresh surface water (§2.5.3), a supplemental database was made to tackle the problem of the changing number of drinking water production stations in the 1992-2002 period. This database was constructed in two steps. First, minor gaps were bridged. If no data was available for a specific station in a certain year, the average of the available values in the period ‘year – 2’ up to and including ‘year + 2’ was used as estimate. If no data was available in that period, the station was designated a ‘no data’ station. Secondly, all stations that were still missing data were removed from the database, so that only ‘data’ (measured or estimated) stations for all years remained.

The drinking water data is used in the chapter on groundwater (Chapter 5, §5.4) for production stations using phreatic and confined groundwater. The data is also used in Chapter 6 (included in the surface water database) for production stations making direct or indirect use of surface waters.

Table 4: **Number of sample locations for drinking water production in the Netherlands in the 1992–2006 period, with production sites identified according to type of water used, i.e. phreatic groundwater, confined groundwater, direct surface water intake, surface water after dune infiltration and surface water after river bank infiltration.**

Year	Phreatic groundwater	Confined groundwater	Surface water	Dune infiltration	River bank infiltration
1992	128	89	13	10	13
1993	126	88	13	11	14
1994	125	90	13	9	14
1995	122	87	14	9	15
1996	122	87	14	9	14
1997	120	88	13	8	14
1998	119	87	13	7	13
1999	116	87	13	8	13
2000	116	88	13	6	12
2001	112	83	10	6	12
2002	104	85	11	4	13
2003	107	83	9	4	13
2004	105	81	7	4	13
2005	101	78	3	6	12
2006	101	78	3	5	12

Figures giving annual averages and maxima for the 1992-2006 period are based on the supplemental database. The annual averages and maxima are calculated as average averages and average maxima of all drinking water stations.

The tables and maps showing the status for each period and trends between periods are based on the original database. For each drinking water station an average value, which may be based on between one and three annual average or maximum values, is calculated per period. Only the stations that have been monitored in both these periods are used as a comparison.

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3 Agricultural practice

3.1 Introduction

This chapter discusses the trend of agricultural practice in the Netherlands in general, and nitrogen and phosphorus use in Dutch agriculture in particular, for the 1992-2006 period. First presented are the changes in land use, number of farms, livestock etc. resulting from policy measures as well as autonomous developments (§3.2). The nitrogen and phosphorus balances of the agricultural system are discussed in §3.3, followed in §3.4 by a description of the other implications of the measures stipulated in the Code of Good Agricultural Practice (LNV, 1993a). The Dutch policy measures in the first (1995-1999) and second Action Programmes (1999-2003) will be summarised first. Here, two periods can be distinguished that do not coincide exactly with the Action Programme periods, i.e. 1996-1998 and 1999-2003. More details are given in the subsequent sections.

In the 1996-1998 period, the desired changes in agricultural practice were effectuated by limiting the amount of manure production (production rights) in combination with a system of manure bookkeeping on livestock farms. In this period the following regulations applied to all farms:
1. the maximum amount of minerals to be applied (application standards).
2. the period of the year in which application of manure was prohibited because of the risk of nitrogen leaching.
3. the way in which manure could be applied so as to reduce ammonia emission.
4. the covering of manure storage facilities to avoid ammonia emission.

A new system was introduced and developed in the 1998-2003 period. The system of manure bookkeeping was replaced in 1998 by the system of minerals accounting at farm level, based on the mineral balance of nitrogen (N) and phosphorus (P) (farm gate balance). In this system, limits are set on the level of the N and P surplus on farms (MINAS loss standards). The loss standards have gradually been tightened. For nitrogen, both N fertilisers and manure N were included in this system. At first (1998-2000) the minerals accounting system was only effective for the larger livestock farms (> 2.5 LU/ha). Since 2001, this system has been in effect for all farms. Lower loss standards for N also became effective for cultivated land on sand and loess soils vulnerable to nitrogen leaching.

On 1 January 2002, the Manure Transfer Contracts (MAO) system became effective in order to comply with the application standards for manure stipulated by 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, for example. For the calculation of the exceedance of the allowable manure production the application limit is 170 kg/ha N (implemented in phases), with a higher level of 250 kg/ha for grassland, in agreement with Dutch notification of derogation at that time. Farmers unable to enter into manure transfer contracts for their excess manure had to reduce their livestock numbers. Extensive advisory efforts and demonstration projects accompanied this policy change. In October 2003, MINAS was rejected by the European court of justice as an improper implementation of the Nitrate Directive, after which the Dutch government decided to abandon MINAS and the Manure contracting system. The MAO system was abolished in early 2005.

In January 2006 the Netherlands adopted a manure policy based on application standards instead of standards for mineral losses. The new manure policy, including application limits for nitrogen in manure and fertilisers as required by the Nitrate Directive, in general sets tighter limits on the use of nitrogen and phosphorus than the previous MINAS. The effect of this new policy cannot be evaluated in this report. The effects can only be seen in the 2006 data on farm management. The period of effectuation has been too short to detect any effects on water quality.

The new Dutch manure policy applies to all manure from animals kept for professional purposes or for profit. The new manure policy therefore has a wider influence than the old manure policy. For example, horse manure is included in the new regulation. There are also new regulations concerning manure and fertiliser application methods. The most important new regulations are;

- the period in which the application of manure is allowed
- regulations concerning the ploughing 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 5). The total land surface area is 3.38 million ha, with a cultivated area of 1.88 million ha (CBS, 2007). Land use in the different reporting periods is presented in the table below.

Table 5: Land use in the Netherlands *(x 1000 ha).*

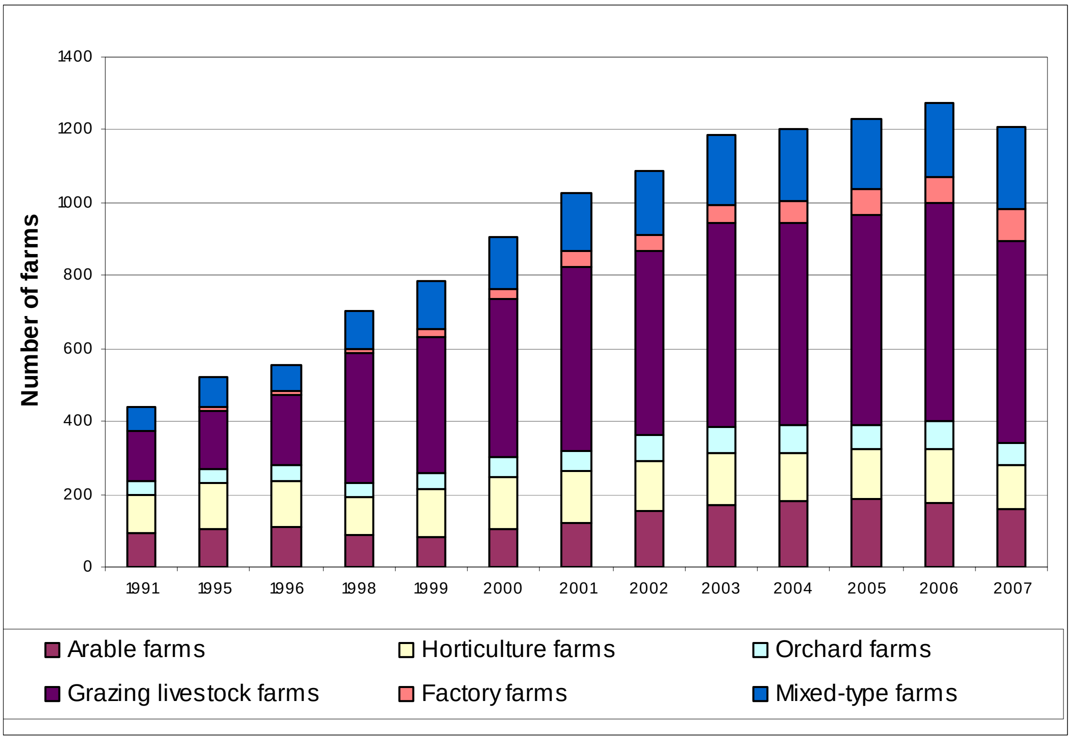
Land use	**1992-1995**	**1996-1999**	**2000-2003**	**2004-2007**
Grassland	1057	1033	998	988
permanent	1021	956	867	782
temporary[1]	36	77	131	206
Silage maize	224	227	210	225
Other arable crops	576	581	589	556
Horticulture	110	114	114	114
Total cultivated area	*1967*	*1954*	*1910*	*1883*
Fallow land	11	14	26	23
Nature and forest areas	452	478	484	484
Other land use	959	934	958	986
Total non-cultivated area	*1422*	*1426*	*1468*	*1493*
Total land surface[2]	*3388*	*3380*	*3378*	*3376*

[1] Grassland used by a farmer for less than five years.
[2] Data only available for 1993 (3,388,000 ha), 1996 (3,380,000 ha), 2000 (3,378,000 ha) and 2003 (3,376,000 ha).
Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?STB=T&LA=nl&DM=SLNL&PA=71284ned&D1=1-7,15-89,165,309,450-452&D2=a&HDR=G1&TT=2).

The total cultivated area steadily decreased during the 1992-2006 period as a result of land being claimed for nature development, the expansion of urban areas and the construction of roads. About 84,000 ha of cultivated land was consigned to other land uses in this period, corresponding to a decrease of 4.3%.

Organic farming
Figure 1 below shows the development in organic farming in the Netherlands.

Figure 1: Number of organic farms in the Netherlands



Source: Milieu en Natuurcompendium, 2008

The growth in organic farming at the end of the 1990s has not developed any further since 2004. In the period 2004-2007, the amount of organic acres remained stable: a slight growth in 2006 was again lost in 2007. In 2007 there were 39,656 ha of organic farm land. Organic agriculture represents 2.1 percent of Dutch agriculture (Milieu en Natuurcompendium, 2008).

3.2.2 Number of farms

The trend of the number of farms is presented in Table 6. The total number of farms decreased by 30% in the 1992-2007 period. There are differences in the extent of the decrease between farm types. The number of dairy farms decreased by 27%, horticultural farms by 34% and pig and poultry farms by 46%. The percentage of farms where farming is the main occupation of the farmer increased on average from 82% to 87%. This increase occurred for all farm types, except for arable farms where the main occupation percentage remained stable.

Table 6: **Total number of farms and number for each of the main farm types in the Netherlands per period[1].**

	1992-1995		1996-1999		2000-2003		2004-2007	
Arable farms	14718	*82*	14369	*81*	13007	*82*	12131	*82*
Horticultural farms [2]	22408	*87*	20205	*91*	17051	*93*	14445	*93*
Dairy farms [3]	56355	*81*	50691	*85*	45160	*87*	40612	*86*
Pig and poultry farms [4]	10997	*81*	9757	*84*	7285	*88*	5974	*89*
Combinations	12831	*79*	11229	*83*	8835	*86*	7312	*86*
Total[#]	117309	*82*	106251	*85*	91337	*87*	81717	*87*

[1] The percentage of farms where farming is the main occupation of the farmer is given in *cursive*.

[2] Including farms with permanent cultivation.

[3] Farms with cows and sheep (grazing animals).

[4] Farms with pigs, poultry and/or intensive veal calves.

Due to rounding off, total may differ from summation.

Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?STB=G1,G2&LA=nl&DM=SLNL&PA=71466ned&D1=0&D2=a&D3=0&HDR=G3,T&TT=2).

3.2.3 Livestock numbers

The trend in the number of heads of livestock in the Netherlands in the 1992-2006 period is given in Table 7. The figures concern the number of heads and not livestock units. The number of cattle and pigs both decreased by 21% in this period, while the volume of the poultry livestock decreased by 3.6%, having shown an increase until 2003. The maximum number of dairy cows is fixed by the milk quota. Due to an increase in milk production per cow, the number of cows needed to produce the amount of milk permitted by the quota decreased.

Table 7: **Livestock numbers (in millions) in the Netherlands.**

	1992-1995	1996-1999	2000-2003	2004-2007
Cattle	4.8	4.4	3.9	3.8
Pigs	14.5	14.2	12.3	11.4
Poultry	94.2	97.0	96.2	90.8
Sheep/goats	1.9	1.6	1.5	1.6

Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?LA=nl&STB=T&DM=SLNL&PA=71284ned&D1=421, 441,445,493,509&D2=a&HDR=G1&TT=2).

3.2.4 Manure and phosphorus production

Manure nitrogen production per head decreased for all animal species in the 1992-2006 period (see Table 8). This is mainly due to a combination of a reduction in the nitrogen content of fodder and an increase in fodder conversion efficiency. The calculated amount of produced nitrogen per head is larger than the amount of manure nitrogen applied to the soil (see Figure 2) because part of the nitrogen is lost via volatilisation during storage and application.

Table 8: Gross nitrogen excretion per animal category (*kg N per animal per year).*

	1992-1995	1996-1999	2000-2003	2004-2006
Dairy cow	141.0	137.0	128.6	128.8
Young cow (1-2 yr.)	93.0	91.5	81.2	75.7
Pigs for meat production	14.6	13.6	12.0	12.0
Sow (with piglets)	31.3	30.4	30.3	30.1
Chickens for meat production	0.61	0.59	0.53	0.53
Laying hens	0.86	0.73	0.68	0.71

Source: CBS, 2007 (http://www.cbs.nl/nl-NL/menu/themas/natuur-milieu/publicaties/artikelen/archief/2007/2005-dierlijke-mest-en-mineralen-art.htm).

Cattle are responsible for about 61% of the total nitrogen production by Dutch livestock (see Table 9). Pigs contribute about 21% and poultry about 12% to the total nitrogen production by livestock. The total annual nitrogen production by livestock amounted to 456 million kg in the 2004-2006 period, which is about 30% lower than the production in the 1992-1995 period. This decrease was caused mainly by a decrease in nitrogen production by cattle (-33%) and pigs (-36%) as a consequence of a decrease in nitrogen production per head and a decrease in the livestock volume.

Table 9: Manure nitrogen production[1] (*million kg N per year).*

	1992-1995	1996-1999	2000-2003	2004-2007*
	million kg N per year			
Cattle (excl. calves)	409	364	302	276
Calves	8	10	12	12
Pigs	153	139	107	98
Poultry	71	66	58	56
Horses. ponies	5	6	6	7
Other (sheep, goat, fur-bearing animal etc.)	24	22	19	14
Total livestock[#]	669	607	504	463

[1] Including evaporation of ammonia and other nitrogen compounds.
* Preliminary figures for 2006 and 2007.
[#] Due to rounding off, total may differ from summation.
Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?STB=G1,G2&LA=nl&DM=SLNL&PA=37767&D1=67-68,79-80,118-119,121-122,130-131,139-140&HDR=T&TT=2).

The phosphorus production of Dutch livestock decreased by about 27% between the first and fourth reporting period (see Table 10), and is mainly due to a decrease in phosphorus production by pigs and cattle. In the 2004-2006 period, half the production was accounted for by cattle, a quarter by pigs and less than one sixth by poultry.

Table 10: Manure phosphorus production (*million kg P per year).*

	1992-1995	1996-1999	2000-2003	2004-2007*
	million kg P per year			
Cattle (excl. calves)	49	42	40	37
Calves	1	2	2	2
Pigs	29	24	19	18
Poultry	15	13	13	11
Horses, ponies	1	1	1	1
Other (sheep, goat, fur-bearing animal etc.)	3	3	3	2
Total livestock#	97	85	77	72

* Preliminary data over 2006 and 2007.
# Due to rounding off, total may differ from summation.
Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?STB=G1,G2&LA=nl&DM=SLNL&PA=37767&D1=67-68,79-80,118-119,121-122,130-131,139-140&HDR=T&TT=2).

3.3 Nutrient balances

3.3.1 Nitrogen balance of the agricultural system

Figure 2 depicts the N flows in the Dutch agricultural system for the year 2005. This balance combines the balance of the livestock production system with the soil surface balance.

Inputs are imported fodder, purchased fertilisers and a number of smaller inputs, including atmospheric nitrogen deposition from other sources in the Netherlands and from abroad (mainly as NO_x). The output is represented by a combination of the sale and export of agricultural products, the export of manure, and the emission and transport of ammonia via the air. The figure illustrates the importance of the different flows. There are two important return flows; first, the harvested crops, used as fodder for livestock and, second, the atmospheric deposition of ammonia from manure and fertilisers on cultivated soil.

The difference between input and output is the surplus on the national farm gate balance (shaded blue), along with the surplus on the national surface balance (shaded yellow). The difference between these two surpluses, due to a difference in the calculation of excretion and of manure production, is about 6% (see § 2.2.3).

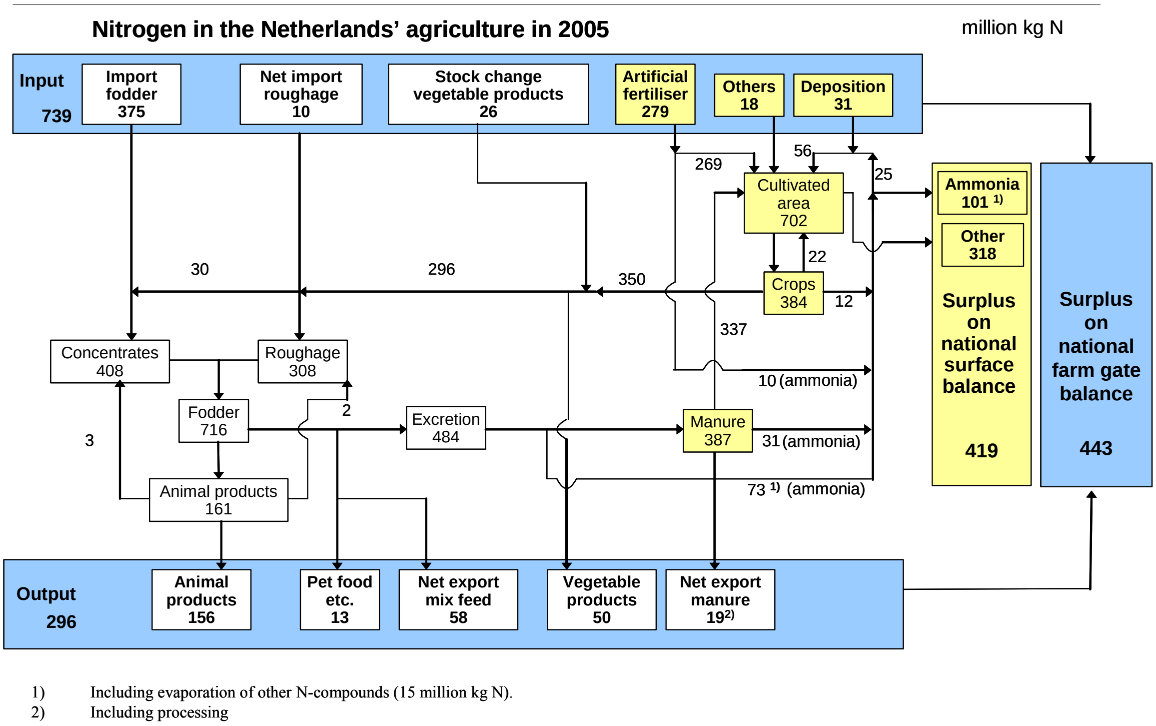


Figure 2: N flow diagram of the Dutch Agricultural system, 2005.

Source: CBS, 2007, (http://www.cbs.nl/nl-NL/menu/themas/natuur-milieu/publicaties/artikelen/archief/2007/2005-mineralen-in-de-landbouw.htm).

3.3.2 Soil surface nitrogen and phosphorus balance

The 'soil surface balance' for nitrogen is given in Table 11 for the four reporting periods. The surplus of this balance is the net input to soil. The nitrogen surplus is on average 323 million kg for the 2004-2006 period, which is 11% lower than in the preceding period. The surplus given in Table 11 is similar to the item 'other' for the surplus on the national surface balance in Figure 2. The effect of this surplus on the environment, i.e. the fate of the N surplus, can not be explained on the basis of statistical data. The surplus may partly leach into groundwater and/or surface water, or may partly be denitrified.

The connecting link between the 'soil surface balance' and the 'farm gate balance' approach, presented in other sections, is the production of manure. In the flow diagram in Figure 2, excretion is computed as the difference between consumed fodder and national agricultural production. The manure production is also computed per animal in a similar way and multiplied by the total number of animals.

Table 11: **Nitrogen soil surface balance for total cultivated area (*million kg N per year*).**

	1992-1995	1996-1999	2000-2003	2004-2006*
Input[1] as:				
Manure	495	448	367	333
Fertilisers	382	384	296	276
Atmospheric deposition	75	78	62	56
Other[2]	39	39	39	40
Total input	991	948	763	705
Total output (harvested crops)	481	450	399	382
Surplus	510	498	364	323

[1] Ammonia emission from manure and fertilizer is excluded.
[2] Includes: crop residues, seeds and plant materials and other organic fertilisers (compost).
* Preliminary figures over 2006.
Source: CBS, 2007
(http://statline.cbs.nl/StatWeb/Download.asp?STB=G1,G2&LA=nl&DM=SLNL&PA=37502&D1=0-1,7,22,37-38,41-42,49-50&D2=0-1&D3=a&HDR=T&TT=2).

The nitrogen input to the cultivated soil accounts for all input items including atmospheric deposition, organic nitrogen fixation and smaller items such as N-containing pesticides. The largest inputs are manure and fertilisers, which are corrected for ammonia emission during grazing and application.

The total nitrogen input given in Table 11 shows a decrease of about 8% between the 2000-2003 period and the 2004-2006 period and of 20% between the 1996-1999 period and the 2000-2003 period. This is larger than the 4% decrease between the 1992-1995 and 1996-1999 periods. The largest input term (manure) shows a decrease of almost 33% between the first and last periods, whereas the fertiliser input is almost 28% lower. The nitrogen output consists entirely of the crops harvested from the fields. The harvest differs from year to year due to variable weather conditions. It is plausible that nitrogen uptake has decreased, but there is no indication that crop production has decreased as a result of lower nitrogen fertilisation. The nitrogen output decreased by 21% between the first and last periods.

The soil surface balance for phosphorus for the four reporting periods is given in Table 12. The main input items are manure and, to a lesser extent, artificial fertiliser. Both are reduced by almost 33% in the 1992-2006 period. As the output via harvested crop was only reduced by 13%, the surplus was reduced by more than 47%.

Table 12: **Phosphorus soil surface balance for total cultivated area (*million kg P per year*).**

	1992-1995	1996-1999	2000-2003	2004-2006*
Input as:				
Manure	93	81	70	64
Fertilisers	30	29	24	20
Other[1]	5	4	5	5
Total input	128	114	98	89
Total output (harvested crops)	60	56	55	52
Surplus	68	58	43	36

[1] Includes: crop residues, seeds and plant materials and other organic fertilisers (compost).
* Preliminary figures for 2006.

Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?STB=G1,G2&LA=nl&DM=SLNL&PA=37502&D1=0-1,7,22,37-38,41-42,49-50&D2=0-1&D3=a&HDR=T&TT=2).

In order to show the effects of weather and other influences in a broader perspective, trends in nitrogen and phosphorus surplus from 1970 onwards are plotted in Figure 3 using 1970 as a reference year (index 1970 = 100%; first year for which nutrient balances are calculated).

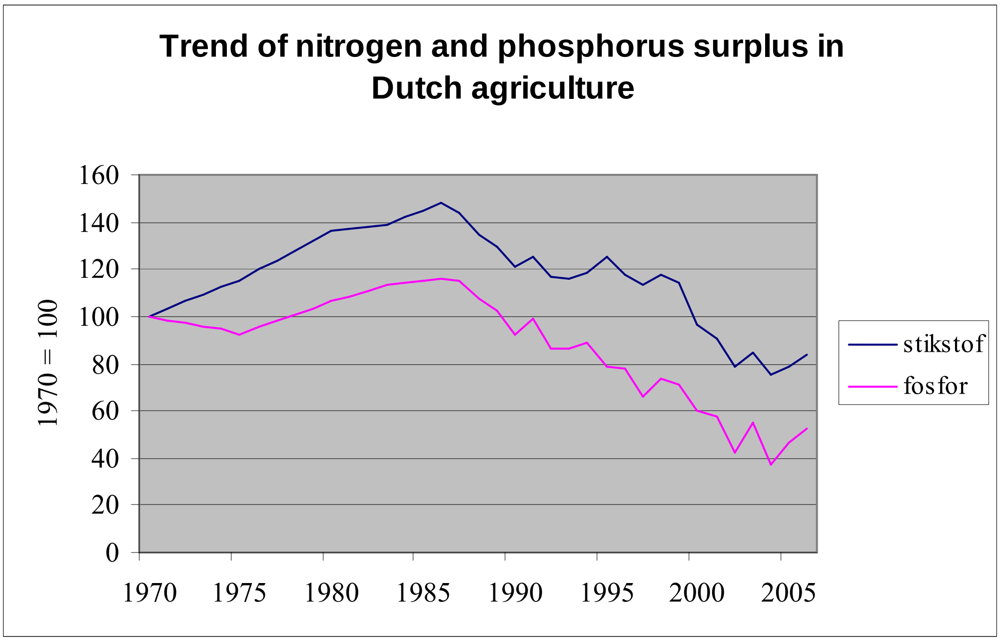


Figure 3: Trend of the nitrogen and phosphorus surplus in Dutch agriculture in the 1970-2006 period, with the 1970 value fixed at 100.
Source: CBS, 2007 (http://www.cbs.nl/nl-NL/menu/themas/natuur-milieu/publicaties/artikelen/archief/2007/2005-mineralen-in-de-landbouw.htm).

The nitrogen surplus shows an almost continuous decrease in the 1986-1990 period. This trend stagnates in subsequent years (1991-1998) and the year to year fluctuations in Figure 3 can be mainly attributed to weather-based fluctuations in crop production. The nitrogen surplus decreases substantially after 1998. This can be largely attributed to the new regulatory system based on the farm gate balance (MINAS) introduced in 1998, especially for dairy farms which reduced the use of nitrogen fertiliser by 40-50% (Fraters, 2004). The phosphorus surplus shows an almost continuous decrease over the entire 1986-2002 period. This decrease is mainly a result of the decrease in manure produced by reduced livestock numbers and more efficient feeding practices (see Table 10). From 2002 onwards, the decrease in the nitrogen and phosphorus surpluses has stagnated. Figure 3 shows subsequent increases and decreases resulting in a slight increase in 2006 compared with the 2002 results. These fluctuations are probably related to weather fluctuations, resulting in higher crop production in 2002 and 2004.

3.4 Developments in agricultural practice

3.4.1 Introduction

The previous section dealt with the use of nitrogen and phosphorus. The present section deals with other aspects of the code of Good Agricultural Practice. First, attention is paid to the regulations with regard to total nitrogen use and manure application, including manure transport, the method and period of application, fertilisation close to waterways, winter cover crops and irrigation (§3.4.2). Figures are then given showing manure storage capacity in the Netherlands (§3.4.3), after which efforts taken with respect to fertilisation advice, demonstration projects and counselling (§3.4.4) are discussed, as well as other developments (§3.4.5), such as winter cover crops, irrigation and limiting of ammonia emissions. Consideration is given in the final sub-sections to compliance with the code of Good Agricultural Practice, the Mineral Accounting system and Manure Transfer contracts, and other aspects of agricultural regulations (§3.4.6).

3.4.2 Regulation of manure application and nitrogen surplus

Application and surplus standard

Legislative measures were taken during the reporting period to limit the maximum quantity of livestock manure that could be applied to the land. Moreover, rules were drawn up with respect to the period and manner in which the livestock manure could be applied. The use of livestock manure was also further limited by means of the manure legislation. This was caused by a tightening of the application standards based on the phosphate content of the manure, prescribing a maximum level for the use of livestock manure (see Table 13). In this way, the maximum nitrogen emission via livestock manure was also further limited.

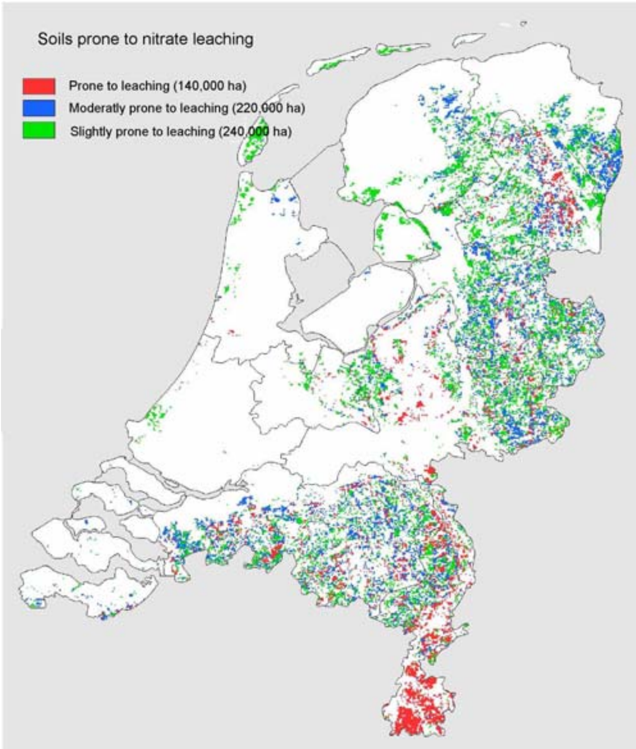
Table 13: Manure application standards in the 1987-2000 period in kg/ha P_2O_5.

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.

In 1998, the Dutch government introduced the mineral accounting system (MINAS). This system regulates the N and P surplus of farms (farm gate balance). A certain amount of N and P surplus is considered to be acceptable and is free of levy. This amount is defined as the loss standard. When farmers have a surplus that exceeds these loss standards they have to pay a levy. These levies have been progressively raised between 1998 and 2003. The MINAS system was introduced in phases. Firstly (in 1998), it applied to high animal density livestock farms (> 2.5 LU/ha). In 2001, it applied to all farms. The levy free loss standards for N in 1998-2002 are given in Table 14.

The MINAS system had a greater impact than the previous system, which focused only on manure. The MINAS system included the regulation of fertiliser nitrogen and nitrogen fixation by legumes (arable land only). Since 2002, special lower nitrogen loss standards are introduced for farms with soils prone to nitrate leaching. In total, 140,000 ha soils prone to nitrate leaching have been designated (see Map 1).



Map 1: Map showing the soils prone to nitrate leaching in the Netherlands (red areas).
Source: LNV, 2001a.

Table 14: Nitrogen loss standard in the 1998-2002 period in kg/ha as N, for arable land and grassland on clay, peat, sand and loess soils[1].

	Grassland		Arable land	
Year	All	Sand[1]	All	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

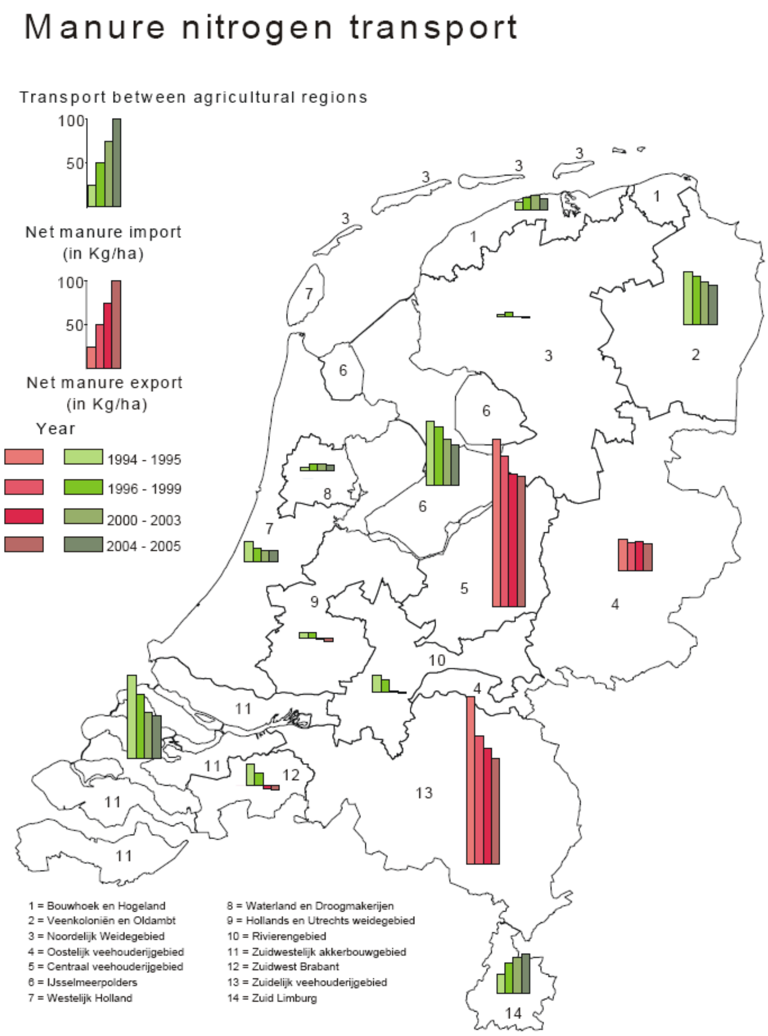
1 Vulnerable soils are sand and loess soils prone to nitrate leaching, or soils with groundwater levels at greater depth than average.

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

Transport and disposal of manure
Due to the tightening of the application standards for livestock manure, increasing amounts of livestock manure had to be transported from farms with a nitrogen surplus to other farms where there was space to accommodate this. Initially, as much of this 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 therefore a surplus at a regional level. Map 2 gives the average distance of this long distance transport for the years 1994-1995, 1996-1999, 2000-2003 and 2004-2005, expressed as the quantity of nitrogen per hectare. A net import (blue) means that on balance, more nitrogen was imported into an area in the form of manure, and a net export (red) means that on balance, nitrogen was exported from the area concerned.

This map shows that manure transport mainly takes place from the Central Livestock Area; no. 5 on map, and the Southern Livestock Area; no. 13, to the South-Western Arable Area; no. 11, the IJsselmeerpolders (Lake IJssel polders); no. 6 and to Veenkolonieën and Oldambt (Reclaimed Peat Areas); no. 2. A steady decrease in transport can be noted in almost all regions with considerable net transport (regions 2, 4, 5, 6, 7, 10, 11, 12 and 13). An exception is South-West Limburg, where an increasing amount of manure is imported.



Map 2: Manure nitrogen transport.

Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?STB=G1,G2&LA=nl&DM=SLNL&PA=7311slmi&D1=63&D2=27-40&D3=a&HDR=T&TT=2).

Manure application, method and period

In the 1993 to 1997 period, both the period and the method of manure application were subjected to an increasing number of limitations. The rules for the method of application were specifically targeted at limiting the emission of ammonia to the atmosphere (see § 3.1). (see Map 3) took place according to the legislation as illustrated in Figure 4. Since 1995, manure application on sand and loess soils manure can only be spread on these soils between 1 February and 1 September, and in a low ammonia-emission manner. On grassland in clay and peat areas manure may be spread until 15 September. On arable land on clay, manure may be spread throughout the entire year as long as this is done in a low ammonia-emission manner.

Map 3: Map showing the sand and loess areas in the Netherlands (yellow areas).
Source: LNV, 1991

In addition to the requirements for the period of manure application, such as those stated above, the application of manure to ground partially or completely covered with snow has been prohibited in the Netherlands since 1994. This ban was extended in 1998 to include the spread of livestock manure on completely or partially frozen ground (though this rarely occurred in practice due to the requirement to incorporate the manure into the soil).

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 the low ammonia-emission application of livestock manure is heavy and therefore causes a lot of damage to the grass and soil structure under wet conditions.

Since 2006 manure spread on arable land has to be incorpotated directly under the ground, before it was allowed to spread first and later incorporate it into the soil.

Fertilisation close to waterways
The requirement to spread manure in a low ammonia-emission manner not only limits the ammonia emission and the associated nitrogen deposition, but also has a favourable effect on surface water quality. With the aid of low ammonia-emission application techniques, the manure is better spread and incorporated in or under the sods. This prevents surface run-off and direct entry of the manure into watercourses.

In addition, the ban on manure application on sand and loess soils during the winter months has prevented the application of manure during the wettest period. As a result, the chance of nitrogen entering watercourses due to surface run-off has been limited.

Since 2000, watercourses have also been protected against pollution by means of the Discharge Open Cultivation and Livestock Farming Decree, which includes rules concerning the manner (distance) of manuring in the vicinity of watercourses. A strip of ground next to a watercourse, a so-called buffer strip, may not be manured. The width of this buffer strip varies from 0.25 m to 6 m (in special cases up to 14 metres) and is equivalent to the width of the strip which may not be sprayed with pesticides. When spreading fertilisers along watercourses and/or their buffer strips it is obligatory to use a limiter for boarder spreading to prevent the fertiliser from entering the watercourse and its buffer strip. These rules are usually complied with; on about 91% of farms the buffer strip has the required width (Vroomen and Van Veen, 2004).

3.4.3 Storage capacity of manure

According to the Dutch Manure Policy 2006 Dutch farms are obligated to be able to store their manure from the first of September until the first of March, i.e. for six months.

Table 15: Trend in available storage capacity (liquid manure) for several categories of livestock farms[1].

	1993	2003	2007
	%		
Dairy farms			
0-6 months	61	55	27
>6-9 months	21	35	51
>9-12 months	7	9	13
>12 months	2	1	8
unknown	9	0	1
Total	100	100	100
Intensive veal calf farms			
0-6 months	63	52	32
>6-9 months	11	23	27
>9-12 months	6	22	26
>12 months	2	3	11
unknown	18	0	4
Total	100	100	100
Pig farms			
0-6 months	46	25	14
>6-9 months	23	29	26
>9-12 months	23	37	36
>12 months	6	9	22
unknown	2	0	2
Total	100	100	100

[1)] Percentage of farms with a period average storage capacity for liquid manure expressed in months.

Source: CBS (landbouwtelling), data is only available for 1993, 2003 and 2007. The information is not collected on a yearly basis.

Table 15 shows the development in storage capacity for liquid manure, calculated in months of manure production at farm level, for farm types on which mainly liquid manure is produced. Due to the irregular collection of data, only one year of data is available from each period. There was a tendency between 1993 and 2007 for an increase in storage capacity. The class of less than six months of storage capacity decreased for all farm categories. In 2007, 73% of the dairy farms, 68% of the pig farms and 86% of the intensive veal calf farms had storage facilities sufficient for at least six months of manure production.

3.4.4 Fertilisation recommendations, advice and demonstration

Fertilisation advice, for arable crops as well as for grassland and other fodder crops, has only changed slightly in the last five years. Since 2006 however, much more distinction has been made between different crops and soil types concerning the standards for total nitrogen as far as policymaking is concerned (see § 3.4.2). In earlier years, arable crops were all treated equally within the MINAS system; this did not take into account the differences in mineral demand between crops.

3.4.5 Other developments

Winter cover crops

Winter grains on arable land play a favourable role in preventing nitrate leaching in the Netherlands. They are sown in the autumn and not manured until the spring. The area of green manure crops sown each year is highly variable and is dependent on the weather conditions in the autumn concerned. Table 16 shows the areas involved.

Table 16: Cultivated area in the Netherlands with crop cover in the winter period (not fertilised)[1].

	1992-1995		1996-1999		2000-2003		2004-2007	
	1000 ha							
Grassland [2]	1057	*54*	1033	*53*	998	*52*	988	*52*
Winter wheat	110	*6*	112	*6*	109	*6*	120	*6*
Winter barley	4	*0.2*	3	*0.1*	3	*0.2*	3	*0.2*
Green manure crops	14	0.7	3	*0.2*	2	*0.1*	1	*0.0*
Total [#]	1186	*60*	1151	*59*	1112	*58*	1109	*59*

[1] The percentage of the total area manured and/or fertiliser application from Table 5 in italic.
[2] Both permanent and temporary grassland (see Table 5).
[#] Due to rounding off, total may differ from summation.
Source: CBS, 2007 (http://statline.cbs.nl/StatWeb/Download.asp?STB=T&LA=nl&DM=SLNL&PA=71284ned&D1=18,22,67,451&D2=a&HDR=G1&TT=2).

After the cultivation of silage maize, grass or rye is increasingly being sown as a winter crop. This subsequent crop is not manured and its purpose is to assimilate the nitrogen that the silage maize did not. No systematically collected data was available on the area of winter crops sown after the cultivation of silage maize. From 2006 onwards it has been obligatory to sow a winter crop after the cultivation of silage maize on sandy soils.

Irrigation
Irrigation in the form of temporarily submerging plots of land does not take place in the Netherlands. If crops experience a lack of water, a sprinkling irrigation system needs to be used. For the 1992-1999 period, between 123,000 and 309,000 ha were irrigated in the Netherlands on one or more occasions during a year (see Table 17a), i.e. between 7% and 17% of the manured cultivated land (Hoogeveen et al., 2003). The irrigated area is larger in dry years and smaller in wet years. In 1997, almost 60% of the sprinkling was on grassland, followed by 13% on potatoes and 7% on outdoor vegetables (Meeusen et al., 2000). Data for the years 2001 to 2006 is obtained from the LEI (see Table 17b). 2001, 2002 and 2005 were wet years and less irrigation was therefore required.

Table 17a: Cultivated area (*1000 ha) sprinkled on one or more occasions a year in the Netherlands in the 1992-1999 period.

Year	1992	1996	1997	1998	1999
Type of weather		Dry		Wet	Average
Acreage (* 1000 ha)	265	309	198	123	161

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

Table 17b: Cultivated area (*1000 ha) sprinkled on one or more occasions a year in the Netherlands in the 2001-2006 period.

Year	2001	2002	2003	2004	2005	2006
Type of weather	Wet(?)		Dry			Dry
Acreage (* 1000 ha)	22	69	278	105	82	180

Source: LEI, 2008, LEI Farm Accountancy Data Network, years 2001-2006.

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

In 1997, 17% of farmers used an irrigation planner, with which the optimum quantity of water to be applied can be determined. This saves water and prevents unnecessarily high emissions of nutrients (as a result of which leaching could occur). The use of planners is stimulated by several provinces (where dry sandy soils are prevalent) and this is where they are used most (Meeusen et al., 2000).

Limiting the ammonia emission

Part of the nitrogen emission from agriculture occurs in the gaseous form, for example, ammonia. Most of these gaseous nitrogen compounds eventually end up in the soil and water via deposition from the atmosphere. A series of government measures has limited the emission via this route. As a consequence of this the non-emitted nitrogen now remains in the manure.

An overview of the pattern of ammonia emission since 1985 is given in Table 18a and 18b. During the previous reporting periods the ammonia emission decreased with 49% (Table 18a). Comparing data from 2003 until 2006 (Table 18b) shows a stabilisation of the emission, therefore we suspect no further decrease during this last reporting period. This is consistent with the fact that during the last period no further policy measures have been implemented to reduce the ammonia emission.

Table 18a: NH_3 emission from agricultural sources (million kg NH_3)*.

	1985	1990	1995	2000	2001	2002
Manure	226	210	166	128	120	114
Stable and storage	86	89	89	73	64	63
Manure application	125	105	62	45	46	43
Grazing	16	16	14	10	10	8
Fertilisers	12	13	13	11	9	9
Total#	239	223	179	139	129	123

Due to rounding off, total may differ from summation.
* Data presented in previous report.
Source: CCDM, 2004

Table 18b: Recent data about NH3 emission from agricultural sources (million kg NH3).

	2003	2004	2005	2006*
Total	122	120	120	120

* Draft results
Source: Milieubalans, 2004-2007.

From the last years only total data have been registered. No further investigation has resulted in detailed data as presented in the previous report.

3.4.6 Compliance with manure legislation in 2006

The new manure legislation resulted in 500,000 euros of penalties in 2006 and 2007. In addition, 300,000 euros of conditional penalties have been imposed, on a daily basis in the case of non-compliance. Most violations are due to non-compliance with the application norms, usually because the administration is insufficient, incorrect or not completed on time (Dienst Regelingen, 2006).

For the implementation of the new manure policy, Programmed Enforcements are being used. The new policy is based on the following standards:

- Primary standards
  - Application norm nitrogen
  - Application norm phosphate
  - Application norm manure
- Secondary standards
  - Duty to account for the manure
  - Time of application manure and organic fertilisers, and other regulations manure and organic fertilisers
  - Administrative obligations, determination of amount, minimum storage of manure
  - Check on number of animals being held compared to the rights to keep animals

- Tertiary standards
  - Check on compliance of the administrative obligations that are of importance for the check on the primary and secondary standards

The information in Table 19 is taken from the document 'Evaluerend verslag van de handhaving van het mestbeleid, Jaaroverzicht 2006'. No information is given in this document about the checks on the primary standards, and so the focus is on the checks on the tertiary and secondary standards. There are two main target groups; the farmers and the manure transporters. Table 19 provides an overview of the checks for these groups.

Table 19: Summary compliance manure policy 2006.

Description target group	Size Target group	Standard	Results in numbers				
			random		select		
			Correct		Size control group	Correct	
			Yes	No		Yes	No
Manure transporters	1,400	Primary	n/a	n/a	n/a	n/a	n/a
		Secondary	15	2	8	6	2
		Secondary / Tertiary	-	-	3136	2765	371
		Tertiary	-	-	**2630**	**2341**	**289**
Farmers	84,500	Primary			-	-	-
		Secondary	**991**	**183**	**1343**	**906**	**437**
		Tertiary			**2390**	**1355**	**1035**
Total	86,000						

Besides the above-mentioned checks, preventive enforcements are also important instruments. These are instruments that focus on the increase in support for target group policies, such as communication, removing irritations, giving warnings to correct mistakes. Communication is an important instrument, i.e. brochures, newsletters, advertisements and information meetings (Dienst Regelingen, 2006).

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3.5 References

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4 Effects of Action Programme on farm management and water quality

4.1 Introduction

The effect of the Dutch Nitrates Directive Action Programmes on the contribution of nitrate from agricultural sources to receiving water and the effects of changing agricultural practice on this contribution is assessed in the Minerals Policy Monitoring Programme (LMM) by monitoring both farm management and on-farm water quality (see Chapter 2).

This chapter presents the results for the four main soil types in the Netherlands: sand, clay, peat and loess. The loess region was added to the LMM programme fairly recently (2002) and information gathered on this region therefore does not date back as far as that for the other regions. Each main soil type region consists of one or more areas. Agriculture in the sand regions accounts for about 46% of the agricultural area in the Netherlands, the loess region about 1.5%, the clay regions about 40% and the peat regions about 12.5%.

Regional results for the most common farm types, i.e. dairy farming, arable farming and other farm types, are shown for all main soil type regions as far as this is relevant. Farm management characteristics for each period are given in the next section (§4.2) and nitrate concentrations in on-farm water in §4.3. The reported periods for farm management characteristics and on-farm water quality differ by one year, e.g. farm management characteristics for 1991-1994 are compared with on-farm water quality for 1992-1995. It is assumed that on-farm water quality in year x is mainly related to farm practice in year x-1. Relationships between changes in farm management characteristics and nitrate concentrations in on-farm water are discussed in §4.4.

4.2 Farm management

Some general characteristics of the farms monitored are given for arable farms in Table 20, for dairy farms in Table 21 and for other types of farms in Table 22. It should be noted that farms of less than 10 ha are not included in the sample (see §2.3). The average size of the LMM farms is therefore slightly larger than the average of all Dutch farms.

Arable farms in the sand regions, which are on average about 97 ha, are slightly larger than those in the clay regions, which are on average 93 ha. The crop rotation also differs somewhat; potatoes and sugar beet account for 64% of the rotation in the sandy regions and about 32% in the clay regions. Arable farms are larger than dairy farms.

The size of dairy farms gradually expanded between 1992 and 2006 in all regions. Dairy farms in the sand and loess regions are smaller (an average of about 46 ha) than those in the clay and peat regions (an average of about 56 ha). The percentage of grassland is highest for dairy farms in the peat regions (92%) and lowest for farms in the sand regions (74%). The remaining area is mainly maize, except for the loess area where 10% is made up of other crops.

The group of other farms in the sand and clay regions is very different with respect to size and crop rotation. Livestock density is on average lower than on dairy farms and the use of manure shows a greater increase than on dairy and arable farms.

The general tendency over time is an increase in farm size, a decrease in livestock density and decrease in fertiliser use.

In the 1999-2001 period, the average use of manure nitrogen on arable farms on sand was 138 kg/ha, in clay regions 96 kg/ha. It fluctuated in both regions. Over the same period, the average use of manure nitrogen on dairy farms was about 237 kg/ha in the sand and clay regions and about 227 kg/ha in the peat and loess regions. No clear decrease occurred between 1996 and 2006, except for farms in the sand regions where the application of manure nitrogen was 109 kg/ha lower than in the 1991-1994 period. In the 2004-2006 period, other farms in the sand regions used about 401 kg/ha and other farms in the clay regions about 368 kg/ha. In both cases, this was clearly higher than in the previous period.

Fertiliser nitrogen use clearly decreased for all farms in all regions. Fertiliser use was higher on dairy farms (from 122 kg/ha in sand regions up to 135 kg/ha in clay regions) than on arable farms (from 86 kg/ha in sand regions up to 121 kg/ha in clay regions) and other farms (from 38 kg/ha in sand regions up to 94 kg/ha in clay regions).

The average storage capacity for manure is sufficient to store manure for six months; this is the longest period during which land application is prohibited (September - February) plus one extra month. The storage capacity has increased over time on dairy farms, but has shown a large variation over time for other types of farm (see Table 15).

Table 20: Arable farms in the Netherlands participating in the LMM; main characteristics of farming practice for farms in the sand and clay regions[1] for each of the reporting periods.

	Sand regions				Clay regions		
	92-95	96-99	00-03	04-06	96-99	00-03	04-06
Area (ha)	59	79	69	97	73	77	93
% potatoes	42	44	29	45	28	26	20
% sugar beets	21	20	24	19	16	14	12
% cereals	23	18	28	26	29	33	31
% other crops	14	17	19	11	28	27	36
Manure N (kg/ha)	120	132	120	138	91	53	96
Fertiliser N (kg/ha)	116	93	85	86	166	136	121
N soil surplus (kg/ha)	166	147	157	118	160	131	133

1 Arable farming is almost non-existent in peat regions; the LMM in the loess region started in 2002.

Table 21: Dairy farms in the Netherlands participating in the LMM; main characteristics of farming practice for farms in the sand, clay and peat regions[1] for each of the reporting periods. Table 21a sand and clay; Table 21b peat and loess.

Table 21a Dairy farms	sand 92-95	sand 96-99	sand 00-03	sand 04-06	clay 96-99	clay 00-03	clay 04-06
Area (ha)	32	37	43	48	42	49	53
% grassland	84	68	75	74	88	75	77
% maize	14	24	22	22	6	17	17
% other crops	2	8	3	4	5	7	7
Livestock (LU/ha)	2.8	2.7	2.2	2.1	2.4	2.3	2.0
Manure N (kg/ha)	346	308	296	237	289	300	237
Fertiliser N (kg/ha)	304	206	144	122	282	159	135
% manure storage [2]	95	105	112	138	98	82	140
N soil surplus (kg/ha)	426	267	204	174	332	217	157

Table 21b Dairy farms	peat 96-99	peat 00-03	peat 04-06	loess 00-03	loess 04-06
Area (ha)	39	50	59	41	46
% grassland	98	95	92	70	82
% maize	2	5	7	11	7
% other crops	0	0	1	19	11
Livestock (LU/ha)	2.0	2.0	2.0	1.7	2.0
Manure N (kg/ha)	249	254	228	210	226
Fertiliser N (kg/ha)	207	155	96	64	59
% manure storage [2]	63	117	141	105	102
N soil surplus (kg/ha)	352	266	132	83	90

1 LMM in the loess region started in 2002.

2 Percentage of total manure production over six months that can be stored on the farm

Table 22: **Other farms in the Netherlands participating in the LMM; main characteristics of farming practice for farms in the sand and clay regions[1] for each of the reporting periods.**

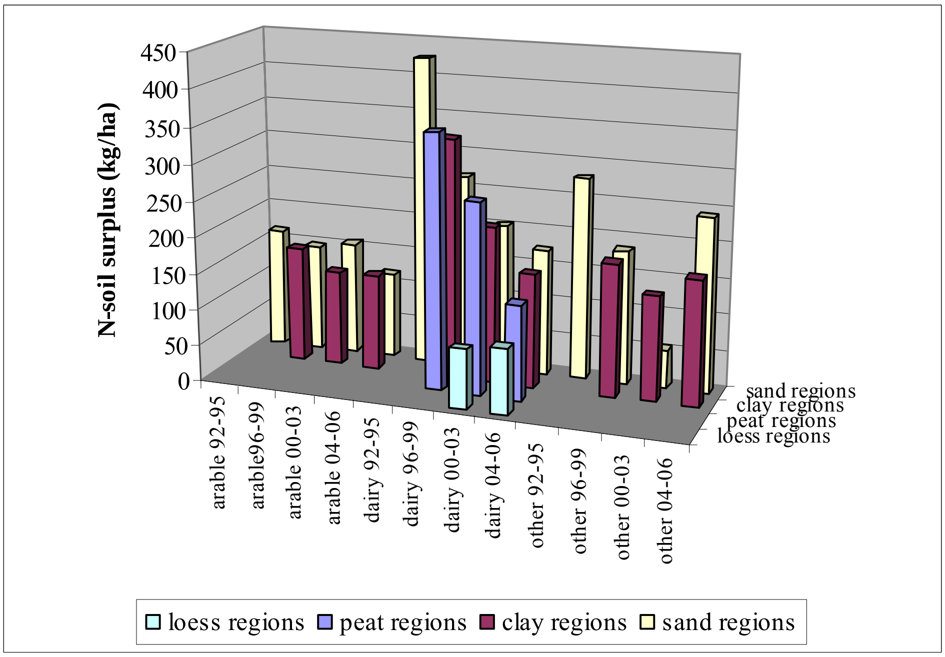
	sand 92-95	sand 96-99	sand 00-03	sand 04-06	clay 96-99	clay 00-03	clay 04-06
Area (ha)	18	36	41	24	61	37	97
% grassland	58	41	38	34	55	34	33
% maize	38	17	8	35	3	7	6
% potatoes, sugar beet, cereals	0	26	22	10	35	39	47
% other crops	5	16	32	21	6	20	14
Livestock (LU/ha)	2.4	2.2	0.8	0.7	1.9	1.0	0.1
Manure N (kg/ha)	397	263	208	401	168	237	368
Fertiliser N (kg/ha)	139	150	45	38	226	151	94
% manure storage [2]	142	90	105	136	61	123	173
N soil surplus (kg/ha)	279	184	54	241	183	145	173

1 Other farm types are rare in peat regions; the LMM in the loess region started in 2002. The number of other farms is very limited in both periods in clay regions and the data should therefore be treated with care.

2 Percentage of total manure production over six months that can be stored on the farm

The average nitrogen surpluses of farms monitored in the LMM differed between farm types and, to a lesser extent, between main soil type areas (see Figure 4). The decrease in nitrogen surplus is similar to the decrease shown in Figure 3 and is due to the decrease in the use of artificial fertilisers and, to a lesser extent, the use of manure (on the farm scale, a decrease in manure use is due to a reduction in the import of fodder and artificial fertiliser).

Figure 4: Average nitrogen farm gate balance surplus (LEI definition) of arable, dairy and other types of farms in the sand, clay and peat regions in the 1992-2006 period.



4.3 Nitrate in on-farm waters

4.3.1 Overview at national level

The average nitrate concentration in the upper metre of groundwater on farms differed between the main soil type areas and increased from peat to clay to sand (see Figure 5). Nitrate forms the main N component in on-farm groundwater in the sand regions (82-87%) and tile drain and groundwater in the clay regions (80-88%) (see Figure 7). Nitrate forms a minor N component in on-farm groundwater and ditch water in the peat regions (< 20%). Ammonium forms the main N component in groundwater in the peat regions (> 50%). Ammonium concentrations increase with depth in peat regions (Van der Grift, 2003) and are attributed to the mineralisation of organic material (Meinardi, 2005).

Differences in the status of and trend in nitrate concentrations were found between farm types and reporting periods (1992-1995, 2000-2003 and 2004-2006) within each area. In the sand regions, a decrease in nitrate concentration was measured during the first three periods in the groundwater of all farm types. During the last period, nitrate concentrations on arable farms and other farms rose slightly, whereas on dairy farms the concentration remained stable. The highest nitrate concentrations were measured in the groundwater of farms belonging to ‘other farms’, i.e. pig and poultry farming and mixed farming (animal husbandry and crop farming) (see Figure 6). In the first reporting period, the nitrate concentration was higher on dairy farms than on arable farms, whereas in the last reporting periods it was the other way around.

In the clay regions, a decrease in nitrate concentration was observed on dairy farms between the second and third periods, while the concentration on arable and other farms stayed the same, though the number of farms that joined this programme is not representative (see Figure 6). Measurements in the fourth period showed an increase in the beginning of the period followed by a decrease in nitrate concentrations on all farm types (see Figure 8). The highest nitrate concentrations are observed on dairy farms in the sand region, though these decreased considerably after the second period (see Figure 6).

In peat regions, the low average nitrate concentrations show a similar trend to those of clay regions, with a decrease during the 2000-2003 period followed by an increase during the 2004-2006 period (see Figure 8).

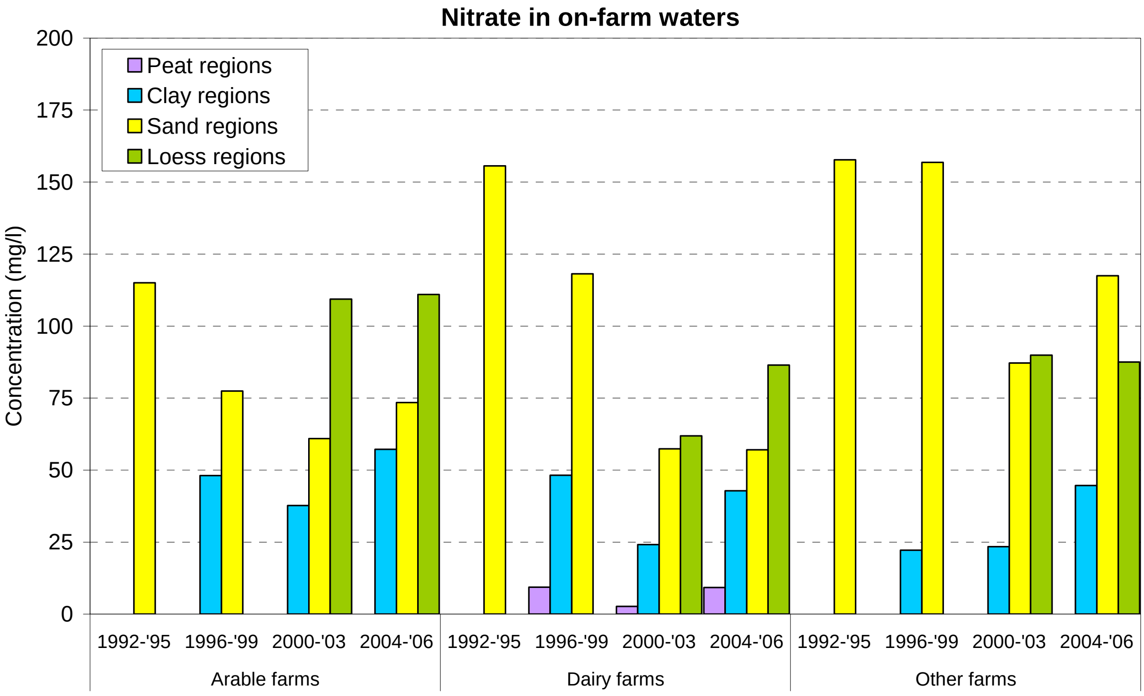


Figure 5: **Average nitrate concentration in the upper metre of groundwater (peat, sand) or tile drain water and groundwater (clay) or soil moisture (loess) of arable, dairy and other types of farms in the 1992-2006 period.**

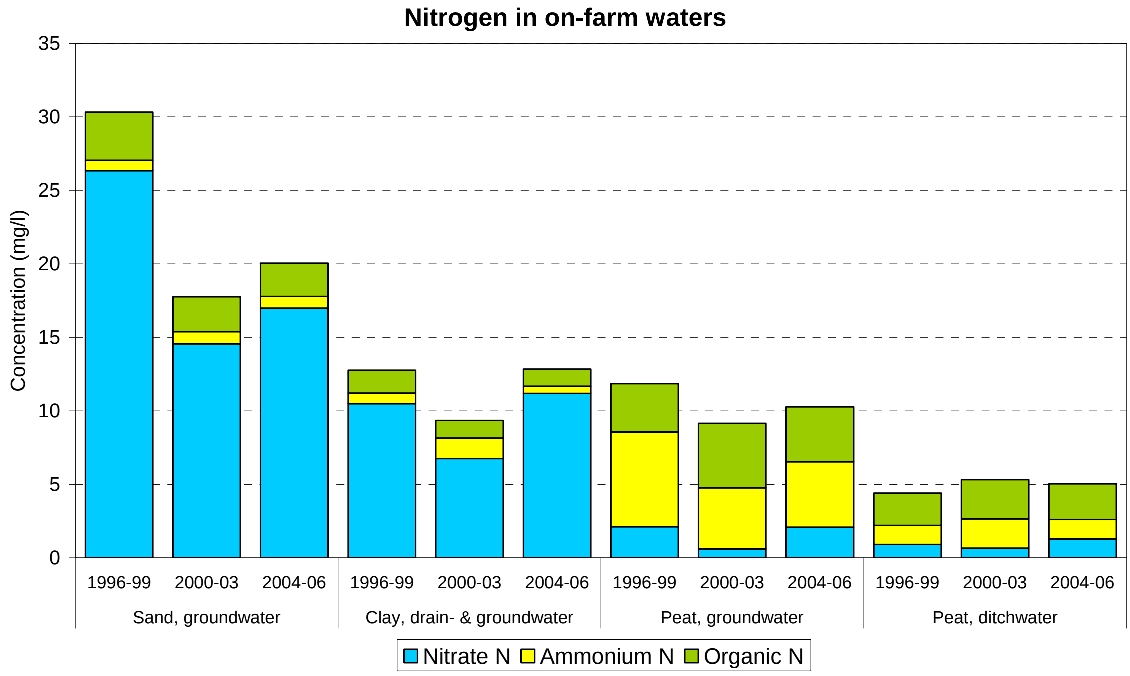


Figure 6: **Nitrogen concentration (mg/l) in on-farm waters of farms in the sand, clay and peat regions of the Netherlands for the 1996-1999, 2000-2003 and 2004-2006 periods.**

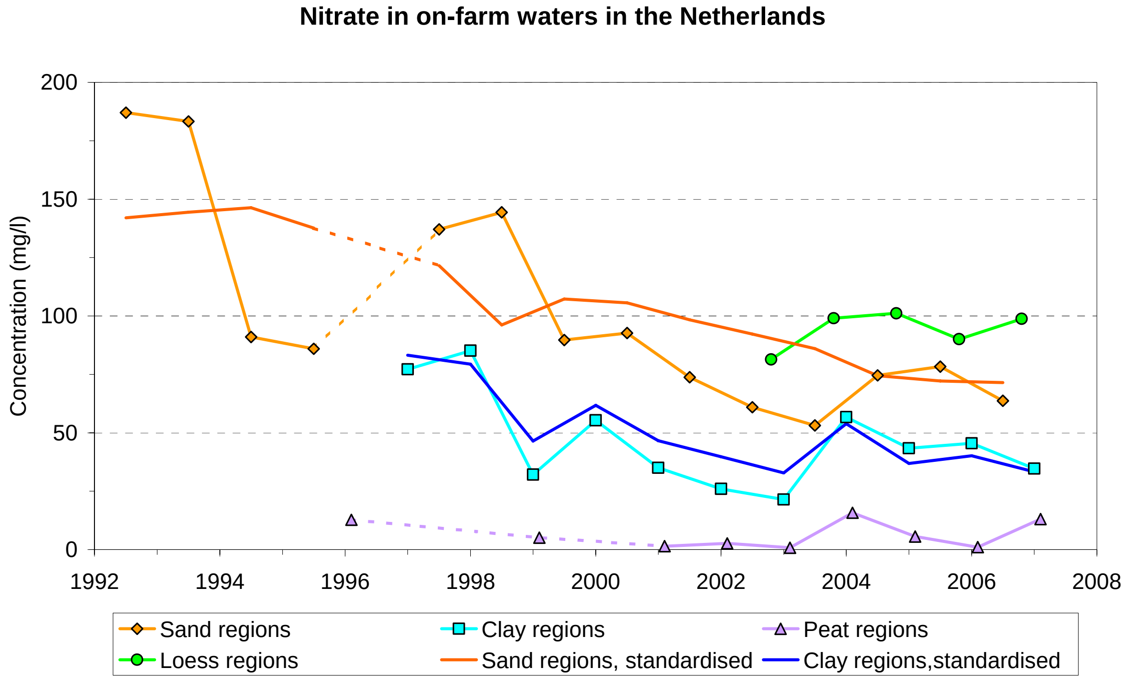


Figure 7: **Nitrate concentration (annual average of measured concentration and computed standardised concentration) in the upper metre of groundwater within 5 m of the soil surface (peat, sand) or tile drain water and groundwater (clay) of farms for the period 1992-2006.**

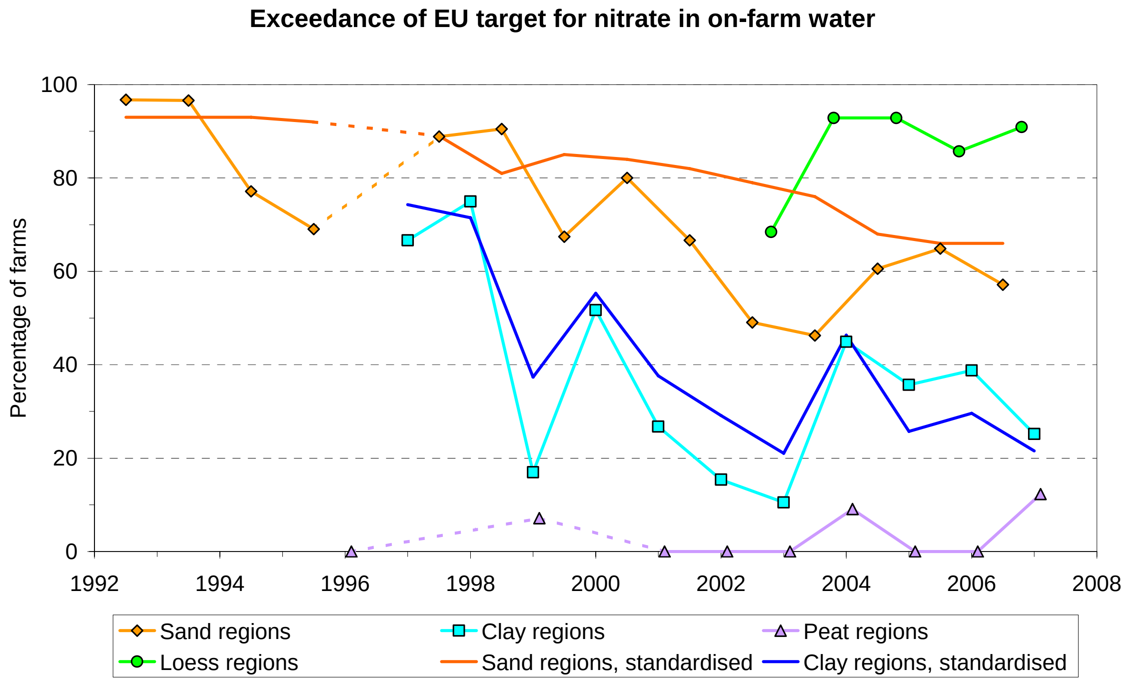


Figure 8: **Exceedance of the EU target value of 50 mg/l for nitrate in the upper metre of groundwater within 5 m of the soil surface (peat, sand, loess) or tile drain water and groundwater (clay) of arable, dairy and other types of farms in the 1992-2006 period.**

Measured nitrate concentrations in on-farm water in the sand and clay regions showed a clear decrease in the 1992-2003 period, followed by a marked increase during the 2004-2005 period. It looks as though the concentrations decreased again from 2005 onwards, though not enough data is available to be able to speak of a clear trend (see Figure 7). The loess region showed a trend similar to clay and sand regions for the 2002-2006 period. No clear trend can be seen for farms in peat regions; the slightly higher concentrations in 2004 and 2007 are due to measurements on farms with a higher component of sand in the soil profiles.

There was a large variation in average nitrate concentration between different years. These differences were mainly due to differences in precipitation surplus, which caused differences in the magnitude of dilution and the depth of the groundwater table (Boumans et al., 2001; 1997). An increase in the groundwater table leads to an increase in the rate of denitrification. Furthermore, there were changes in the group of farms monitored, either due to farms ceasing operation and being replaced or to farms being involved in the buying, selling and exchange of land. These changes led to changes in the soil type fraction, for example, an increase in the fraction of peat soil on farms within the sand regions led to a decrease in measured nitrate concentrations. A statistical model approach has been developed to detect the effects of the Minerals Policy and to filter out these confounding factors from the effects of the changes in farm practice on the nitrate concentration (Fraters et al, 2004).

There was a clear decrease in standardised nitrate concentration in on-farm water for farms in the sand regions, from about 135 mg/l in the 1992-1995 period to about 75 mg/l in the 2004-2006 period. The standardised nitrate concentration in the clay regions also showed a decrease, although the series of data for representative farms is rather limited (see § 2.3.2).

The percentage of farms with a nitrate concentration in on-farm water higher than the EU target value of 50 mg/l showed a similar tendency (see Figure 8). The target value was more frequently exceeded in the sand regions than in the clay regions and very rarely in the peat regions. There was a strong decrease in exceedance after 1998, partly due to confounding factors. Nevertheless, the computed exceedance of the target value based on the average annual standardised concentration also showed a decrease. The standardised exceedance in the sand regions decreased from about 95% in the 1992-1995 period to about 65% in the 2004-2006 period.

The following sections provide details for each of the main soil type areas using, for example, other cumulative frequency diagrams. Although this type of diagram is very informative, it needs some explanation. This section explains how to read such a diagram, using Figure 10 as an example. From the diagram it can be deduced that about 20% of the monitored arable farms show an average nitrate concentration lower than the EU target in the 2004-2006 period, while 80% show a higher concentration. Follow the horizontal 50 mg/l line (EU target) from the y-axis until it crosses the cumulative frequency line of symbols for the 2004-2006 period (circles). Then draw a vertical line perpendicular to the '50 mg/l line' down to the x-axis. Here you read off what percentage of farms have a measured nitrate concentration in on-farm water that is lower than 50 mg/l. It is also possible to deduce that about 80% of the arable farms had an average concentration lower than 150 mg/l – and 20% a higher concentration – in the 1992-1995 period. Draw a line perpendicular to the x-axis starting at '80' until it crosses the cumulative frequency line of symbols for the 1992-1995 period (squares). Then draw a line perpendicular to this line until it crosses the y-axis. From the y-axis you can read off the concentration that is not exceeded by, in this case, 80% of the farms.

4.3.2 Sand and loess regions

Agriculture in the sand and loess regions accounts for about 47.5% of the agricultural area in the Netherlands. Dairy farming covers 47% of the area, arable farming about 14% and pig and poultry farms and mixed husbandry farms about 23%. About 16% of the area is used by farm types not included in the LMM, mainly horticulture, protected crop farming, arboriculture and farms with less than 10 ha of land. Nitrate concentrations in the upper groundwater of arable farms decreased in the second and third monitoring periods and remained stable during the fourth period (see Figure 9). The percentage of arable farms with a period average concentration lower than the EU target first increased from about 5% to about 40%, then decreased to about 20% in the fourth period. For dairy farms there was a continuous decrease in nitrate concentration during the first three periods, which then stabilised in the fourth period (see Figure 10). The percentage of dairy farms with a concentration lower than the EU target increased from about 5% in the 1992-1995 period to about 50% in the 2000-2003 and 2004-2006 periods. The nitrate concentration in the upper groundwater of other farms decreased between the second and third monitoring periods, but showed a rise between the third and fourth periods (see Figure 11). The percentage of other farms with a period average concentration lower than the EU target increased from about 8% in the 1996-1999 period to about 25% in the 2004-2006 period.

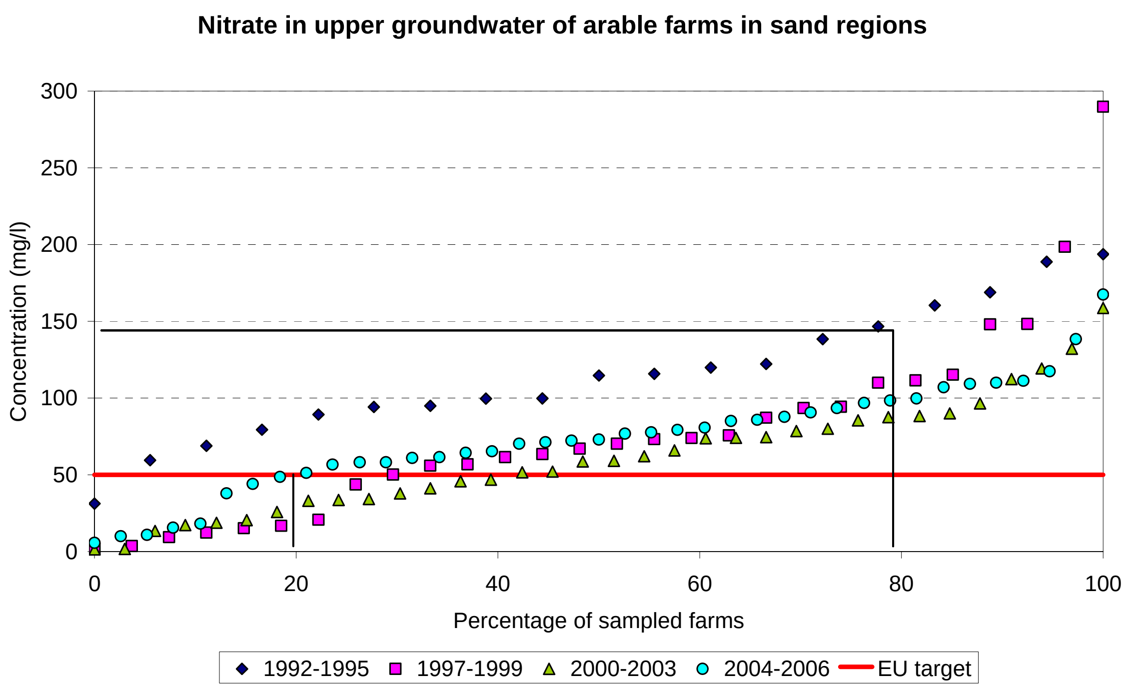


Figure 9: **Nitrate concentration in the upper metre of groundwater within 5 m of the soil surface for arable farms in the sand regions in a cumulative frequency diagram of farm average per period.**

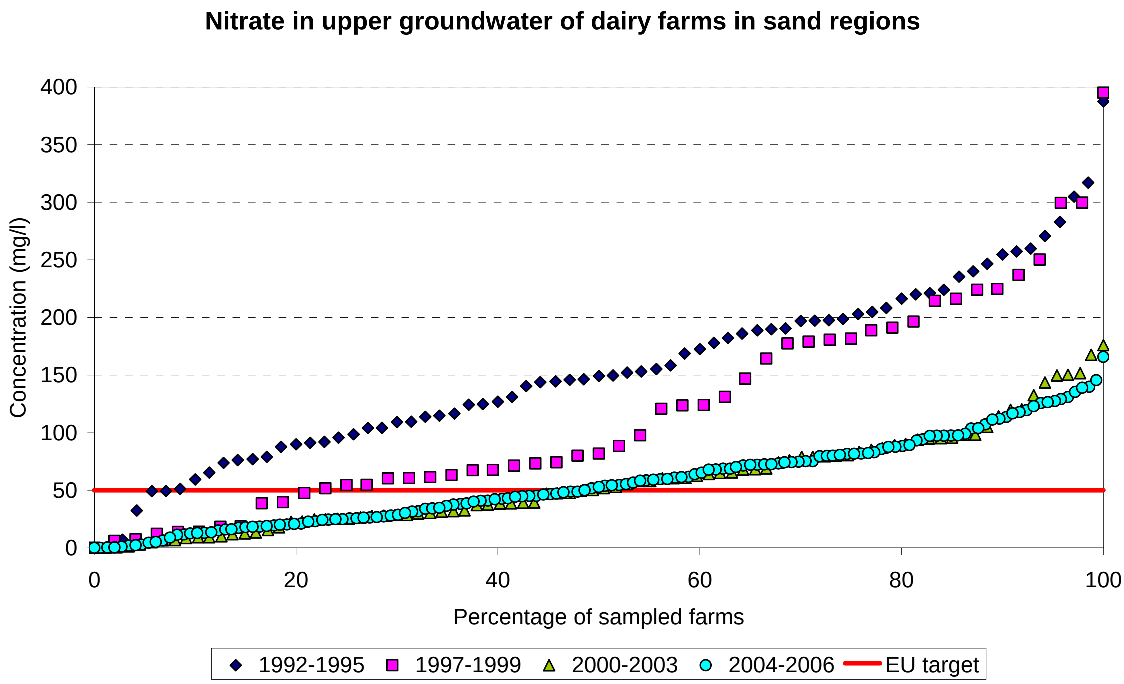


Figure 10: **Nitrate concentration in the upper metre of groundwater within 5 m of the soil surface for dairy farms in the sand regions, shown in a cumulative frequency diagram of farm average per period.**

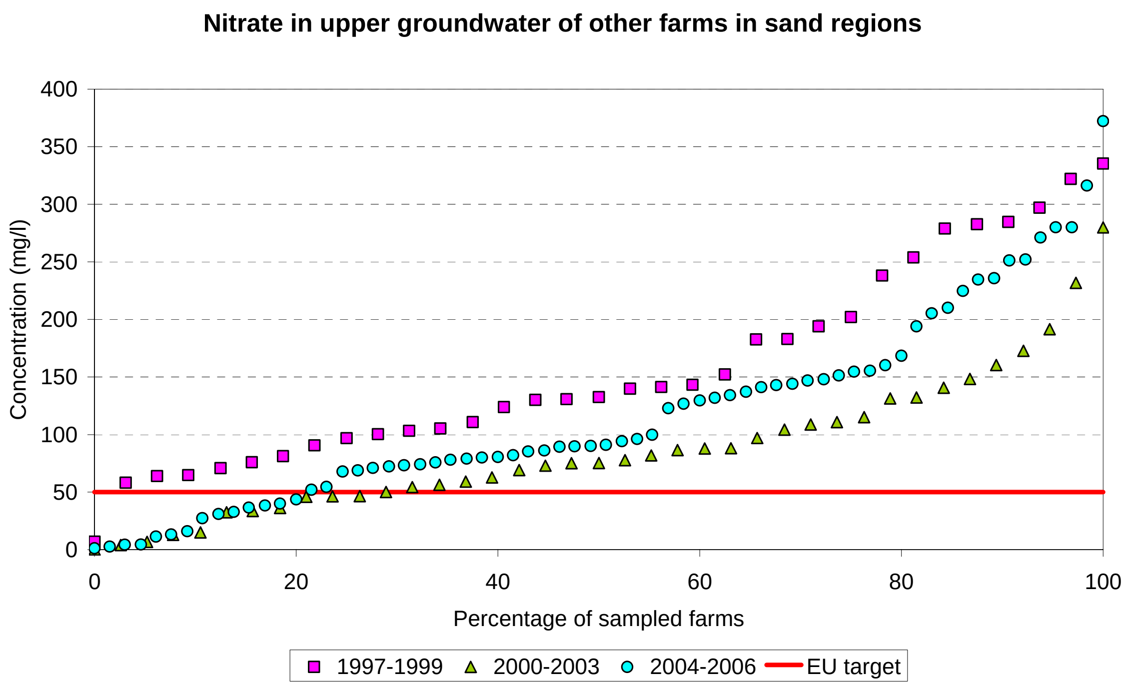


Figure 11: **Nitrate concentration in the upper metre of groundwater within 5 m of the soil surface for other farms in the sand regions, shown in a cumulative frequency diagram of farm average per period.**

The trend in the nitrate concentration and the level of nitrate concentration under agricultural land in the loess region was similar to that in the sand regions (see Figure 12), though the concentrations under the loess region were higher. The percentage of locations in the BVM (Provincial monitoring data) with a nitrate concentration below the EU target value increased from about 8 % to about 40 % (see Figure 13). The LMM data (Figure 14) measured soil moisture per farm. The percentage of farms below the EU target was about 10%. The discrepancy between BVM and LMM data might be due to the sampling scale (farm versus parcel). Willems and Fraters (1995) showed that the scale used for presenting the monitoring results affects the percentage exceedance of the target value if the total average nitrate concentration is the same.

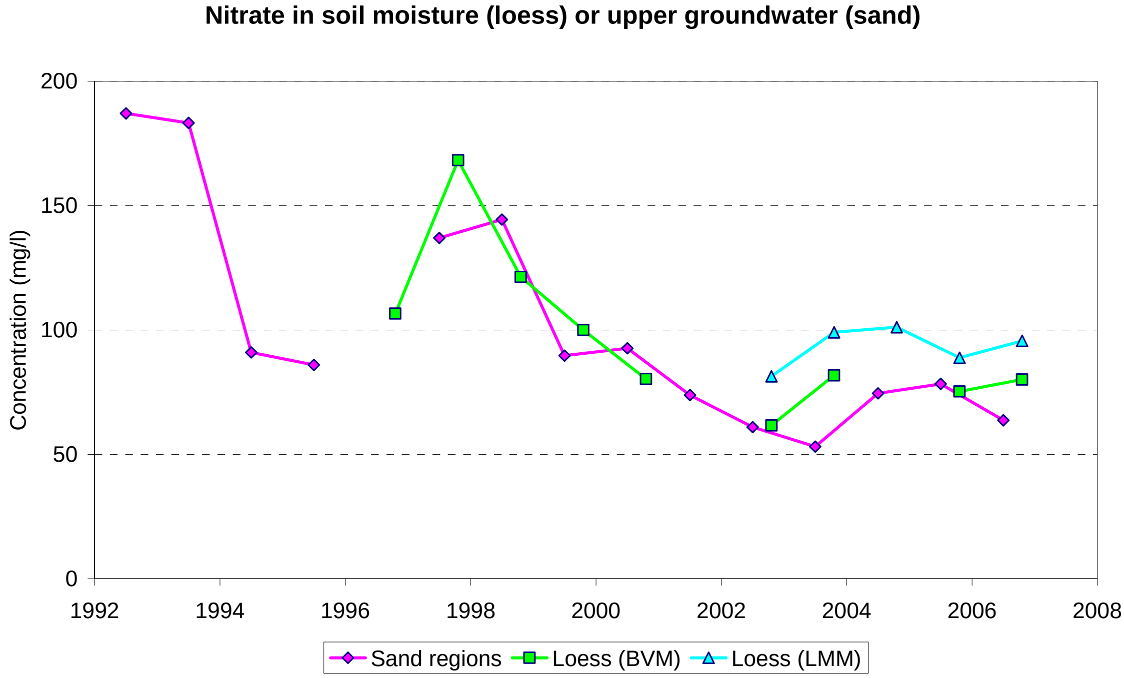


Figure 12: **Nitrate concentration in the upper metre of groundwater within 5 m of the soil surface of farms (sand) and in soil moisture at 1.4 m (BVM) and 1.5-3 m (LMM) below the soil surface of agricultural land (loess) for the 1992-2006 period.**
Source: RIVM (sand / LMM loess); Province of Limburg (BVM loess).

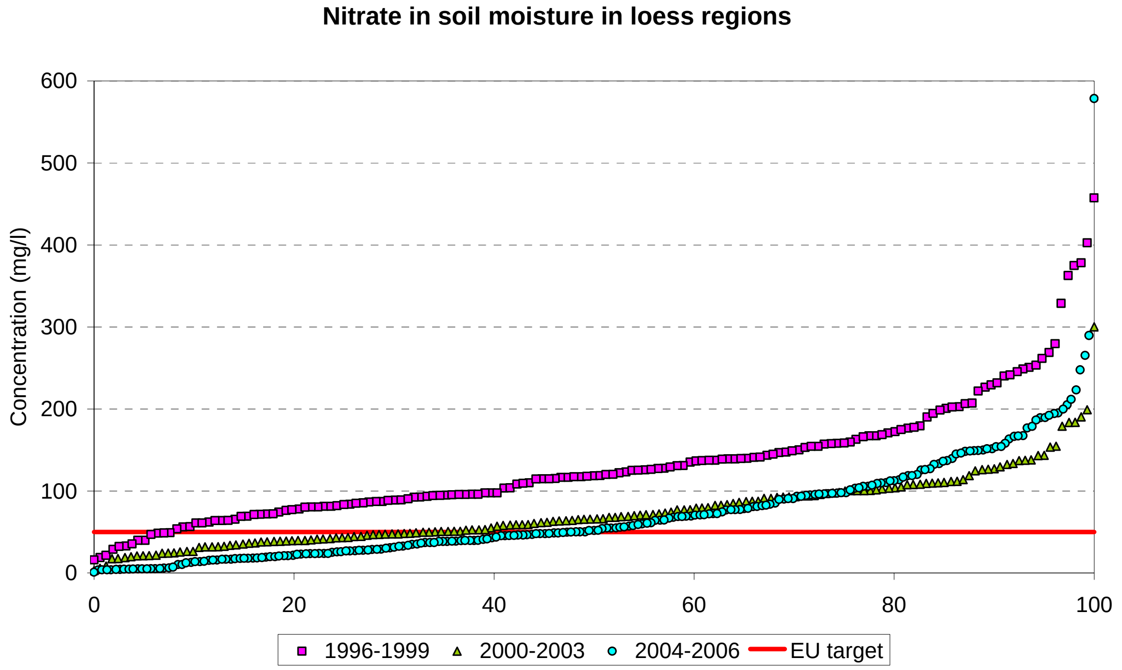


Figure 13: **Nitrate concentration in soil moisture at 1.4 m below the soil surface for parcels used for agriculture in the loess region, shown in a cumulative frequency diagram of parcel average per period.**
Source: Province of Limburg

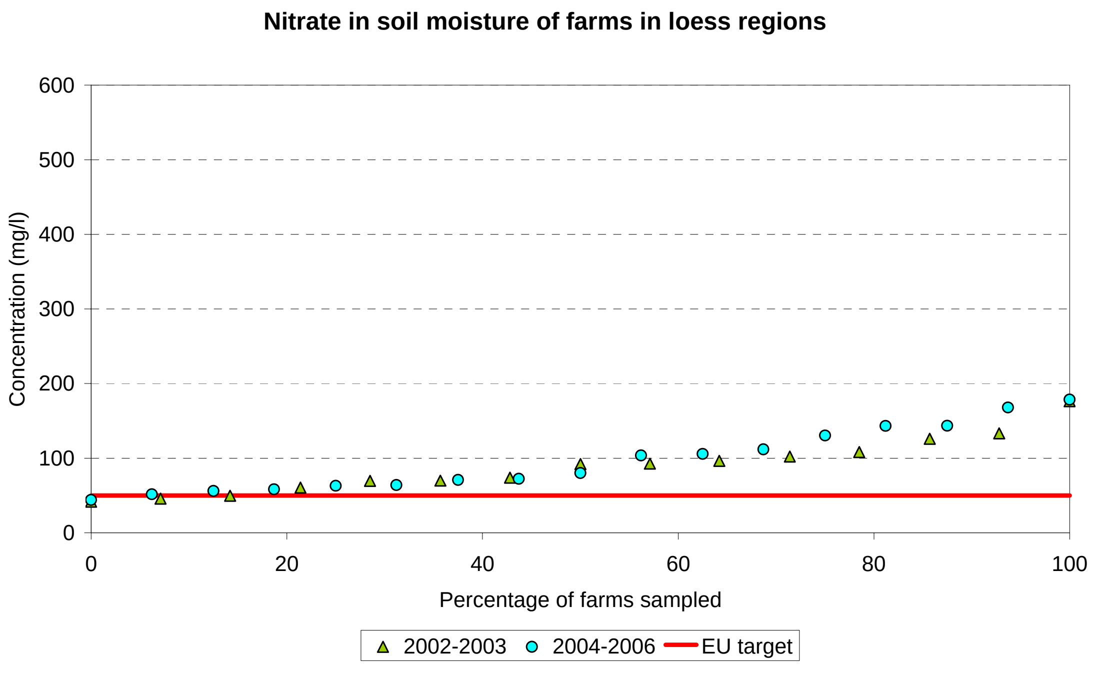


Figure 15: **Nitrate concentration in soil moisture at 1.5-3 m below the soil surface for farms in the loess region, shown in a cumulative frequency diagram of farm average per period.**
Source: RIVM.

4.3.3 Clay regions

Agriculture in the clay regions accounts for about 40% of the agricultural area in the Netherlands. Specialised dairy farming covers about 30% of the area, other forms of dairy farming cover about 13% and arable farming about 38%. About 19% of the area is covered by other forms of agriculture not included in the LMM, these are mainly horticulture, different types of mixed farming and farms with less than 10 ha of land. The nitrate concentration in tile drain water and groundwater of arable farms in the clay regions did not change between 1997-2003, but showed an increase during the 2004-2006 period. The percentage of arable farms with a nitrate concentration below the EU target was 55% to 70%, this percentage decreased to about 40% (see Figure 15). Nitrate concentrations on dairy farms did not change as much in the 1997-2006 period. The percentage of dairy farms not exceeding the EU target was 65-80% (see Figure 16).

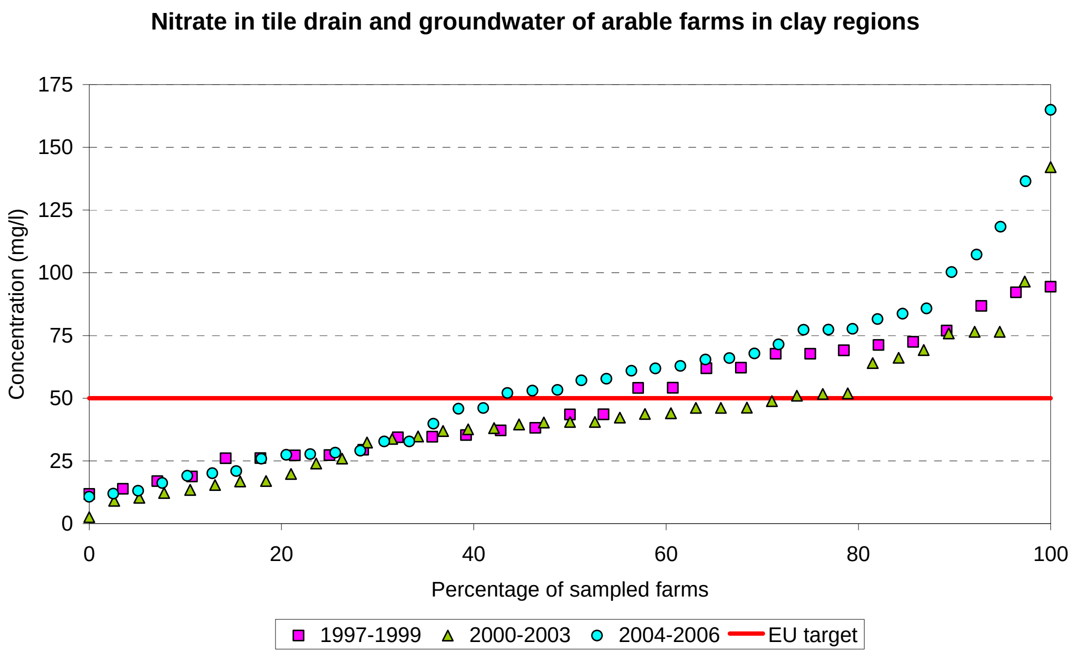


Figure 15: **Nitrate concentration in tile drain water for arable farms in the clay regions shown in a cumulative frequency diagram of farm average per period.**

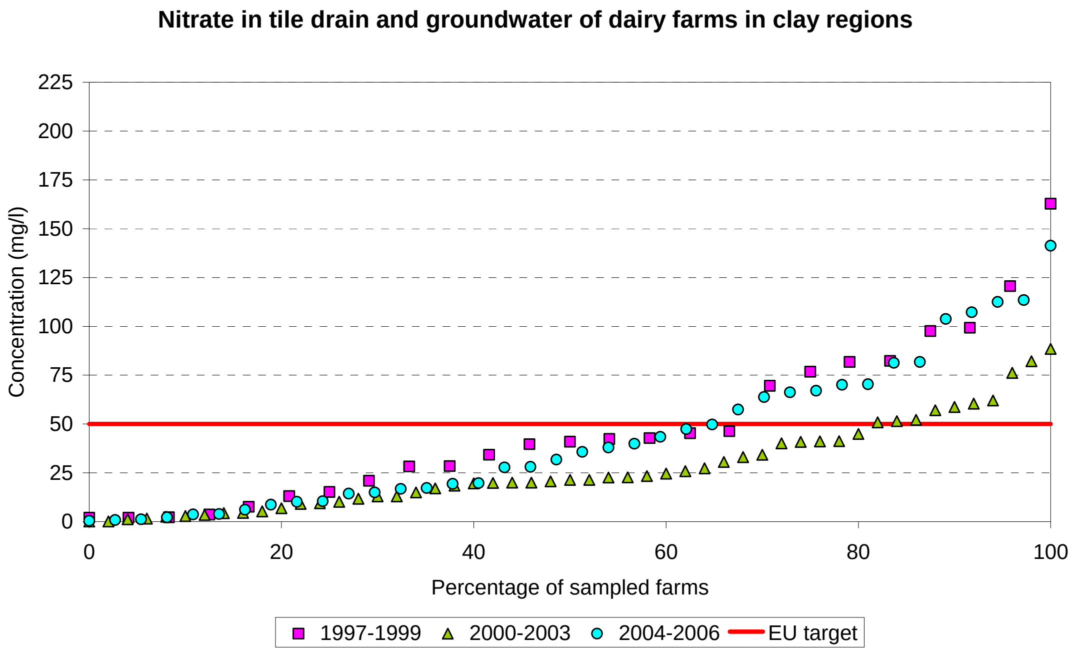


Figure 16: **Nitrate concentration in tile drain water for specialised dairy farms in the clay regions shown in a cumulative frequency diagram of farm average per period.**

4.3.4 Peat regions

Agriculture in the peat regions accounts for about 12.5% of the agricultural area in the Netherlands. About 75% of the area is covered by specialised dairy farming and the rest is covered by other farm types, mainly other forms of dairy and cattle farming. Period average nitrate concentrations in the upper metre of groundwater were usually below 25 mg/l for dairy farms in the peat regions (see Figure 17). The EU target value of 50 mg/l was only rarely exceeded in all monitoring periods. Period average nitrate concentrations in ditchwater were usually below 10 mg/l (NO_3) (see Figure 18). The EU target value was not exceeded throughout all monitoring periods. In the one case where the target level was exceeded, the farm had a mixed soil type with a relatively large percentage of sandy soils.

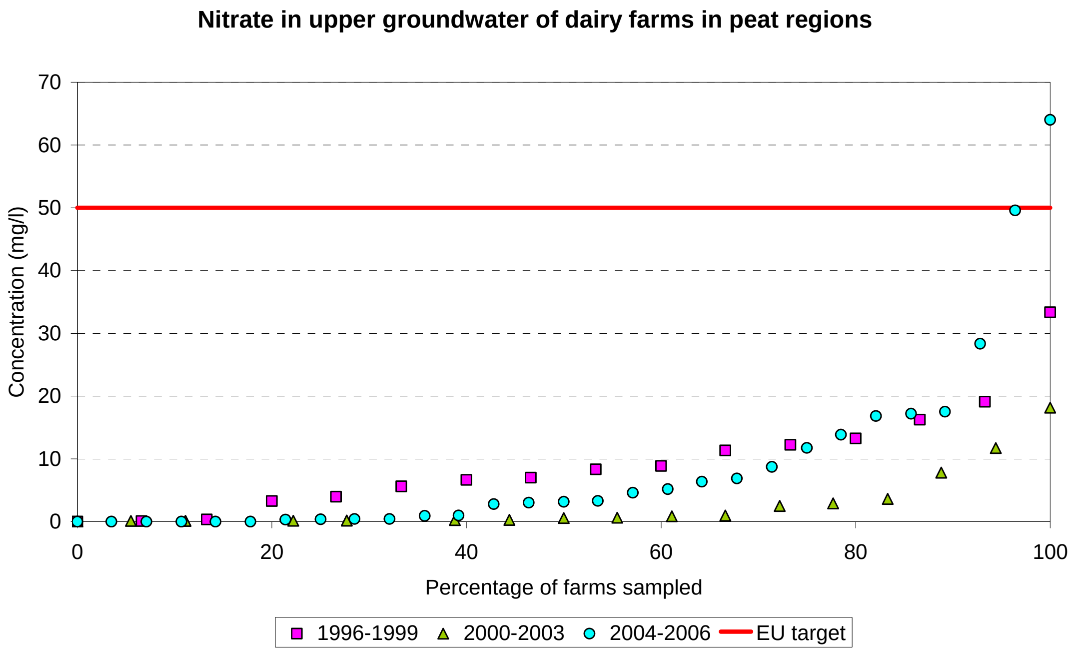


Figure 17: Nitrate concentration in the upper metre of groundwater within 5 m of the soil surface for dairy farms in the peat regions, shown in a cumulative frequency diagram of farm average per period.

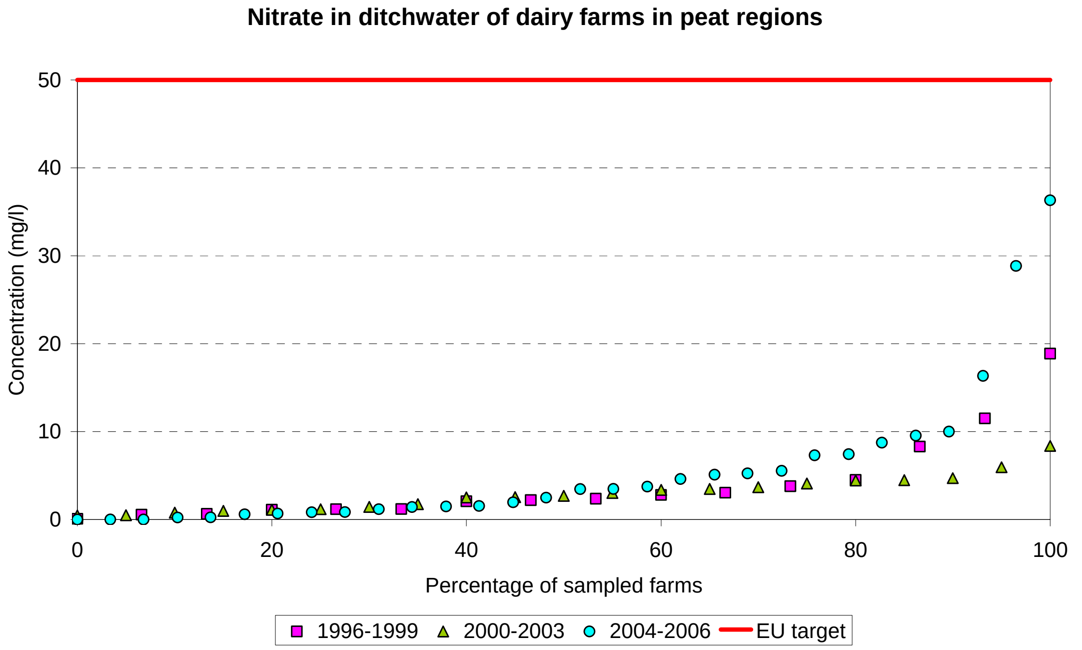


Figure 18: Nitrate concentration in ditchwater of dairy farms in the peat regions in winter, shown in a cumulative frequency diagram of farm average per period.

4.4 Relationship between trend in farm management and nitrate concentration

Overall the following trend can be detected: farmers use less fertiliser, the number of livestock has decreased and produce less manure and farms show a decreasing N soil surplus. This is correlated with the effects which can be seen in the nitrate concentrations in groundwater, which also show an overall decrease. The measures resulting in a quick win were taken about a decade ago and the effects of new measures are therefore getting smaller. Effects of changes in farm management can be seen in groundwater with a delay of three to five years, depending on the depth of measurement. It can therefore be expected that water quality will show a decrease in the next reporting periods, due to current measures taken on farms.

In addition to the effects of farm management measures, climate, hydrogeological processes, etc. also have an effect on the process of increasing or decreasing nitrate levels in soils and can erase the positive effect on water quality.

4.5 References

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5 Groundwater quality

5.1 Introduction

Groundwater in the Netherlands shows a large variation in nitrate concentration, both in space and depth, which is only partly accounted for by the variation in land use and differences in nitrogen load. Other key factors are year-to-year variations in net precipitation, soil type and geohydrological characteristics of the aquifer (see previous chapter).

In general, the nitrate concentration is low in groundwater below agricultural peat soils, relatively high below agricultural sandy soils and has an intermediate level on clay soils (Reijnders et al., 2004). With respect to depth, the general trend is a decrease in nitrate concentration with an increase in depth. This is caused by the reduction of nitrate in transport (denitrification), the mixing of waters of different age and source and lateral transport due to the presence of layers that partially or completely inhibit downwards movement (semi-confined or confined aquifers).

The data in this chapter is presented in three sections, each of which is confined to the three levels of monitoring depths used in the Dutch groundwater and drinking water monitoring system, i.e. groundwater at a depth of 5-10 m, 15-30 m and more than 30 m. In the first (§ 5.2) and second (§ 5.3) sections, the results are presented in figures and maps. The figures present average nitrate concentrations and exceedance of the EU target value for the different soil types (sand, clay, peat) and different forms of land use (agriculture, nature, others). The maps detail differences in groundwater age between wells as well as the nitrate concentration class. The third section (§ 5.4) details nitrate in groundwater used for drinking water production. This water is obtained from sandy aquifers and usually originates from areas with a mixed land use. The tables, figures and maps only detail the differences between phreatic and confined aquifers.

5.2 Nitrate in groundwater at a depth of 5–15 m

In the 1992-2006 period, the average nitrate concentration in groundwater in the Netherlands at 5-15 m below the soil surface was about 20 mg/l. The average for agricultural land was 24 mg/l and fluctuated between 21 and 28 mg/l (see Figure 19). The highest concentration was measured in 1996, about ten years after the peak in nitrogen surplus in the national nitrogen balance (see Chapter 3, Figure 3). For nature and other land use types, the average concentration was about 13 mg/l and fluctuated between 9 and 21 mg/l (see Figure 19).

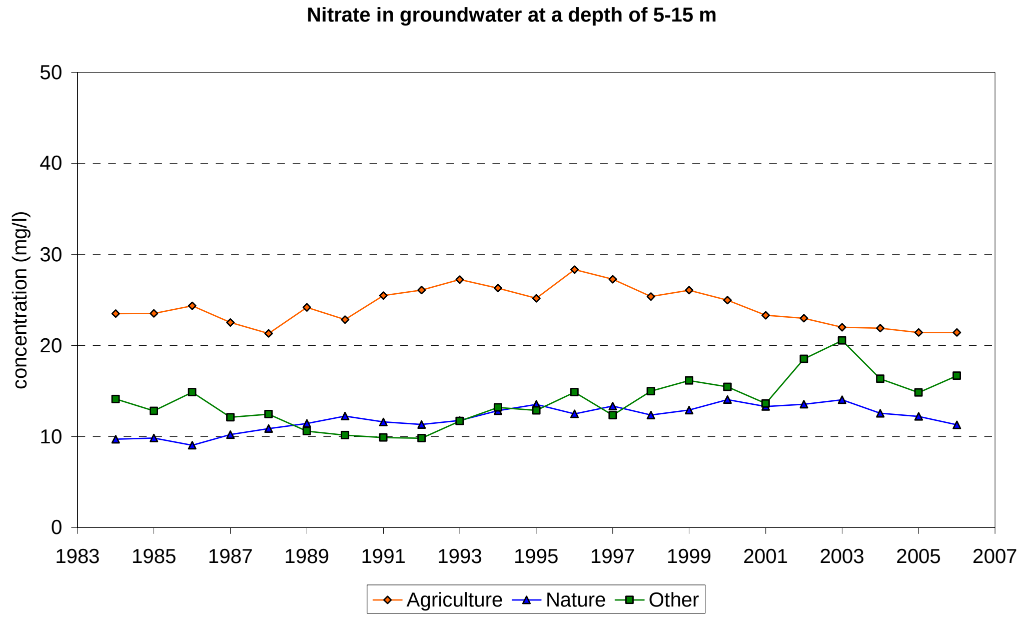

Figure 19: **Average annual nitrate concentration (mg/l) in groundwater in the Netherlands at a depth of 5-15 m below the surface level per land use type for the 1984-2006 period.**

The nitrate concentration in groundwater originating from agriculture on sandy soils (40 mg/l) was higher than on clay (< 10 mg/l) and peat soils (< 5 mg/l) (see Figure 20). Prior to 1992, concentrations were mostly below 40 mg/l, whereas in the 1992-2000 period, concentrations fluctuated between 42 and 47 mg/l. Since 2001, the average nitrate concentration has remained below 40 mg/l.

In the 1992-2006 period, the EU target value of 50 mg/l for nitrate was on average exceeded in 12% of the groundwater wells at a depth of 5-15 m. For agricultural sites this figure was 13%, for nature sites 7% and for other sites 10% (see Figure 21 and Table 23). There were slight differences between years.

For agricultural sites on sandy soils the target value was exceeded in 21% of the wells, whereas for clay and peat soils, this was the case for about 1% of the wells (see Figure 22).

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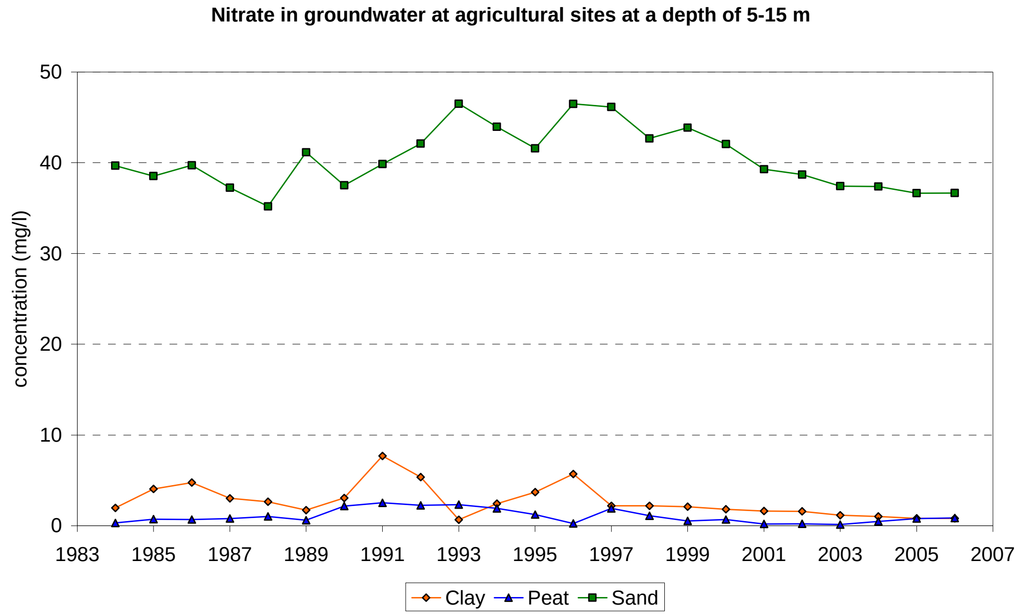


Figure 20: **Average annual nitrate concentration (mg/l) in groundwater in the agricultural areas of the Netherlands at a depth of 5 – 15 m below the surface level per soil type for the 1984 – 2006 period.**

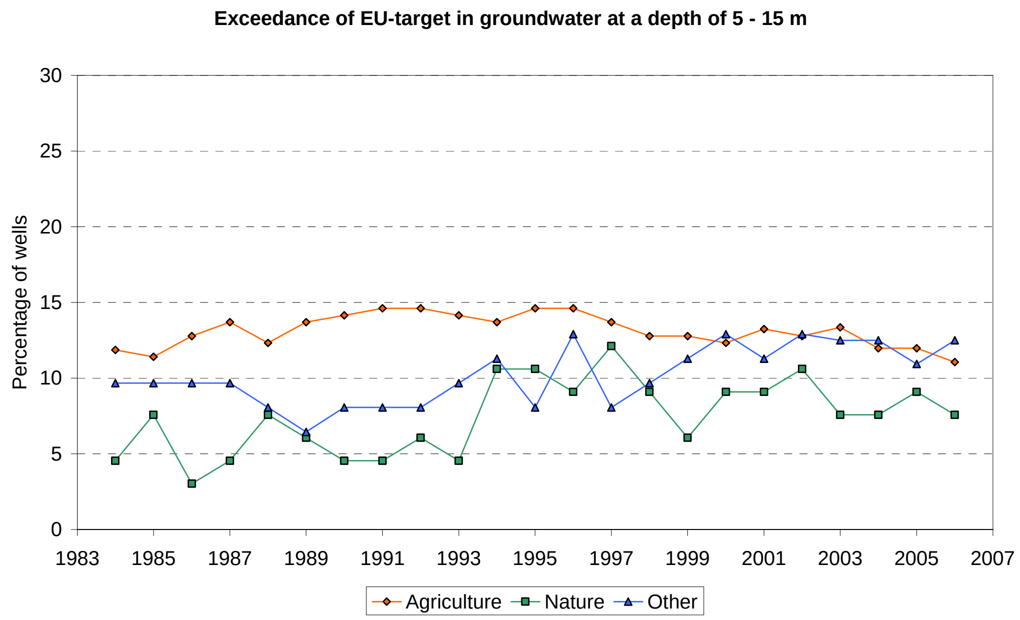


Figure 21: **Exceedance of the EU target value of 50 mg/l for nitrate in groundwater in the Netherlands at a depth of 5-15 m below the surface level per land use type for the 1984-2006 period.**

Other land uses include orchards and urban areas. Exceedance is expressed as a percentage of all monitored wells.

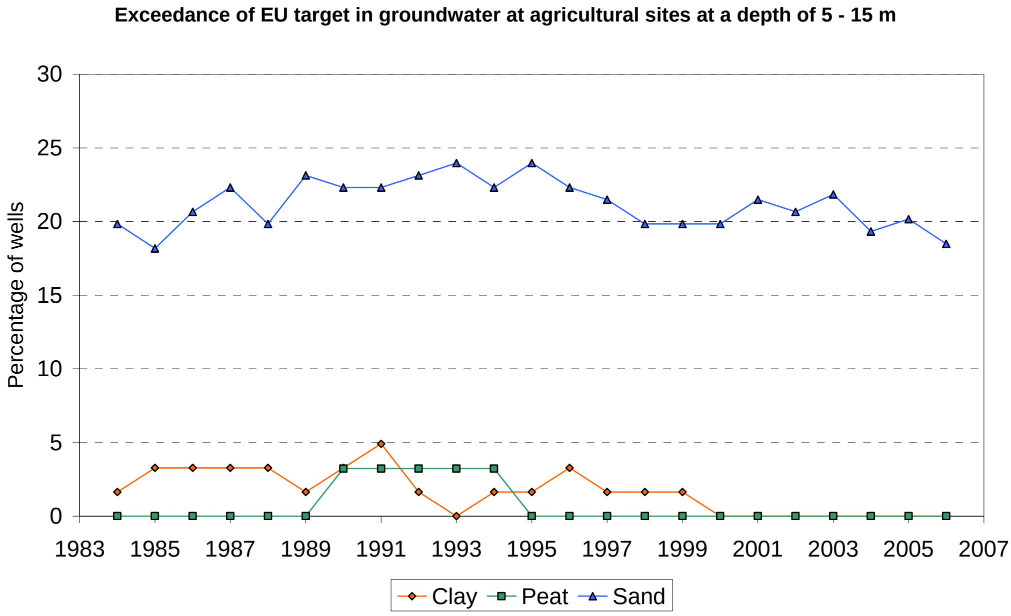


Figure 22: **Exceedance of the EU target value of 50 mg/l for nitrate in groundwater in the agricultural areas of the Netherlands at a depth of 5-15 m below the surface level for the 1984-2006 period.**

Table 23: **Nitrate in groundwater at a depth of 5-15 m for the 1992-2006 period (%)[1].**

	All monitoring wells			Agricultural wells		
Concentration range	'92-'95	'00-'03	'04-'06	'92-'95	'00-'03	'04-'06
0 - 15 mg/l	79.0	80.4	81.3	80.4	83.1	82.6
15 - 25 mg/l	3.7	3.5	3.5	1.8	1.8	2.3
25 - 40 mg/l	2.0	2.3	3.2	0.5	0.9	2.3
40 - 50 mg/l	2.6	1.7	0.9	1.8	0.9	0.5
> 50 mg/l	12.7	12.1	11.2	15.5	13.2	12.3
Number of sites	347	347	347	219	219	219

[1] Percentage of monitoring wells with a period average within a given concentration range for all monitoring wells and for monitoring wells with water specificaly influenced by agriculture. Total percentage may exceed 100 because of rounding off.

Most wells (about 72%) did not show a change in nitrate concentration between reporting periods (1992-1995, 2000-2003 and 2004-2006) (see Table 24). Between the third and fourth reporting periods, the number of wells showing an increase was greater than those showing a decrease, whereas the number of wells showing a decrease was slightly larger between the first and third periods.

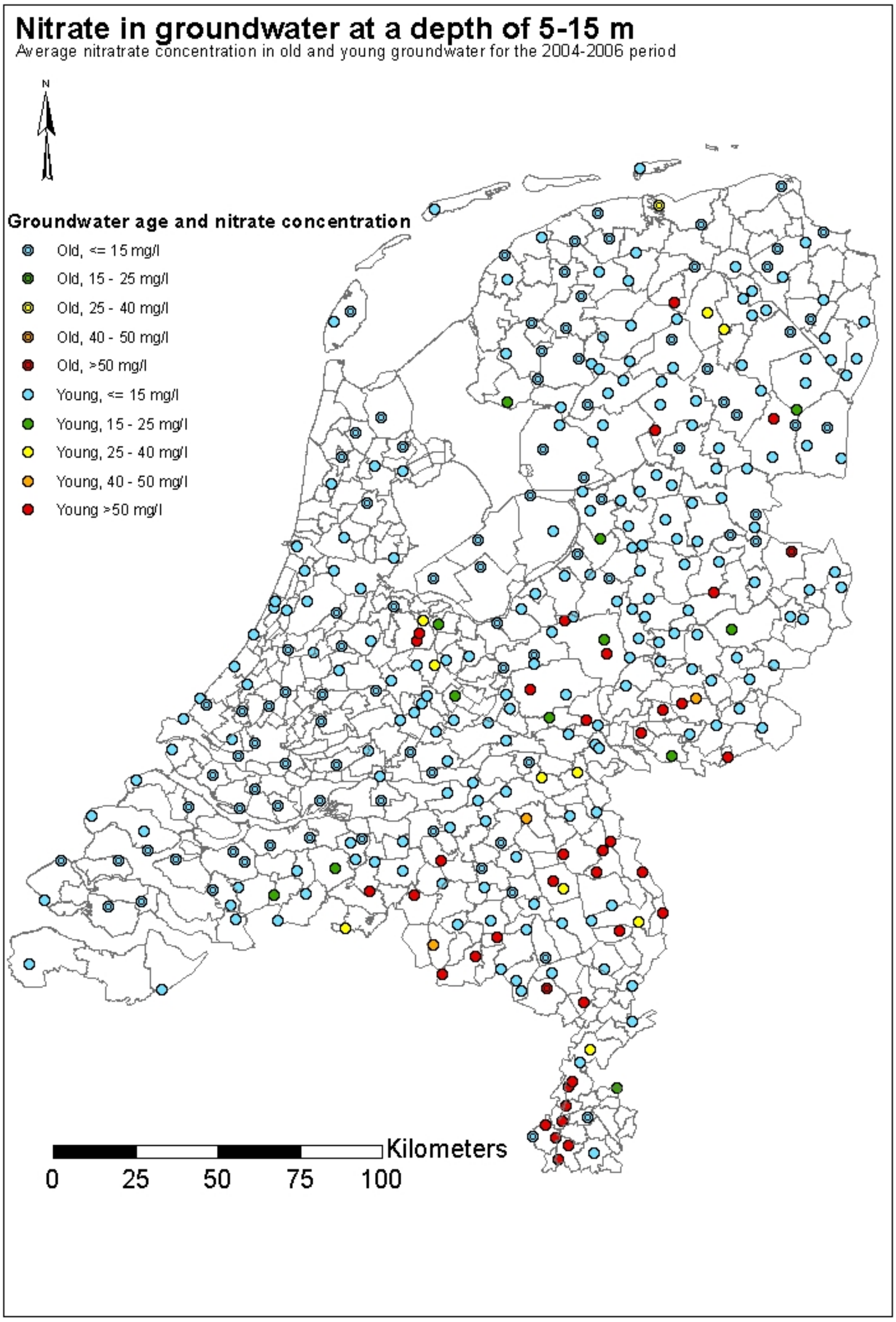
Table 24: Change in nitrate concentration in groundwater at a depth of 5-15 m for the 1992-2006 period (%)[1].

Concentration range	All monitoring wells		Agricultural wells	
	'92-'95/'00-'03	'00-'03/'04-'06	'92-'95/'00-'03	'00-'03/'04-'06
Large increase (% > 5 mg/l)	8.9	5.8	7.3	4.6
Small increase (% 1-5 mg/l)	4.3	5.8	5.0	5.5
Stable (% ± 1 mg/l)	68.6	71.5	72.6	75.3
Small decrease (% 1-5 mg/l)	6.3	4.3	3.7	3.2
Large decrease (% > 5 mg/l)	11.8	12.7	11.4	11.4
Number of sites	347	347	219	219

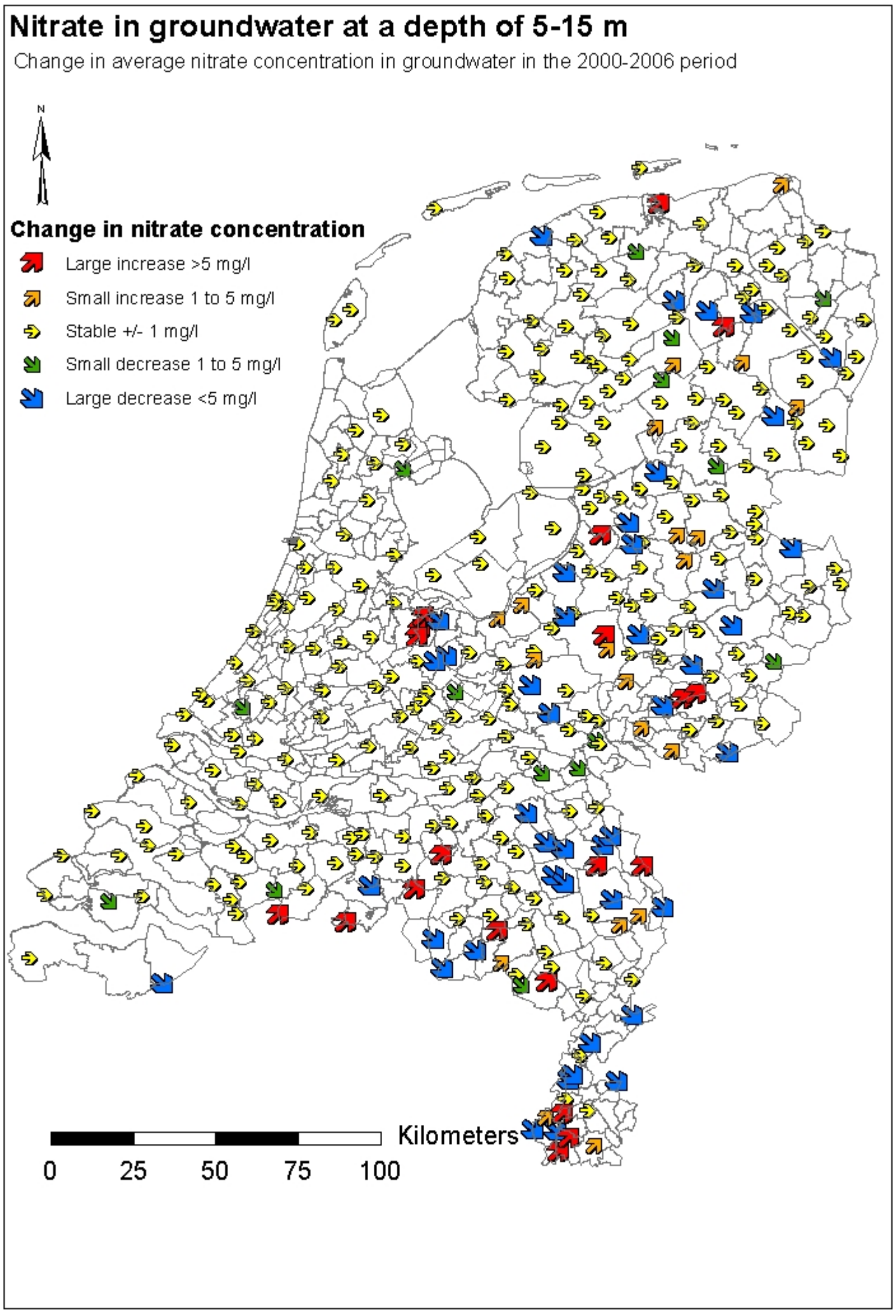
1) Percentage of wells with given rates of change in concentration between the first and second and between the second and third reporting periods. Data is for all monitoring wells and for monitoring wells with water specificaly influenced by agriculture. Total percentage may exceed 100 because of rounding off.

Map 4 shows the average nitrate concentration for each monitoring well with a well screen between 5 and 15 m below the soil surface, for the 2004-2006 period. The wells are classified as those containing old (> 25 years) and young (< 25 years) groundwater. The wells containing old groundwater usually draw water from confined or semi-confined aquifers, while those containing young groundwater usually draw water from phreatic aquifers. High nitrate concentrations (> 50 mg/l) are 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 2000-2003 and 2004-2006 periods is shown in Map 5. Most changes occurred in the sand and loess regions. Both increases and decreases in nitrate concentrations were found.



Map 4: Average nitrate concentration in groundwater in the Netherlands at a depth of 5-15 m for the 2004-2006 period.



Map 5: Change in average nitrate concentration in groundwater in the Netherlands at a depth of 5-15 m for the 2000-2006 period.
Change expressed as difference between averages for the 2000-2003 and 2004-2006 periods.

5.3 Nitrate in groundwater at a depth of 15–30 m

The average nitrate concentration in groundwater in the Netherlands at 15-30 m below the soil surface was about 5.7 mg/l in the 1992-2006 period. The average for agricultural land was 6.2 mg/l and fluctuated between 4.9 and 7.6 mg/l (see Figure 23). For nature and other land use types, the average concentration was about 3.2 and 6.2 mg/l, respectively. There is no explanation for the increase in nitrate concentrations in groundwater for other land use types since 1998. From 2003 on, this increase seems to have stopped.

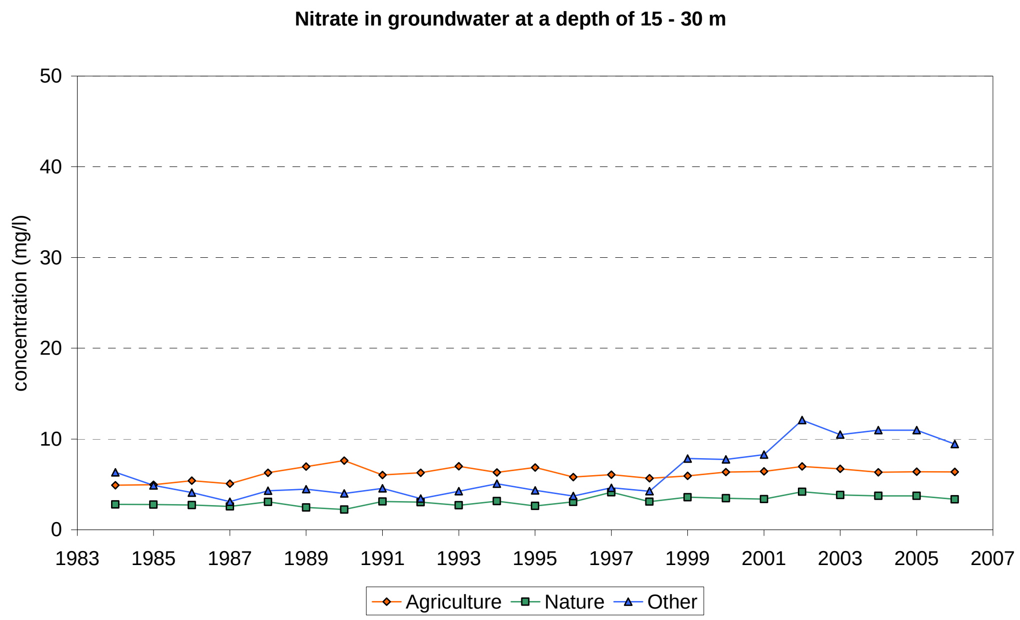


Figure 23: Average annual nitrate concentration (mg/l) in groundwater in the Netherlands at a depth of 15–30 m below the surface level per land use type for the 1984–2006 period.

The nitrate concentration in groundwater from agricultural sites on sandy soils (10 mg/l) was higher than on clay and peat soils (< 1 mg/l) (Figure 24). There is no visible trend in nitrate concentration.

In the 1992-2006 period, the EU target value of 50 mg/l for nitrate was, on average, exceeded in 3% of the groundwater wells at a depth of 15-30 m. For agricultural sites this was 4%, for nature sites 1% and for other sites about 4% (see Figure 25 and Table 25). There were slight differences between years.

For agricultural sites on sandy soils, the target value was exceeded in about 6% of the wells, while on clay and peat soils this was the case in less than 1% of the wells (see Figure 26).

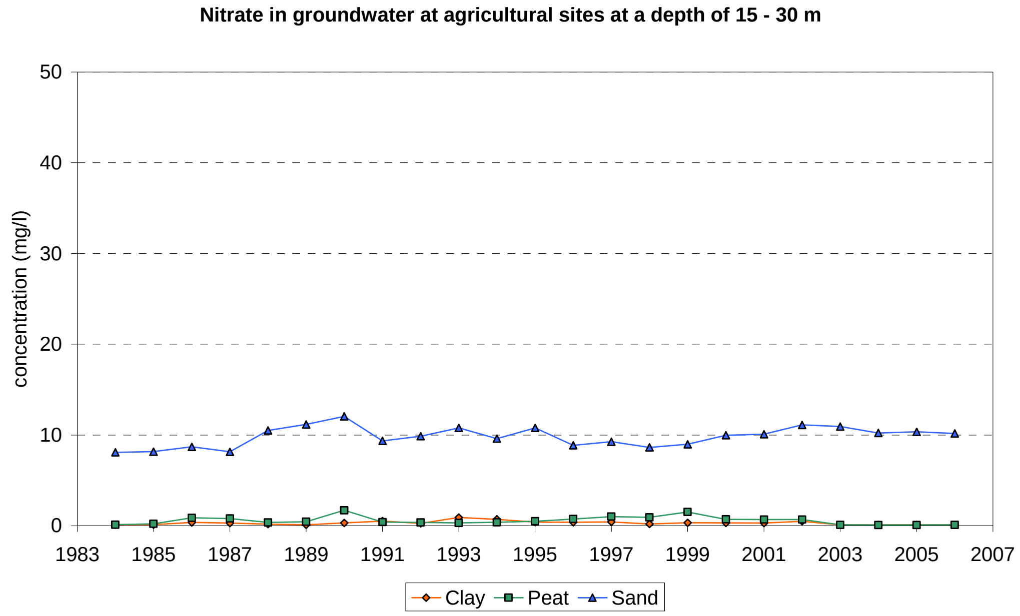


Figure 24: **Average annual nitrate concentration (mg/l) in groundwater in agricultural areas of the Netherlands at a depth of 15–30 m below the surface level per soil type for the 1984–2006 period.**

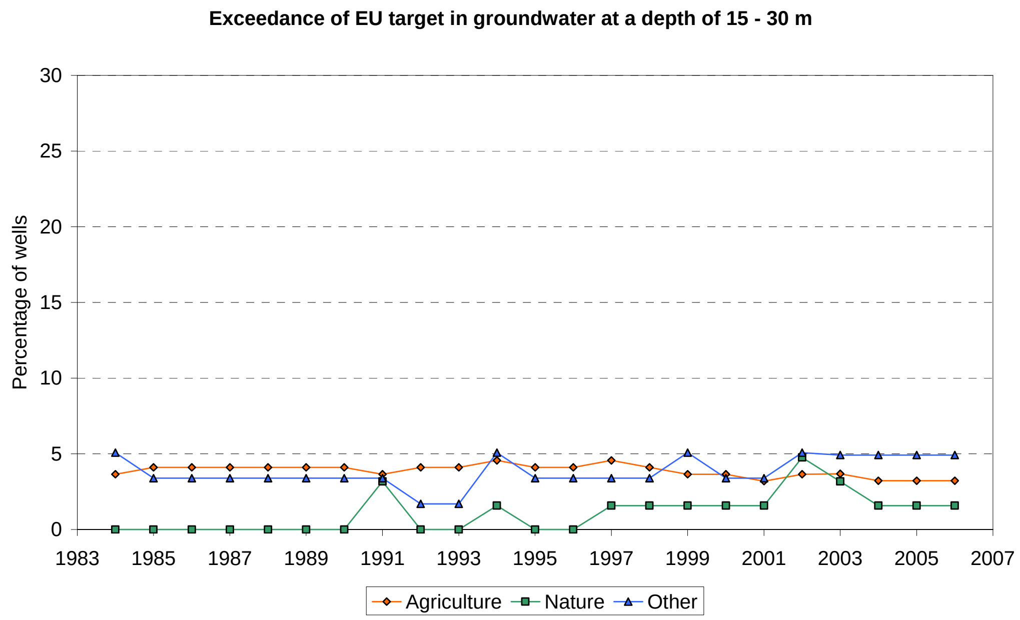


Figure 25: **Exceedance of the EU target value of 50 mg/l for nitrate in groundwater in the Netherlands at a depth of 15-30 m below the surface level per land use type for the 1984-2006 period.**

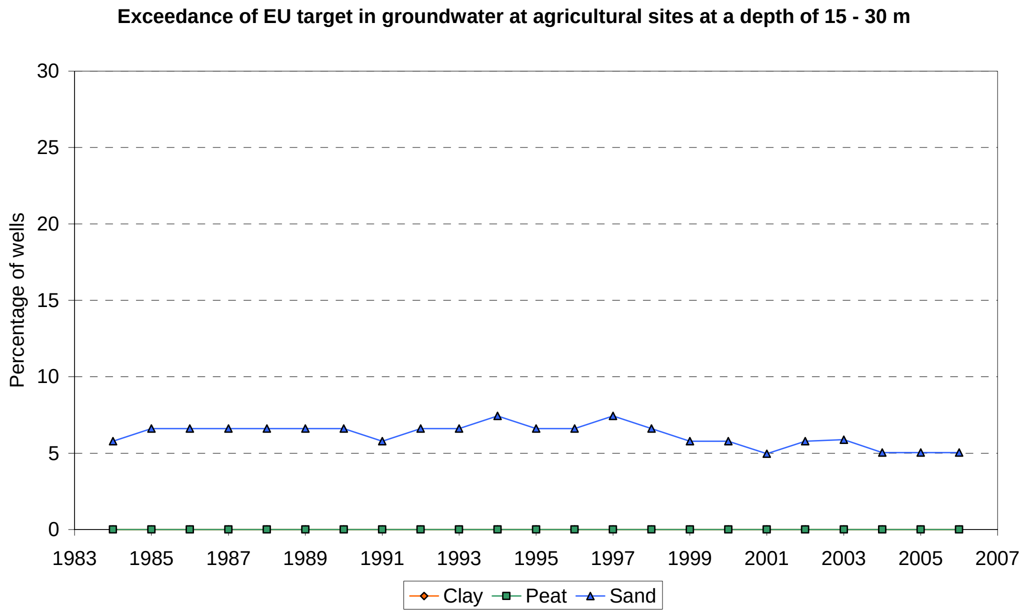


Figure 26: **Exceedance of the EU target value of 50 mg/l for nitrate in groundwater in the agricultural areas of the Netherlands at a depth of 15-30 m below the surface level in the 1984-2006 period.**

Table 25: **Nitrate in groundwater at depth of 15-30 m for the 1992-2006 period (%)[1].**

	All monitoring wells			Agricultural wells		
Concentration range	‘92-‘95	‘00-‘03	’04-‘06	‘92-‘95	‘00-‘03	’04-‘06
0 - 15 mg/l	93.8	93.2	92.4	94.4	94.4	93.9
15 - 25 mg/l	0.9	0.3	1.5	-	1.4	0.9
25 - 40 mg/l	1.5	2.4	1.8	0.9	0.5	1.4
40 - 50 mg/l	0.6	0.9	1.5	0.5	3.8	0.5
> 50 mg/l	3.2	3.2	2.9	4.2	0.0	3.3
Number of sites	340	340	340	213	213	213

[1] Percentage of monitoring wells with a period average within a given concentration range for all monitoring wells and for monitoring wells with water specificaly influenced by agriculture. Total percentage may exceed 100 because of rounding off.

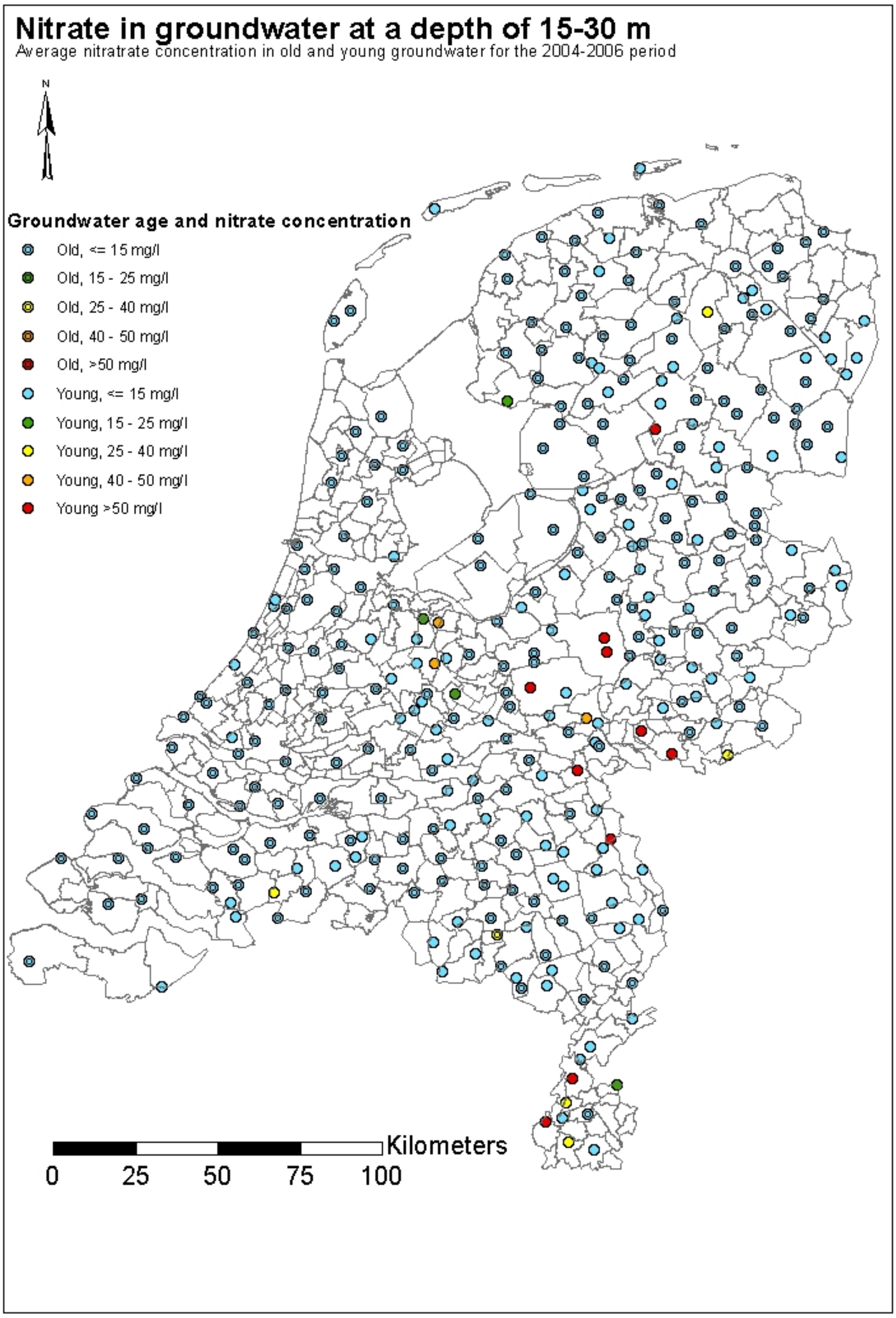
Most wells (> 80%) did not show a change in nitrate concentration between reporting periods (1992-1995, 2000-2003 and 2004-2006) (see Table 26). Between the first and third periods, the number of wells with a slight increase was slightly larger than those with a slight decrease, while between the third and fourth periods, the number of wells with a decrease was slightly higher.

Table 26: Change in nitrate concentration in groundwater at a depth of 15-30 m for the 1992-2006 period (%)[1].

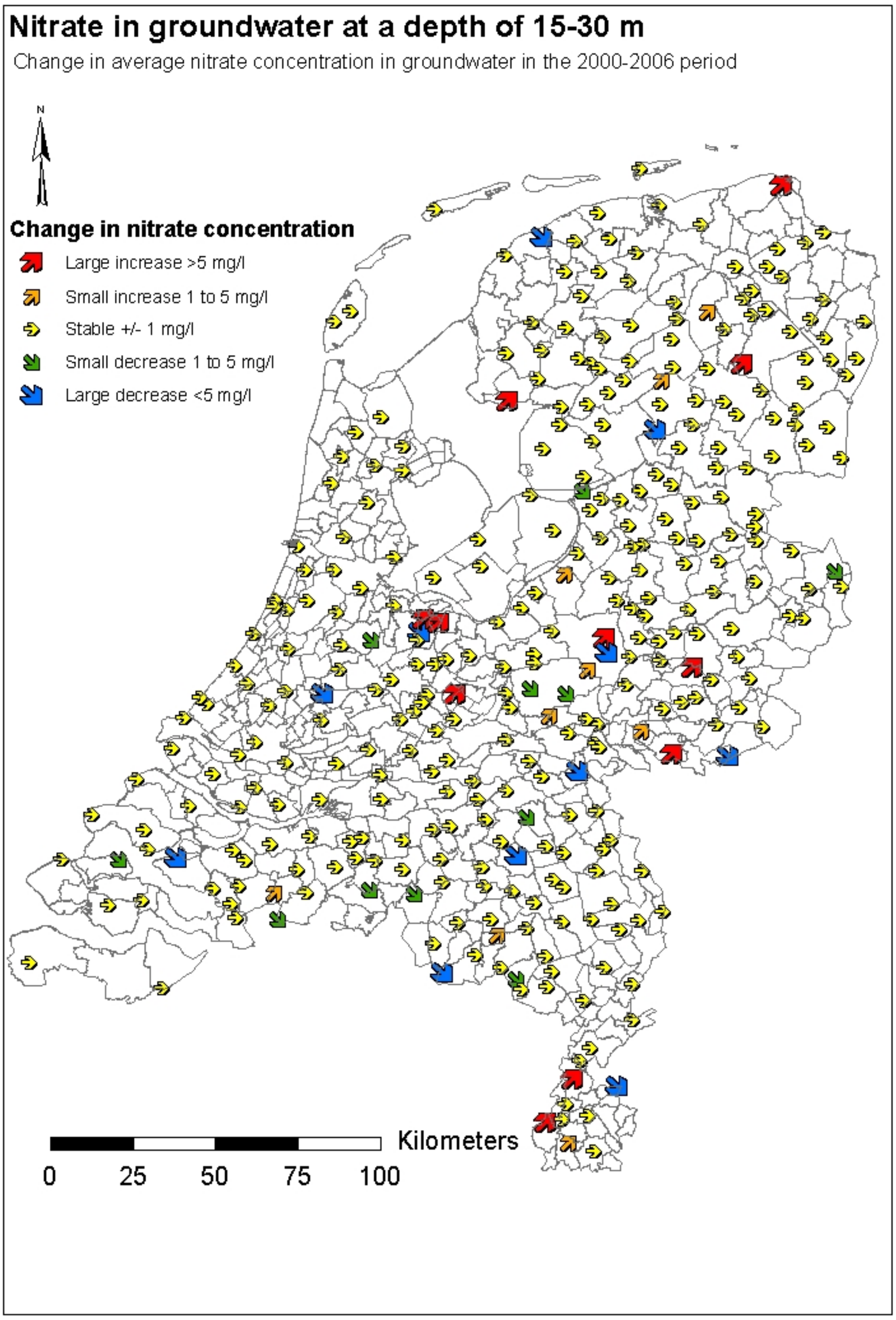
Concentration range	All monitoring wells		Agricultural wells	
	‘92-‘95/‘00-‘03	‘00-‘03/’04-‘06	‘92-‘95/‘00-‘03	‘00-‘03/’04-‘06
Large increase (% > 5 mg/l)	6.3	3.3	4.8	2.4
Small increase (% 1-5 mg/l)	2.7	2.7	2.4	1.4
Stable (% ± 1 mg/l)	82.6	87.4	83.8	89.0
Small decrease (% 1-5 mg/l)	4.8	3.3	5.2	3.3
Large decrease (% > 5 mg/l)	3.6	3.3	3.8	3.8
Number of sites	340	340	213	213

[1] Percentage of wells with given rates of change in concentration between the first and third and between the third and fourth reporting periods. Data is for all monitoring wells and for monitoring wells with water specificaly influenced by agriculture. Total percentage may exceed 100 because of rounding off.

Map 6 shows the average nitrate concentration for each monitoring well with a well screen placed between 15 and 30 m below the soil surface, for the 2004-2006 period. The wells are classified as those with old (> 25 years) and young (< 25 years) groundwater. The wells with old groundwater usually draw water from confined or semi-confined aquifers, while those with young groundwater usually draw water 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 2000-2003 and 2004-2006 periods is shown in Map 7. Most changes occurred in the sand and loess regions. Both increases and decreases in nitrate concentrations were found.



Map 6: Average nitrate concentration in groundwater in the Netherlands at a depth of 15-30 m for the 2004-2006 period.



Map 7: Change in average nitrate concentration in groundwater in the Netherlands at a depth of 15-30 m for the 2000-2006 period.
Change is expressed as the difference between averages for the 2000-2003 and 2004-2006 periods.

5.4 Nitrate in groundwater below a depth of 30 m

In the 1992-2006 period, the average nitrate concentration in groundwater used for drinking water production (raw water) in the Netherlands was about 6.8 mg/l for phreatic aquifers and less than 1 mg/l for confined aquifers. The nitrate concentration in raw water from phreatic aquifers showed a slightly increasing trend until 2003, followed by a decrease (see Figure 27) (Versteegh and Biesebeek, 2002; Versteegh and Lips, 1998; Versteegh et al., 1997, 1996, 1995).

The percentage of drinking water production sites with an average nitrate concentration in raw water above 50 mg/l was less than 2 % (see Figure 28 and Table 27). In the 2004-2006 period, less than 0.05% of the total volume of raw groundwater used for drinking water production had a nitrate concentration higher than 50 mg/l.

The slow increase in nitrate concentration in raw water is also shown in Table 27 and Table 28. The percentage of wells with a nitrate concentration between 15 and 25 mg/l increased from 12% in 1992-1995 to 16% in 2004-2006 and the percentage of wells with a concentration of more than 25 mg/l increased from 9% to 13% in the same period.

The EU target value of 50 mg/l in distributed drinking water was hardly ever exceeded. In 2006, only two of the 227 drinking water production stations had a nitrate concentration of more than 50 mg/l (maximum of 54 and 62 mg/l).

In the 1992-2006 period, the average maximum nitrate concentration in groundwater used for drinking water production in the Netherlands was about 15 mg/l for phreatic aquifers and less than 1 mg/l for confined aquifers. The nitrate concentration in raw water from phreatic aquifers showed a decreasing trend, and the percentage of drinking water production sites with a maximum nitrate concentration in raw water above 50 mg/l was 13% (see Figure 30 and Table 29).

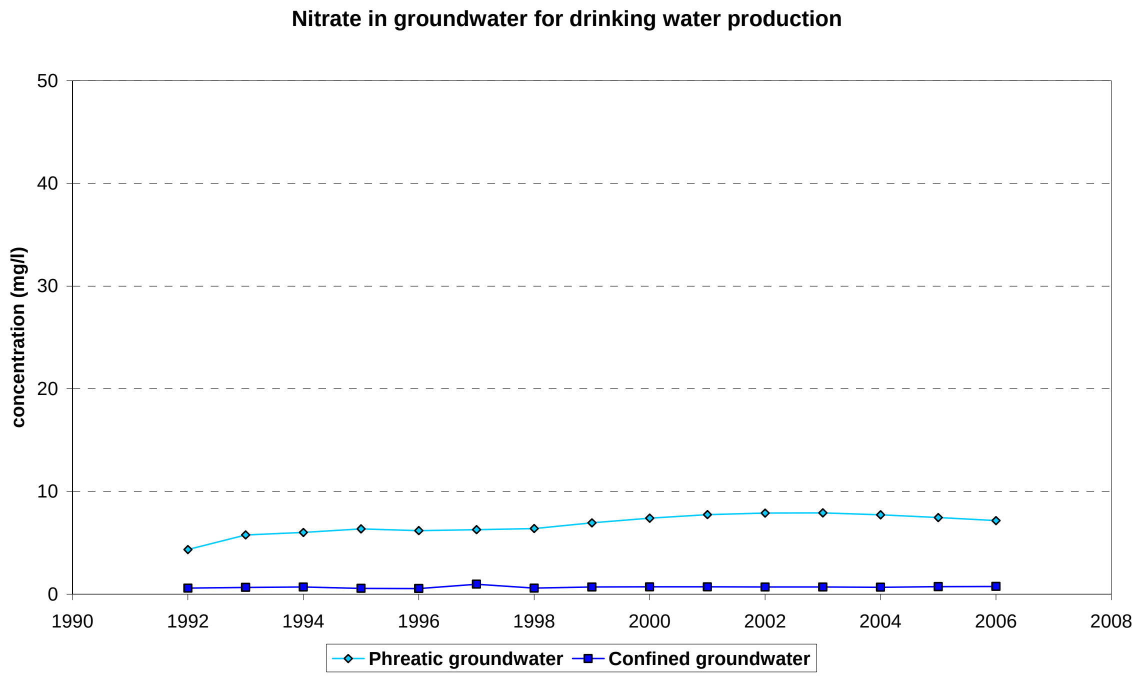


Figure 27: **Average annual nitrate concentration (mg/l) in groundwater in the Netherlands at drinking water production sites for phreatic groundwater and confined groundwater for the 1999–2006 period.**

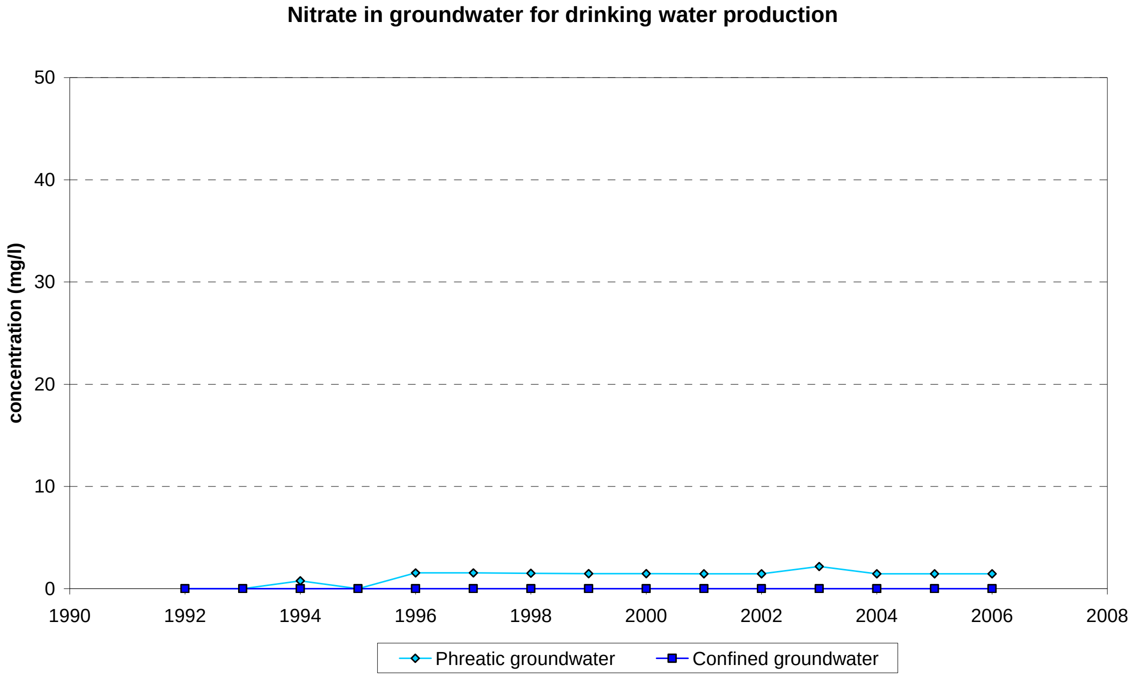


Figure 28: **Exceedance of the EU target value of 50 mg/l for average nitrate concentration in groundwater in the Netherlands at drinking water production sites for phreatic groundwater and confined groundwater for the 1992-2002 period.**
Exceedance is expressed as percentage of all production sites.

Table 27: **Average nitrate concentration in groundwater at a depth of more than 30 m for the 1992-2006 period (%)[1].**

	All production sites			Phreatic sites		
Concentration range	1992-1995	2000-2003	2004-2006	1992-1995	2000-2003	2004-2006
0–15 mg/l	91	87	89	85	79	81
15–25 mg/l	5	6	6	8	10	10
25–40 mg/l	3	4	3	5	7	5
40–50 mg/l	0	2	1	1	3	2
> 50 mg/l	0	1	1	0	1	1
Number of sites	219	227	227	130	138	138

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 phreatic groundwater only. Total percentage may exceed 100 because of rounding off.

Table 28: Change in average nitrate concentration in groundwater at a depth of more than 30 m for the 1992-2006 period (%)[1].

Rate of change	All production sites		Phreatic sites	
	1992/1995-2000/2003	2000/2003-2004/2006	1992/1995-2000/2003	2000/2003-2004/2006
Large increase (% > 5 mg/l)	6	2	11	3
Small increase (% 1-5 mg/l)	8	4	12	7
Stable (% ± 1 mg/l)	80	87	67	79
Small decrease (% 1-5 mg/l)	5	3	8	5
Large decrease (% > 5 mg/l)	1	4	2	7
Number of sites	217	227	129	138

[1] Percentage of drinking water production sites using groundwater with given rates of change in concentration between the first and second and between the second and third reporting periods. Data is for all production sites and sites with phreatic groundwater only. Total percentage may exceed 100 because of rounding off.

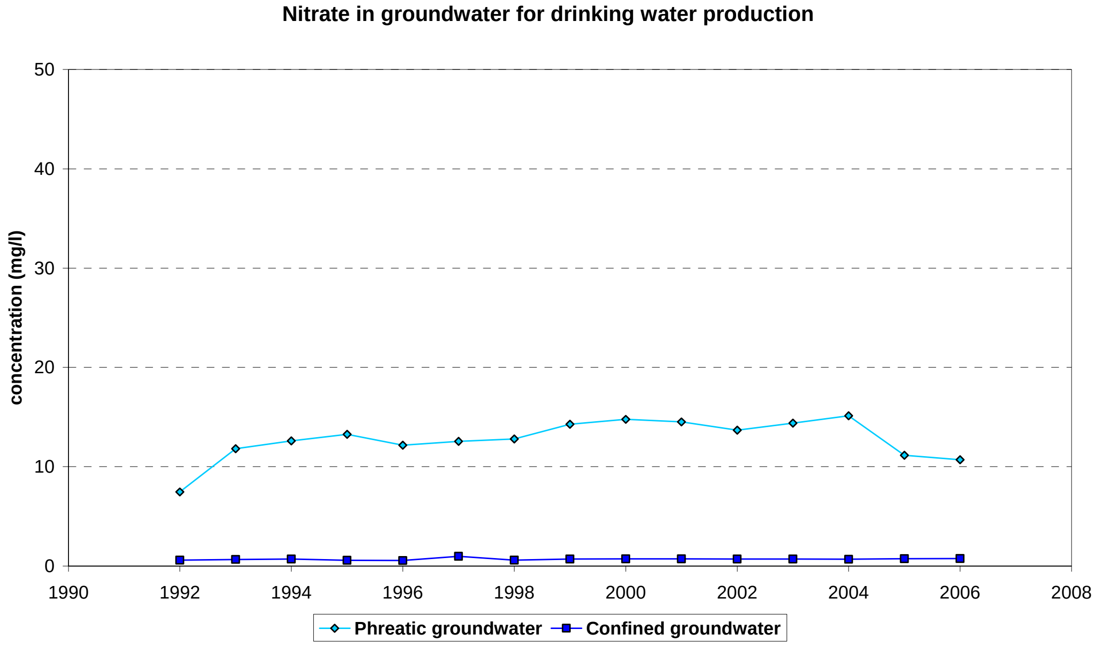


Figure 29: Maximum nitrate concentration (mg/l) in groundwater in the Netherlands at drinking water production sites for phreatic groundwater and confined groundwater for the 1992–2006 period.

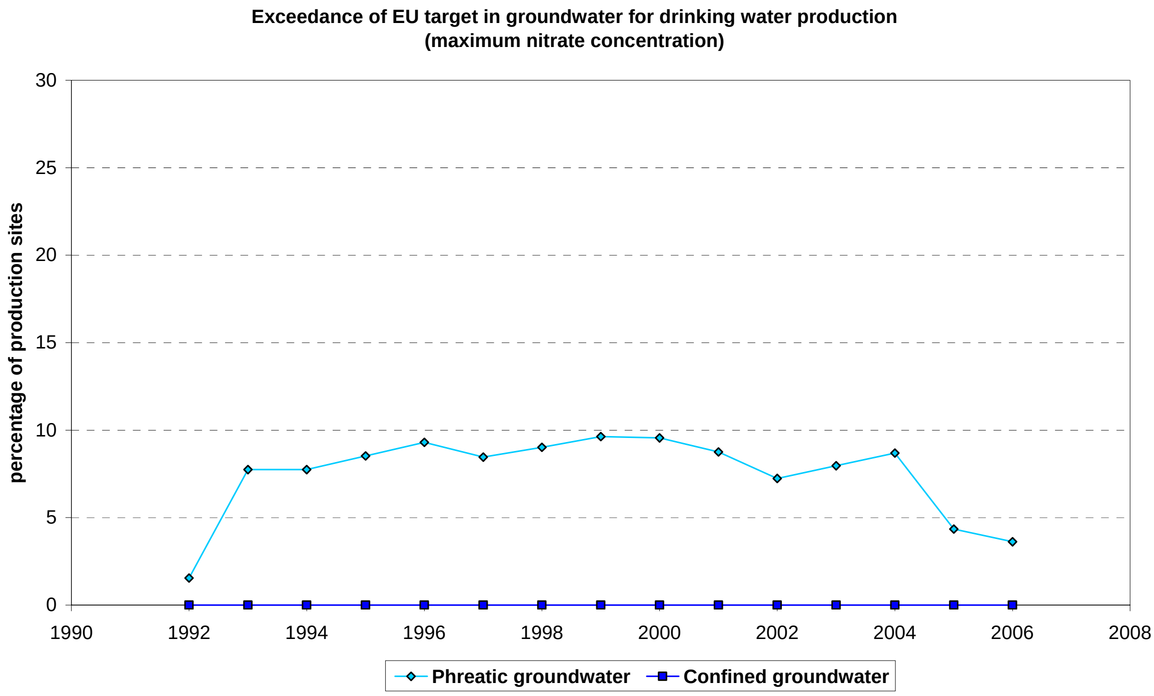


Figure 30: **Exceedance of the EU target value of 50 mg/l for the maximum nitrate concentration in groundwater in the Netherlands at drinking water production sites for phreatic groundwater and confined groundwater for the 1992-2006 period.**
Exceedance is expressed as a percentage of all production sites

Table 29: **Maximum nitrate concentration in groundwater at a depth of more than 30 m for the 1992-2006 period (%)[1].**

	All production sites			Phreatic sites		
Concentration range	1992-1995	2000-2003	2004-2006	1992-1995	2000-2003	2004-2006
0–15 mg/l	86	84	84	78	75	74
15–25 mg/l	4	3	4	5	4	5
25–40 mg/l	5	3	5	8	5	9
40–50 mg/l	2	4	3	4	7	4
> 50 mg/l	3	6	5	5	9	8
Number of sites	220	227	227	130	138	138

[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 phreatic groundwater only. Total percentage may exceed 100 because of rounding off.

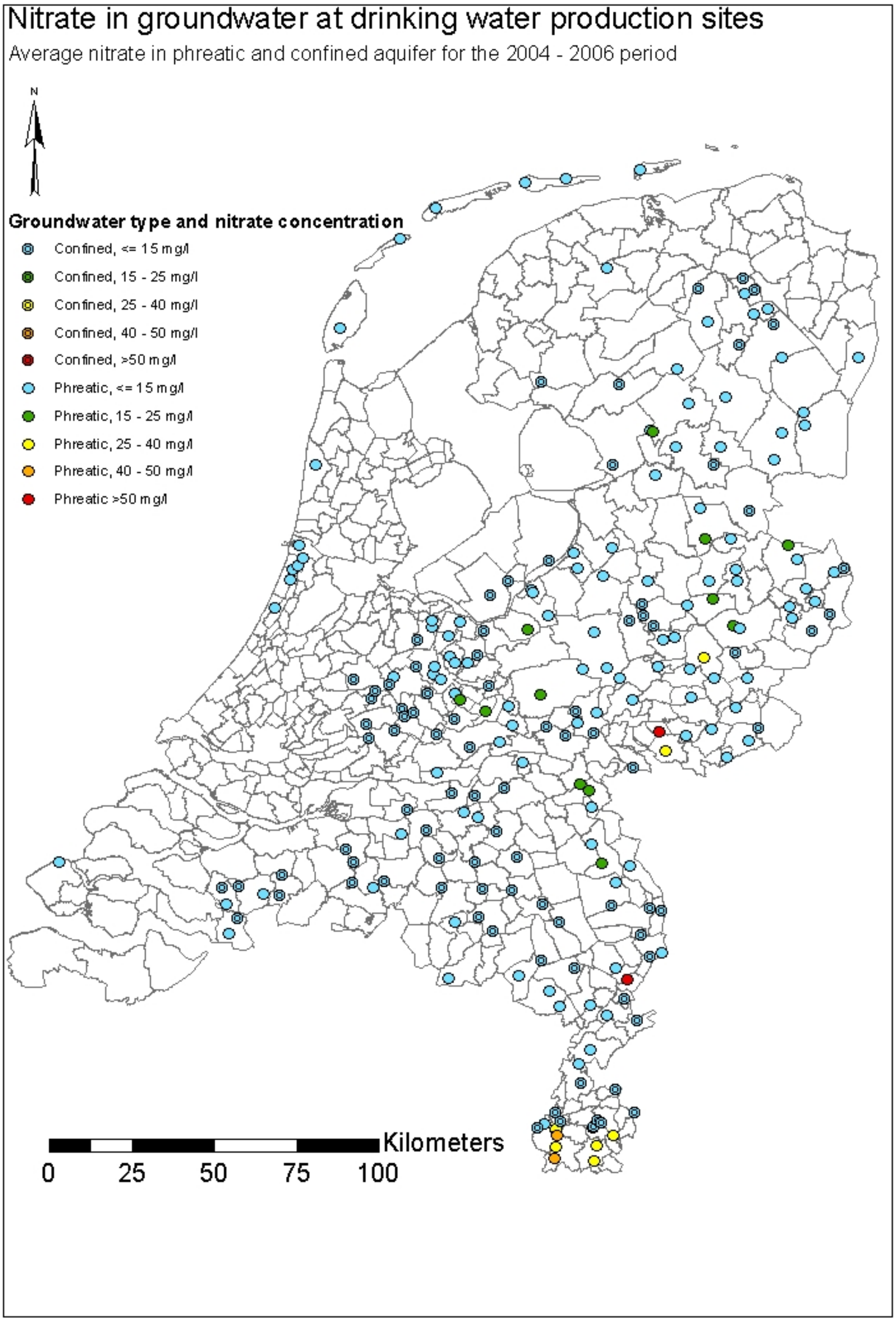
Table 30: Change in maximum nitrate concentration in groundwater at a depth of more than 30 m for the 1992-2002 period (%)[1].

Rate of change	All production sites 1992/1995-2000/2003	2000/2003-2004/2006	Phreatic sites 1992/1995-2000/2003	2000/2003-2004/2006
Large increase (% > 5 mg/l)	11	2	19	3
Small increase (% 1-5 mg/l)	11	5	18	7
Stable (% ± 1 mg/l)	70	79	54	68
Small decrease (% 1-5 mg/l)	5	9	5	13
Large decrease (% > 5 mg/l)	3	5	4	9
Number of sites	218	227	129	138

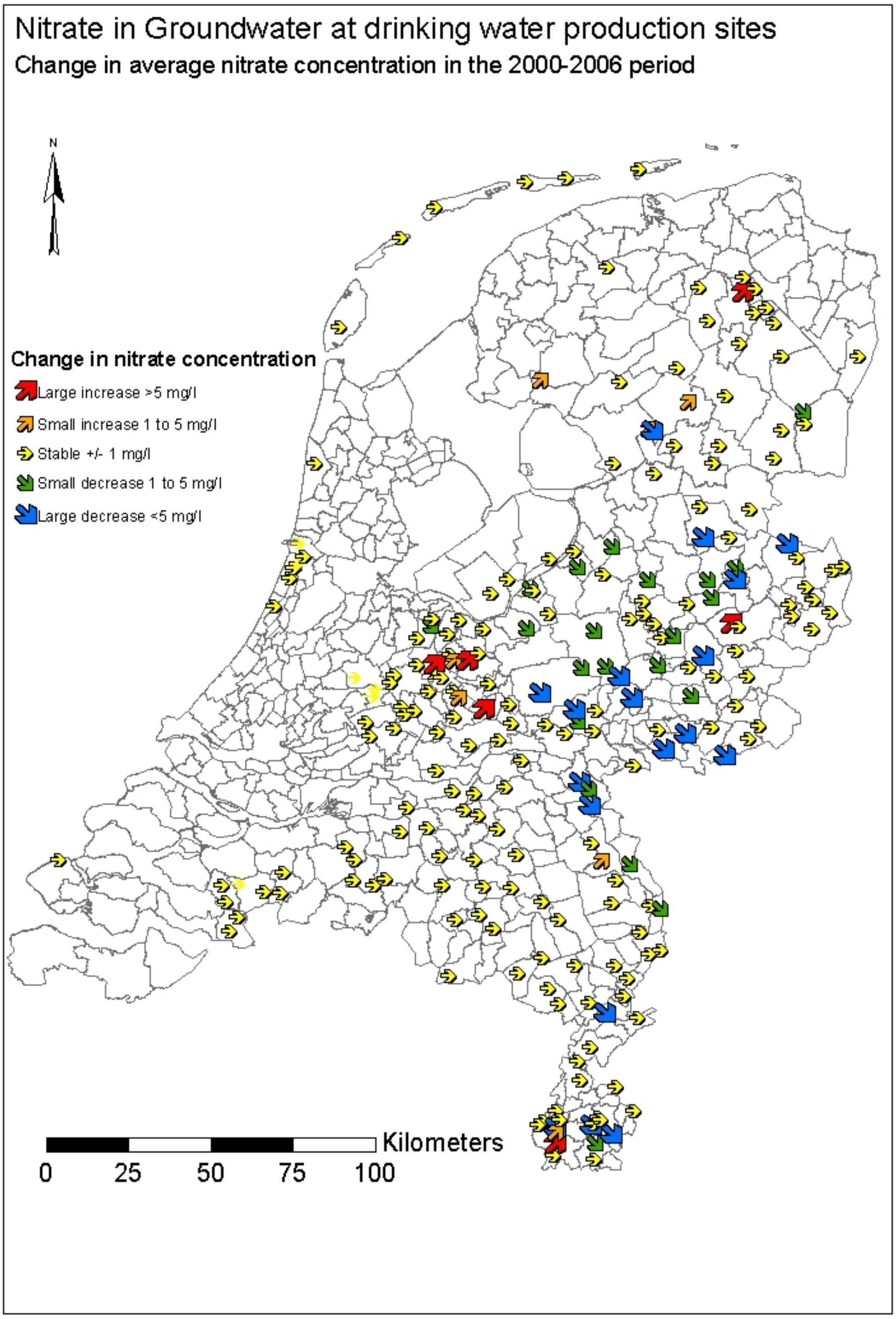
1) Percentage of drinking water production sites using groundwater with given rates of change in concentration between the first and third and between the third and fourth reporting periods. Data is for all production sites and sites with phreatic groundwater only. Total percentage may exceed 100 because of rounding off.

Map 8 shows the average concentration per drinking water station for the 2004-2006 period, while Map 9 shows the change between the 2000-2003 and 2004-2006 periods. The highest nitrate concentrations occur in the southern part of the Netherlands in mainly loess soils and in the eastern part of the Netherlands near the German border in sandy soils. These parts of the Netherlands in particular show decreasing trends.

Map 10 shows the maximum concentration per drinking water station for the 2004-2006 period, while Map 11 shows the change in maxima between the 2000-2003 and 2004-2006 periods. The highest maximum nitrate concentrations also occur in the southern and the eastern parts of the Netherlands.

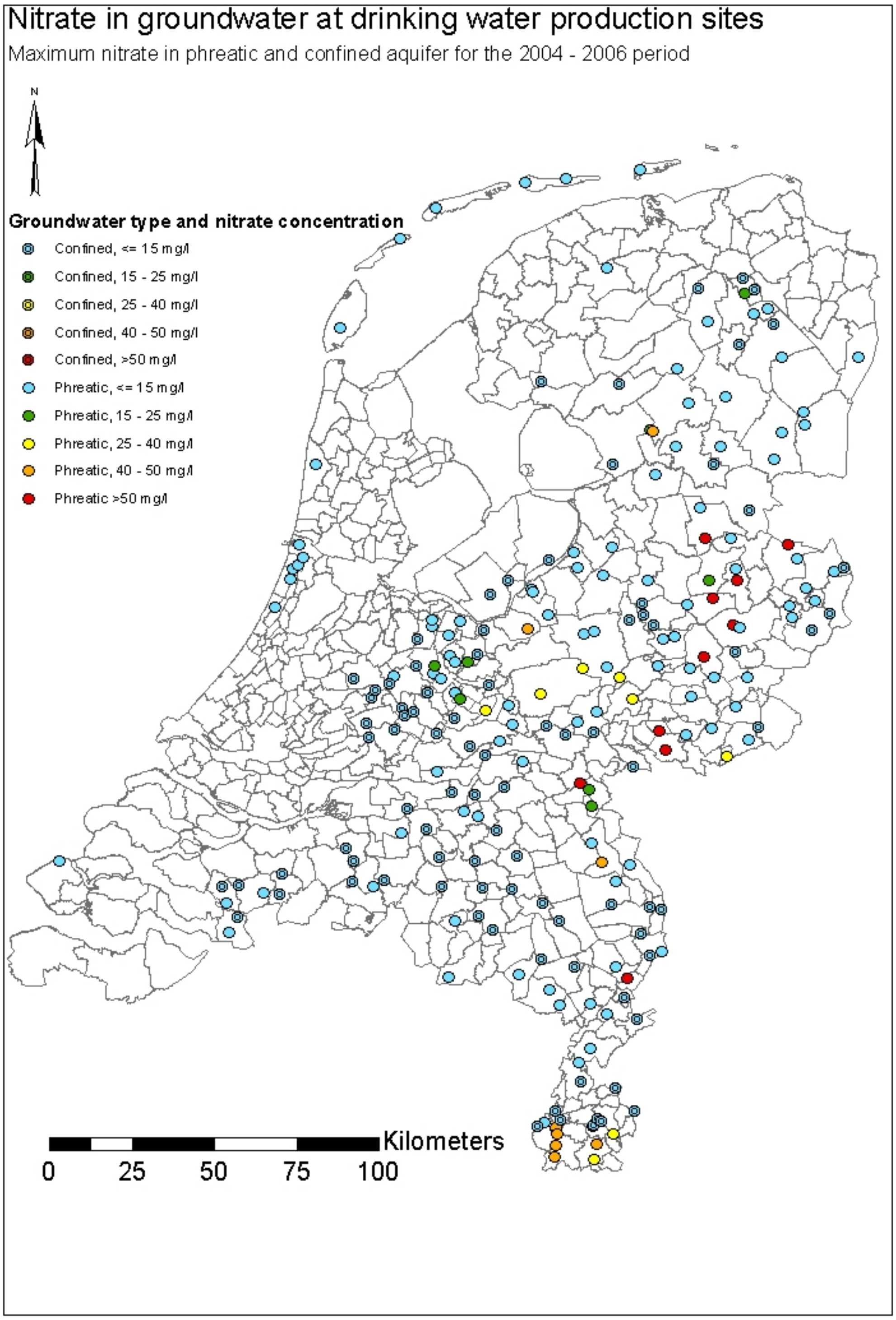


Map 8: Average nitrate concentration in groundwater used for drinking water production in the Netherlands for the 2004-2006 period.

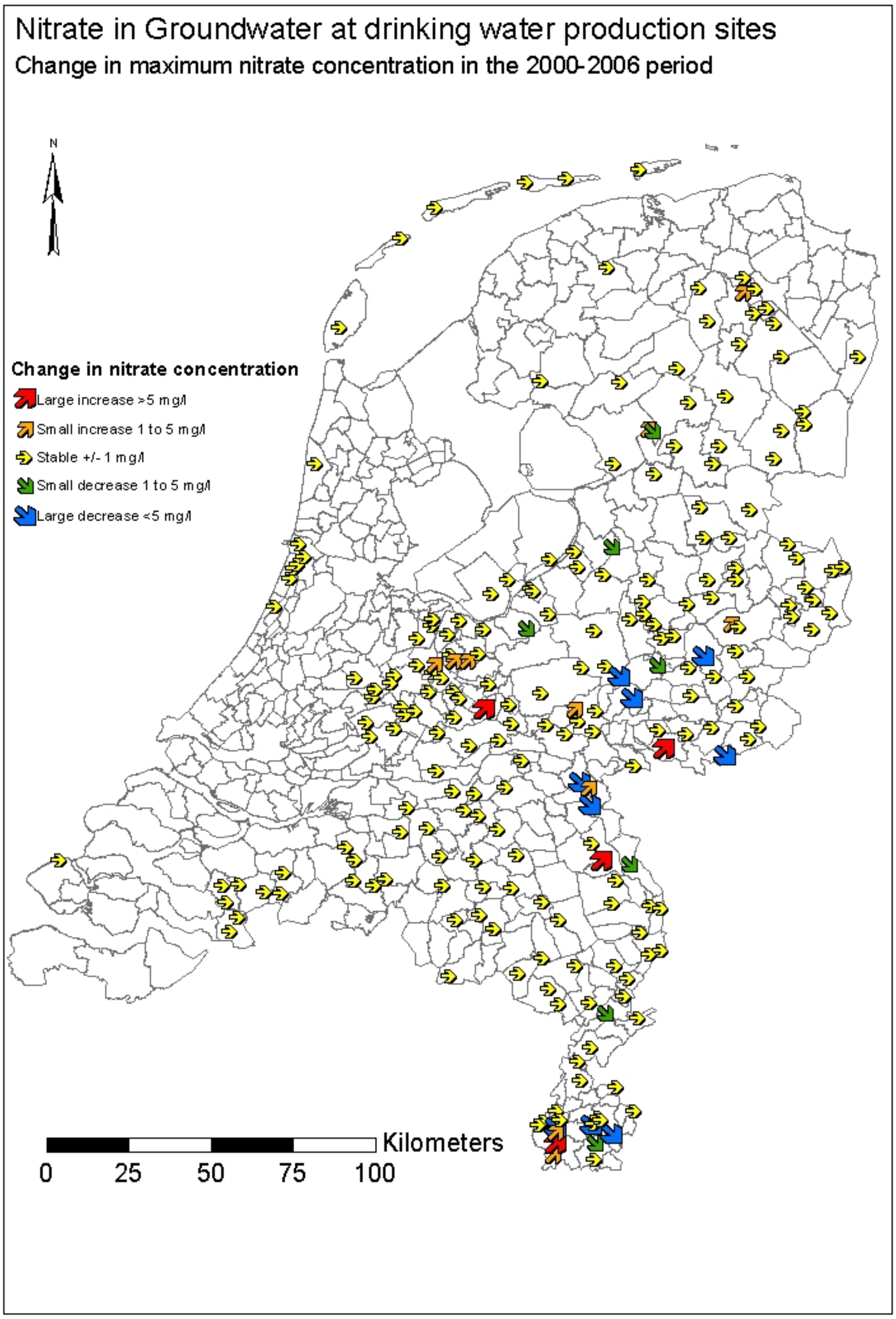


Map 9: Change in average nitrate concentration in groundwater used for drinking water production in the Netherlands for the 2000-2006 period.

Change expressed as difference between averages for the 2000-2003 and 2004-2006 periods.



Map 10: Maximum nitrate concentration in groundwater used for drinking water production in the Netherlands for the 2004-2006 period.



Map 11: Change in maximum nitrate concentration in groundwater used for drinking water production in the Netherlands for the 2000-2006 period.

Change expressed as difference between averages for the 2000-2003 and 2004-2006 periods.

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6 Freshwater quality

6.1 Introduction

The opening section (Section 6.2) of this chapter provides a summary of the various freshwater nutrient loads in the Netherlands. The substances nitrogen and phosphorus both affect the degree of eutrophication. In Section 6.3, the trend in the nitrate concentration over three various periods is shown. Section 6.4 deals with the various parameters which define the eutrophication status of freshwater.

The data presented in this chapter is obtained from surveys of all waters and, in particular, of waters strongly influenced by agriculture. Waters which are strongly affected by agriculture belong to the so-called regional waters. In addition to waters which are strongly influenced by agriculture, ‘main locations’ are also presented in this chapter.

Main locations are singled out as a separate category for two reasons. The first reason is that they give an indication of foreign influences on water quality and, secondly, because the effects of domestic sources, i.e. sources other than agriculture, on water quality in the coastal zone are readily depicted using nitrate concentrations at the main locations.

Chlorophyll-*a*, total nitrogen content and total phosphorus content are used to assess the degree of eutrophication in the Netherlands. Chlorophyll-*a* concentrations are at their highest during the summer months, i.e. April to October. The summer average is therefore used to determine the extent of eutrophication of the various watercourses in the Netherlands over the defined periods. In Dutch standards, eutrophication is depicted not only using the summer average of chlorophyll-*a*, but also using the summer average of total phosphorus and total nitrogen (V&W, 1998; CIW, 2000). The latter is an indication of both the available nutrients and the algal biomass.

In this report, nitrate nitrogen is considered to be the most important variable depicting the effects of agriculture on surface water quality, in accordance with EU standards. In watercourses liable to eutrophication, nitrates disappear to a variable extent through uptake by algae in the summer period, which can skew the monitoring results. The more eutrophicated a water body is, the lower the nitrate level during the summer. The winter average (October to March) is therefore more representative than the annual average. The winter period is also the period in which leaching processes play an important role. In this report however, the winter, summer and annual averages are presented for nitrates.

6.2 Nutrient load to fresh waters

The greatest source of total nitrogen in the Dutch freshwater system is of foreign origin, accounting for 58% of the total amount of nitrogen found in Dutch freshwater. This is shown in Table 31. The other 42% of total nitrogen found in the Dutch water system is attributed to various other sources, as shown in Figure 31. Figure 31 shows that agricultural activities comprise most of the inland nitrogen load to the Dutch freshwater system. This is mainly because of direct discharges, leaching and run-off. Also shown is the extensive decrease in nitrate contribution originating from communal and industrial sources between 1985 and 2005.

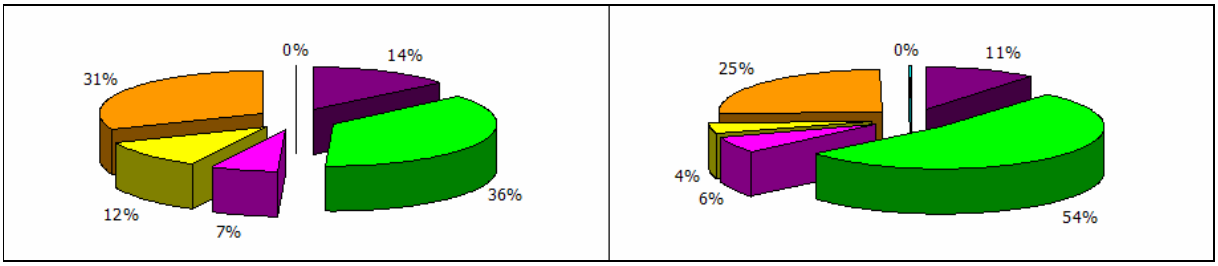

Figure 31: Origins of inland nitrate in the Dutch freshwater system (1985 left and 2005 right). Atmospheric deposition [dark purple], agriculture [green], nature [light purple],industry [yellow], communal [orange] and shipping [blue].
Source: Emission registration.

Table 31: Nitrogen and phosphorus load of freshwater in the Netherlands (in thousand kg) for 1985 and 2005.

	N	
	1985	**2005**
Atmospheric deposition	23594	10166
Industry	19529	3932
Communal	52143	23411
Agriculture	62048	48736
Nature	11172	5745
Shipping	184	229
Inland amount	**168670**	**92213**
Foreign influence		
Rhine	398900	222580
Meuse	29160	27430
Scheldt	33860	20200
Total foreign influence	**461920**	**270210**

Source: EMW; 2007.

Various periods will be compared in this chapter to determine the trend in nitrate concentration. In general, the amount of nitrogen attributed to foreign sources shows a slight decrease between the last two periods. This decrease did however stabilise in the last period (2004-2006). The amount of nitrogen attributed to inland sources only decreased by approximately 10% within the last period. The most important inland sources are run-off from rural areas and discharge from sewerage treatment plants (Water in Beeld, 2008). Atmospheric deposition also accounts for approximately 10% of the total inland nitrogen load.

For smaller water bodies, i.e. regional waters, inland sources account for almost all the nitrogen present. For larger water bodies, i.e. the major rivers, foreign sources account for the majority of nitrogen found in those water bodies. The reduction of foreign sources will have the greatest effect on the amount of nitrogen found in these water bodies.

Agreements with neighbouring countries will be necessary to decrease foreign loads to the Dutch water system. These agreements have already been made in ‘river basin management plans’, which are obligatory within the Water Framework Directive.

6.3 Nitrate concentration in fresh waters

6.3.1 Nitrate concentration – winter average

The vast majority of freshwater locations have a winter average nitrate concentration below the EU target value of 50 mg/l (Table 32 and Map 12). As shown in Table 32, there is a decrease in the number of locations with an average above 50 mg/l when the first period is compared with the latter periods. A comparison of the last two periods leads to the conclusion that the change in nitrate concentration has stagnated.

The winter average nitrate concentrations for the last period (2004-2006) are shown in Map 12. Waters exceeding the EU target value of 50 mg/l are found in West Brabant, the southern part of Limburg, the Westland region and the eastern region of the Netherlands. The same situation occurred in the previous period (2000-2003). Most of the locations which exhibit large increases in nitrate are located on sandy soil.
As in the preceding period (2000-2003), low nitrate concentrations were found in the 'Gelderse Valley', a region with intensive stockbreeding, in the last period.

Table 32: Nitrate concentration (winter average) in fresh surface waters in the various periods (%).

	All waters			Waters strongly influenced by agriculture		
Concentration range	1992-1995	2000-2003	2004-2006	1992-1995	2000-2003	2004-2006
0-2 mg/l	2	5	7	0	7	7
2-10 mg/l	20	37	42	28	42	44
10-25 mg/l	50	41	37	44	34	37
25-40 mg/l	17	12	11	13	11	7
40-50 mg/l	5	3	1	5	4	2
>50 mg/l	7	1	2	11	2	3
Number of sites	373	505	507	130	178	177

As shown in Table 33 and Map 13, comparison of the last two periods shows a steady state or decrease for the winter average for about 67% of the locations. About 8% of the locations show a large increase in nitrate concentration. Table 33 also clearly shows that more than 90% of the locations exhibit a steady state or decrease in nitrate winter average, when comparing the first and third reporting periods. In other words, the situation in the Netherlands for the first period (1992 to 1995) was worse than in later periods. The situation improved drastically in the second and third reporting periods.

There was no significant difference between agricultural waters and main locations in the last two periods. Figure 32 clearly illustrates this observation. The nitrate winter average concentrations were almost halved between the first and third periods. Between the last two periods, no significant change took place.

Table 33: Change in nitrate concentration (winter average) in fresh waters in various periods (%).

	All waters		Waters strongly influenced by agriculture	
Rate of change	1992/1995-2000/2003	2000/2003-2004/2006	1992/1995-2000/2003	2000/2003-2004/2006

Rate of change	All waters 1992/1995-2000/2003	All waters 2000/2003-2004/2006	Waters strongly influenced by agriculture 1992/1995-2000/2003	Waters strongly influenced by agriculture 2000/2003-2004/2006
Large increase (> 5 mg/l)	3	6	7	8
Small increase (1 - 5 mg/l)	3	20	5	26
Stable (+/- 1 mg/l)	8	25	8	24
Small decrease (1 - 5 mg/l)	34	31	32	24
Large decrease (> 5 mg/l)	52	18	48	19
Number of sites	373	506	130	177

The changes in winter average nitrate concentrations for all surface waters in the Netherlands are shown in Map 13. In general, the increase in winter average nitrate concentration was mainly found in West Brabant; most of the locations in this region show an increase of more than 5 mg/l.

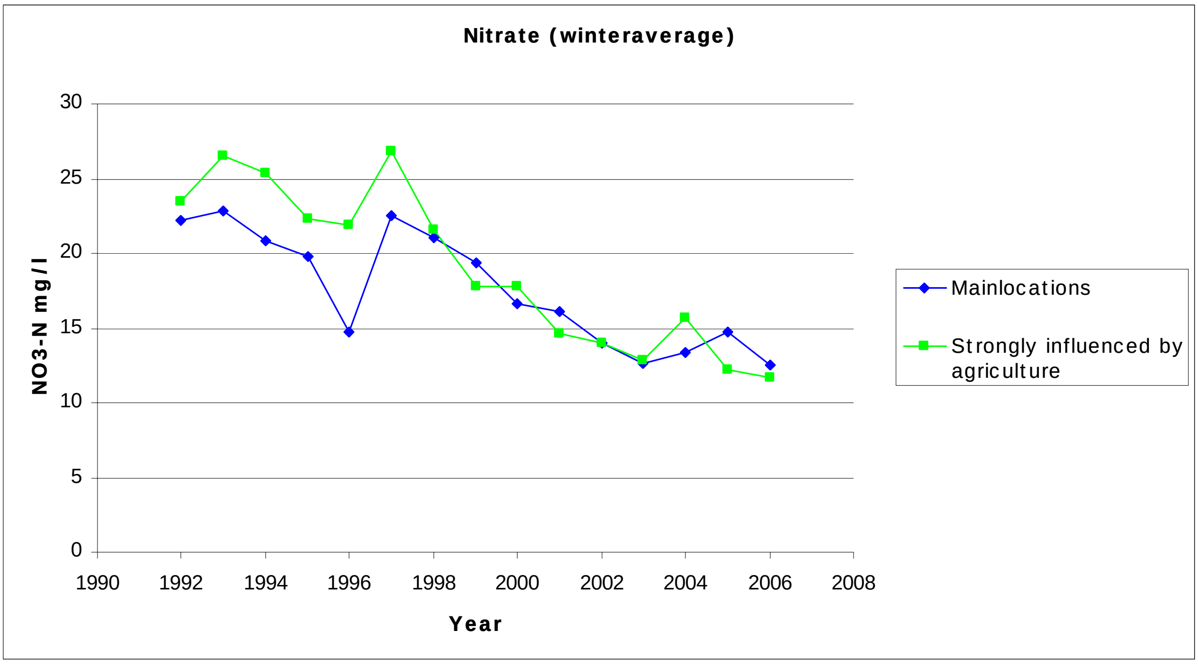

Figure 32: Nitrate concentration (winter average) in fresh surface waters between 1992 and 2006.

6.3.2 Nitrate concentration – winter maximum

For the vast majority of locations, the winter maximum nitrate concentration was below the EU target value of 50 mg/l, as shown in Table 34.

Table 34: Nitrate concentration (winter maximum) in fresh surface waters for the various periods (%).

Concentration range	All waters 1992-1995	2000-2003	2004-2006	Waters strongly influenced by agriculture 1992-1995	2000-2003	2004-2006
0-2 mg/l	1	3	4	0	4	5
2-10 mg/l	10	23	26	13	28	25
10-25 mg/l	39	43	42	38	39	38
25-40 mg/l	26	17	14	24	12	16
40-50 mg/l	7	8	6	5	8	5
>50 mg/l	17	6	8	20	9	10
Number of sites	373	505	507	130	178	177

As was also the case with the winter average concentrations, winter maximum concentrations did not change much between the last two periods. The greatest change occurred between the first and third reporting periods, as shown in Table 35.

Table 35: Change in nitrate concentration (winter maximum) in fresh waters for the various periods (%).

Rate of change	All waters 1992/1995-2000/2003	2000/2003-2004/2006	Waters strongly influenced by agriculture 1992/1995-2000/2003	2000/2003-2004/2006
Large increase (> 5 mg/l)	6	19	10	29
Small increase (1 - 5 mg/l)	6	19	10	20
Stable (+/- 1 mg/l)	8	16	5	10
Small decrease (1 - 5 mg/l)	23	24	17	20
Large decrease (> 5 mg/l)	58	22	58	21
Number of sites	373	506	130	177

6.3.3 Nitrate concentration – annual average

As stated earlier, in addition to the summer average, the annual average for nitrate is also presented in this chapter.

As mentioned earlier, nitrates sometimes disappear in the summer period because of uptake by algae. Winter average concentrations give a better indication of nitrates at the various locations. This assumption is confirmed by comparison of the results presented in Table 36 and Table 32.

Table 36: Nitrate concentration (annual average) in fresh waters for various periods (%).

	All waters			Waters strongly influenced by agriculture		
Concentration range	1992-1995	2000-2003	2004-2006	1992-1995	2000-2003	2004-2006
0-2 mg/l	3	8	9	3	8	8
2-10 mg/l	33	51	50	44	61	57
10-25 mg/l	46	33	32	34	21	25
25-40 mg/l	9	5	5	5	4	3
40-50 mg/l	4	1	1	4	2	2
>50 mg/l	5	2	2	10	4	4
Number of sites	374	507	511	128	171	178

Most locations now have an annual average nitrate concentration of between 2-10 mg/l, which differs from the winter average concentrations. For all waters, 50% have a nitrate concentration between 2 and 10 mg/l when annual averages are observed, as opposed to 42% when winter average concentrations are observed. For locations strongly influenced by agriculture, the percentages are 57% and 44%, respectively.

6.4 Eutrophication status of freshwater

6.4.1 Chlorophyll-*a*

The summer average chlorophyll-*a* concentration is used to express eutrophication in this chapter. However, the occurrence of eutrophication phenomena, expressed as chlorophyll-*a*, is not only determined by nitrate concentrations in surface waters. Other nutrients, especially phosphorus, as well as physical and meteorological conditions, also play a role. Chlorophyll-*a* is related to the amount of algae present in surface water and is therefore related to the eutrophication status of surface water. The reporting guidelines define waters with chlorophyll-*a* amounts between 25 and 75 µg/l as eutrophic and chlorophyll-*a* amounts of above 75 µg/l result in a hypertrophic status (EC/DGXI; 2000). Dutch standards define surface waters with chlorophyll-*a* concentrations above 100 µg/l as hypertrophic.

Table 37 shows a large decrease in chlorophyll-*a* concentration between the first and the third reporting periods. After that, a somewhat steady-state situation occurs with respect to the third and fourth reporting periods. This scenario is even more clearly shown in Table 38, in which the change in chlorophyll-*a* concentration between the first and third periods, and between the third and fourth periods is reported.

Table 37: Chlorophyll-*a* concentration (summer average) in fresh waters in various periods (%).

Concentration range	All waters 1992-1995	2000-2003	2004-2006	Waters strongly influenced by agriculture 1992-1995	2000-2003	2004-2006
0-2.5 µg/l	2	0	1	3	0	0
2.5-8.0 µg/l	6	5	10	9	6	11
8.0-25 µg/l	32	42	41	28	37	40
25-75 µg/l	36	40	36	27	37	32
>75 µg/l	24	13	12	32	19	17
Number of sites	235	391	356	74	139	110

Table 38: Change in chlorophyll-*a* concentration (summer average) in fresh waters between various periods (%).

Rate of change	All waters 1992/1995-2000/2003	2000/2003-2004/2006	Waters strongly influenced by agriculture 1992/1995-2000/2003	2000/2003-2004/2006
Large increase (> 10 µg/l)	16	16	20	17
Small increase (5 - 10 µg/l)	8	7	10	7
Stable (+/- 5 µg/l	24	40	32	42
Small decrease (5 - 10 µg/l)	12	15	3	10
Large decrease (> 10 µg/l)	40	22	34	24
Number of sites	202	327	59	109

The largest decrease in chlorophyll-*a* concentration was reached between the first and third periods, after which most of the locations (approximately 40%) exhibit a steady state. At the same time, approximately the same amount of locations show an increase in chlorophyll-*a* (about 20%).

The same statement is visualised in Figure 33, in which the chlorophyll-*a* concentration (summer averaged) is shown between 1992 and 2006.

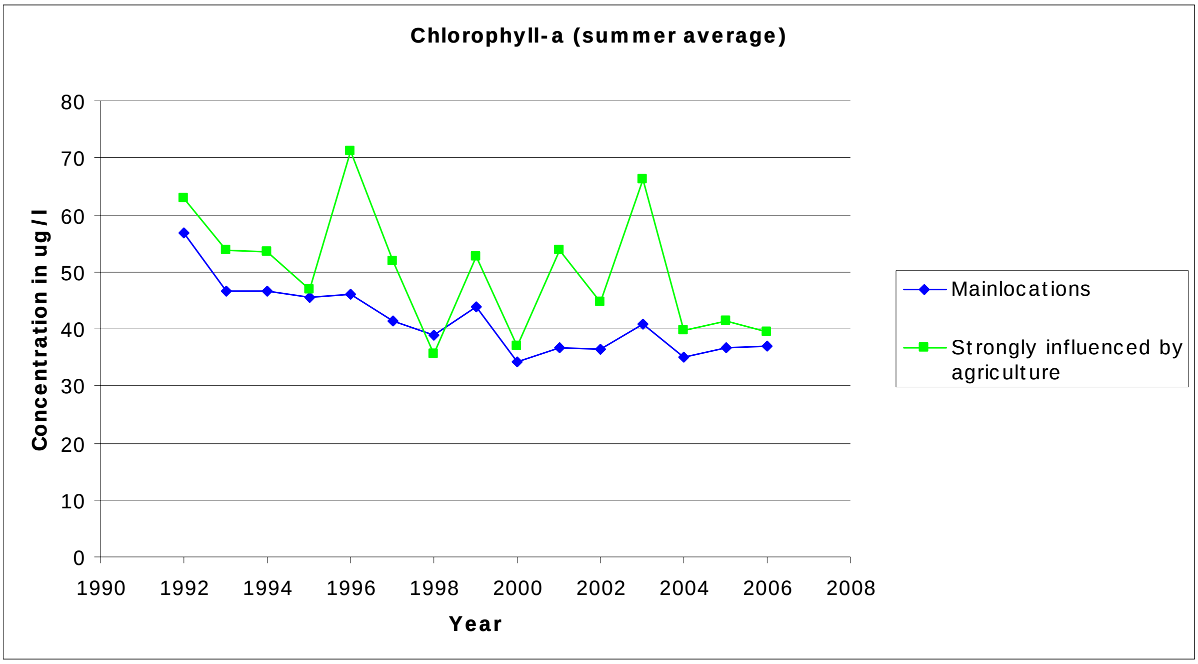

Figure 33: **Chlorophyll-*a* concentration (summer average) in fresh waters in the Netherlands between 1992 and 2006.**

Figure 33 shows a decline in chlorophyll-a concentration over the various years. Locations strongly influenced by agriculture show the same trend as the other locations, although the concentrations are slightly higher and more variable between consecutive years.

6.4.2 Other parameters depicting the eutrophication status

As well as chlorophyll-*a* in surface waters, summer average total nitrogen and total phosphorus concentrations also exhibit a decline over the years. The Dutch target value of 2.2 mg/l for total nitrogen (CIW; 2000, V&W; 1998) is however still exceeded at more than 75% of all locations.

Table 39a: Total nitrogen concentration (summer average) over various periods (%).

	All waters			Waters strongly influenced by agriculture		
Concentration range	1992-1995	2000-2003	2004-2006	1992-1995	2000-2003	2004-2006
0-2 mg/l	5	19	24	4	20	25
2-5 mg/l	64	62	60	65	61	58
5-7 mg/l	12	12	9	10	10	6
>7 mg/l	19	7	8	21	9	11
Number of sites	350	506	510	113	178	177

Table 39b: Change in total nitrogen concentration (summer average) in fresh waters between various periods (%).

Rate of change	All waters		Waters strongly influenced by agriculture	
	1992/1995-2000/2003	2000/2003-2004/2006	1992/1995-2000/2003	2000/2003-2004/2006
Large increase (> 0.5 mg/l)	7	13	8	19
Small increase (0.25 - 0.50 mg/l)	5	7	8	5
Stable (+/- 0.25 mg/l	11	34	10	39
Small decrease (0.25 - 0.50 mg/l)	7	18	4	14
Large decrease (> 0.50 mg/l)	69	28	70	24
Number of sites	349	506	113	177

For total nitrogen, the same situation is observed as for chlorophyll-*a* (previous paragraph), though less pronounced. Here a large decrease is observed in the total summer average nitrogen concentration between the first and third periods, just as for all other parameters discussed in this chapter.

Table 40a: Total phosphorus concentration (summer average) over various periods (%).

Concentration range	All waters			Waters strongly influenced by agriculture		
	1992-1995	2000-2003	2004-2006	1992-1995	2000-2003	2004-2006
< 0.05 mg/l	0	2	4	0	1	2
0.05 - 0.10 mg/l	8	11	15	15	10	13
0.10 - 0.20 mg/l	38	40	37	31	33	31
> 0.20 mg/l	31	27	26	18	22	19
> 0.50 mg/l	23	19	19	36	34	35
Number of sites	331	503	507	102	175	175

Table 40b: Change in total phosphorus concentration (summer average) in fresh waters between various periods (%).

Rate of change	All waters		Waters strongly influenced by agriculture	
	1992/1995-2000/2003	2000/2003-2004/2006	1992/1995-2000/2003	2000/2003-2004/2006
Large increase (> 0.10 mg/l)	5	8	8	21
Small increase (0.05 - 0.10 mg/l)	5	6	9	7
Stable (+/- 0.05 mg/l)	42	60	42	47
Small decrease (0.05 - 0.10 mg/l)	18	15	14	13
Large decrease (> 0.10 mg/l)	29	10	27	12
Number of sites	330	500	102	172

For total phosphorus, there is an increase in summer average concentration at about 30% of the locations which are strongly influenced by agriculture. In other words, the decrease in the summer average concentration of total phosphorus takes place more slowly at locations strongly influenced by agriculture than at other locations. The summer average concentration at locations strongly influenced by agriculture is higher than 0.50 mg/l in 35% of all cases, as opposed to 19% overall.

Figures 34 and 35 depict the situation for summer average total nitrogen and total phosphorus for each year in between 1992 and 2006. Both figures show concentrations above the Dutch target value of

2.2 mg/l and 0.15 mg/l for total nitrogen and total phosphorus respectively. Readers should however bear in mind that both figures depict summer averages per given year. As should be clear from Tables 39 and 40, locations do exist at which total nitrogen and total phosphorus concentrations are below the Dutch standard values.

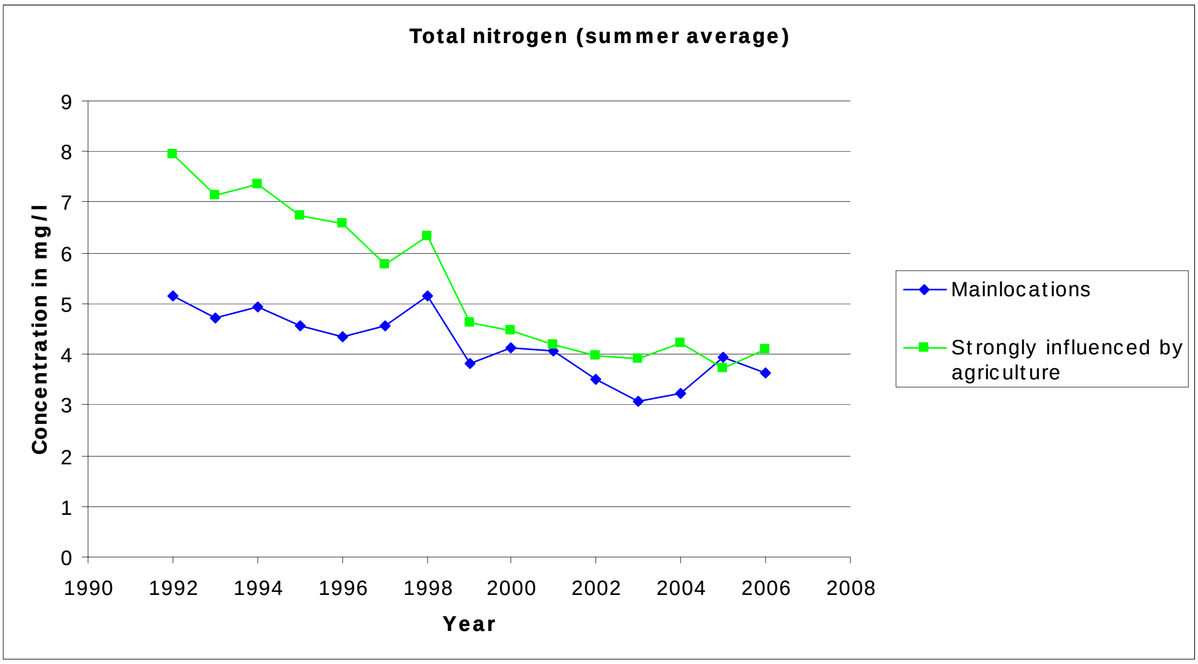

Figure 34: Total nitrogen concentration (summer average) in fresh waters between 1992 and 2006.

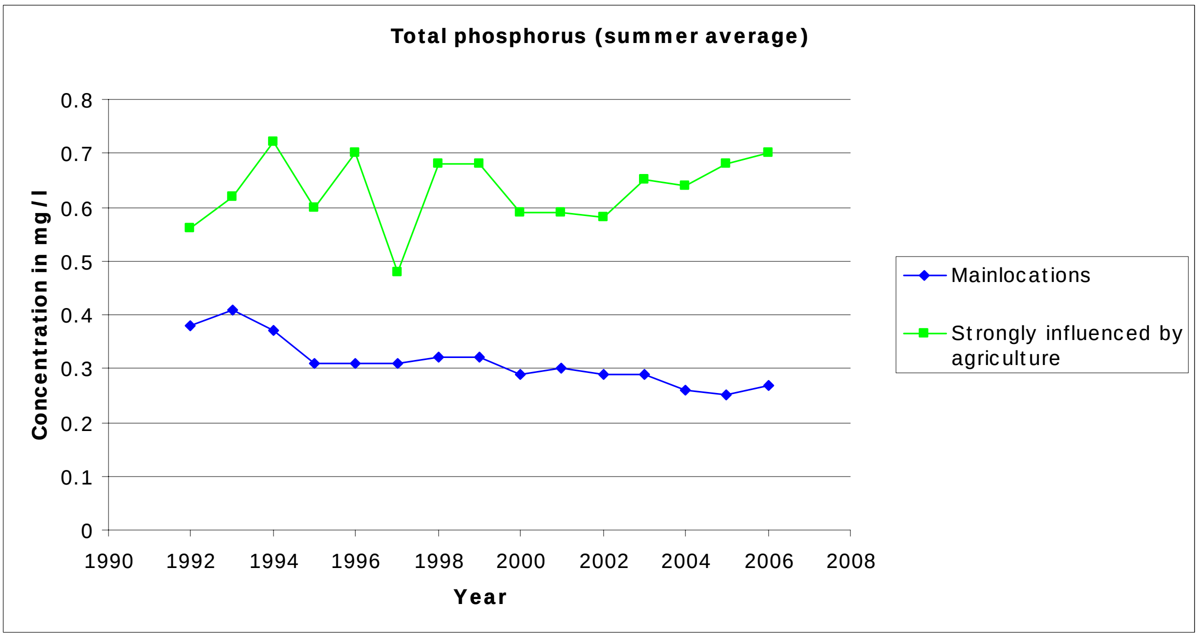

Figure 35: Total phosphorus concentration (summer average) in fresh waters between 1992 and 2006.

6.5 Trends

In general, more than 90% of all locations, e.g. main locations and locations strongly influenced by agriculture, exhibit a steady state of decrease in winter average nitrate when the first period is compared with the other periods. In other words, when nitrate is accounted for, the situation has improved since 1992. The same situation is shown for total phosphorus and chlorophyll-*a*, although the situation for the latter is less pronounced.

6.6 Literature

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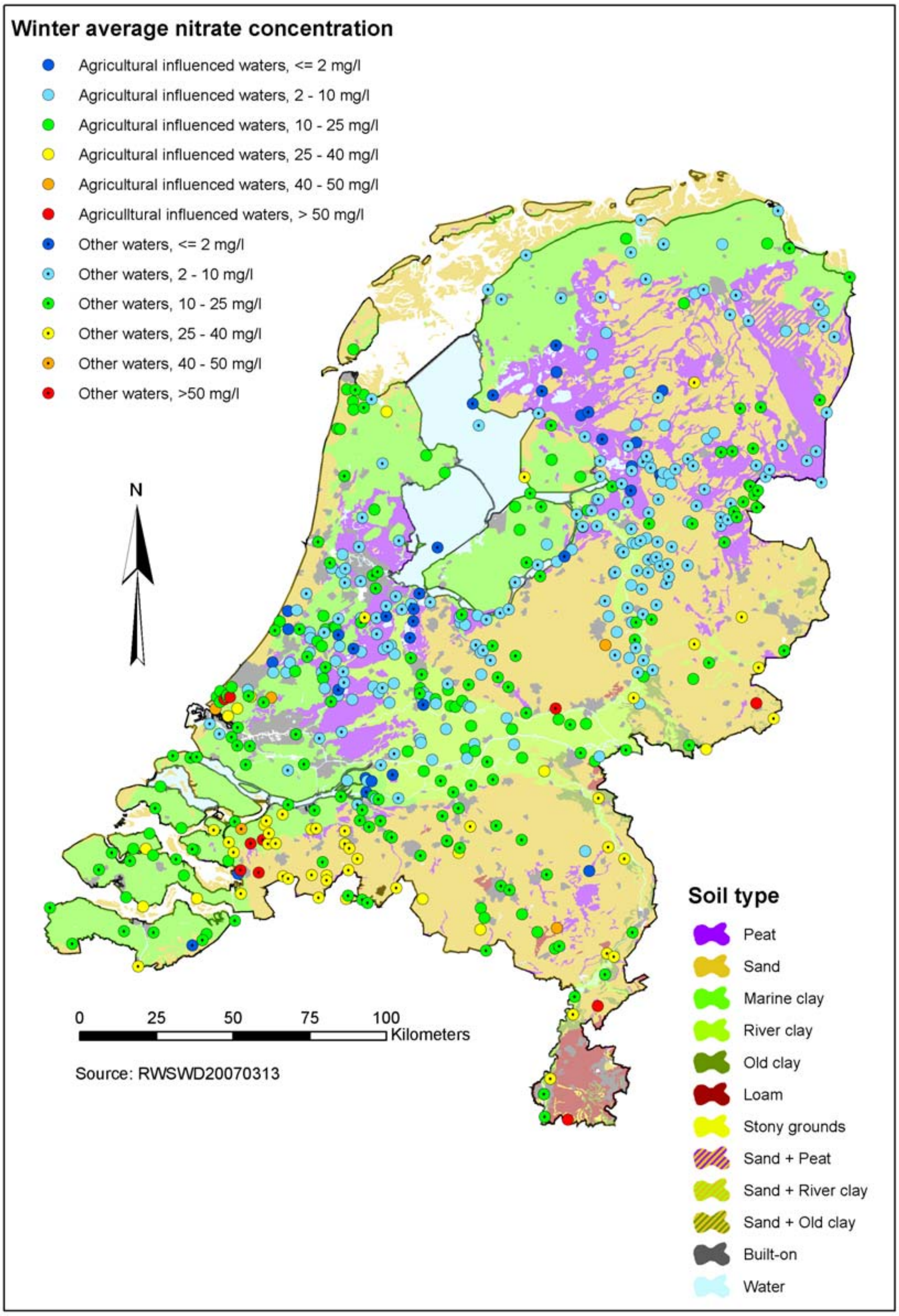
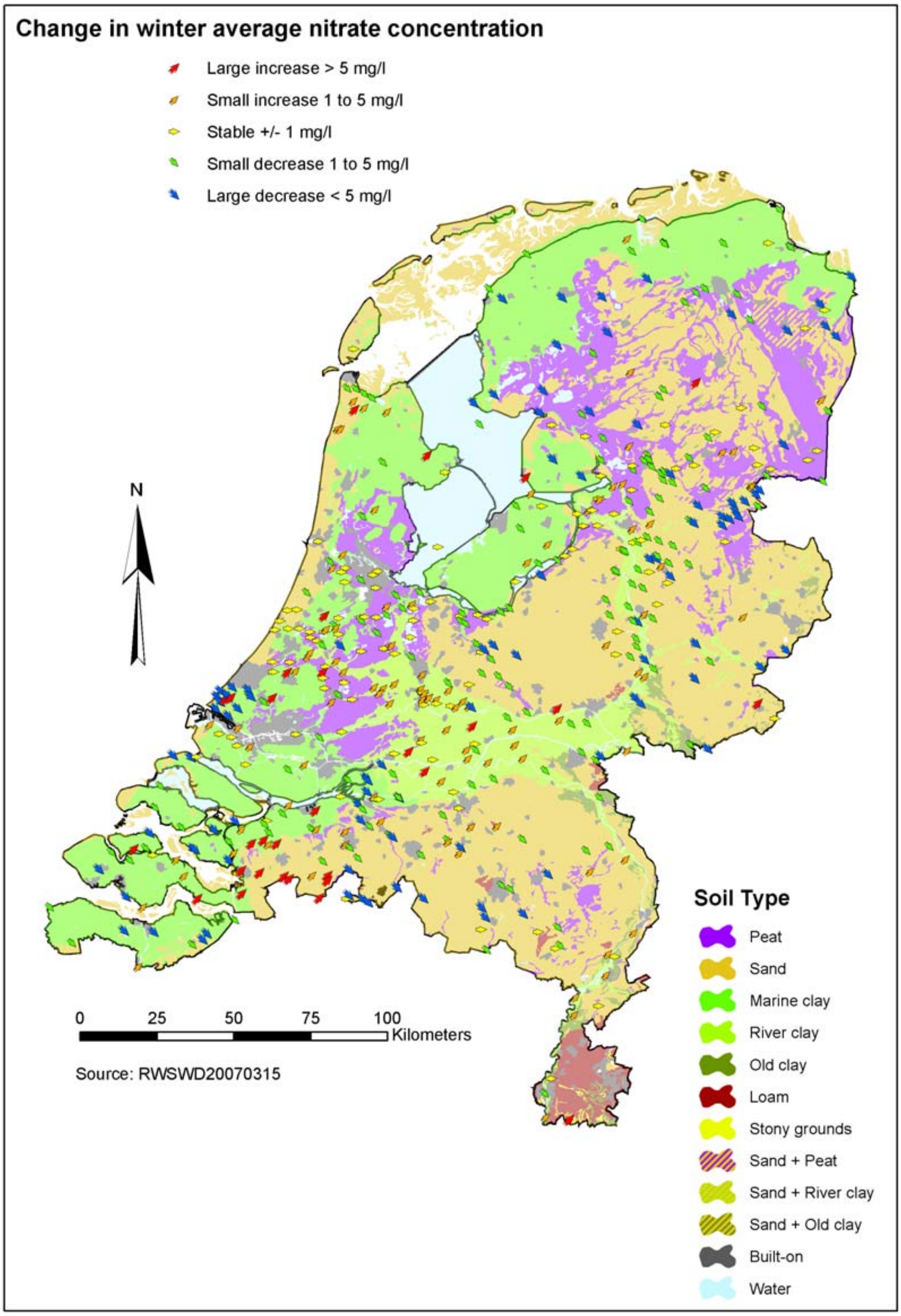
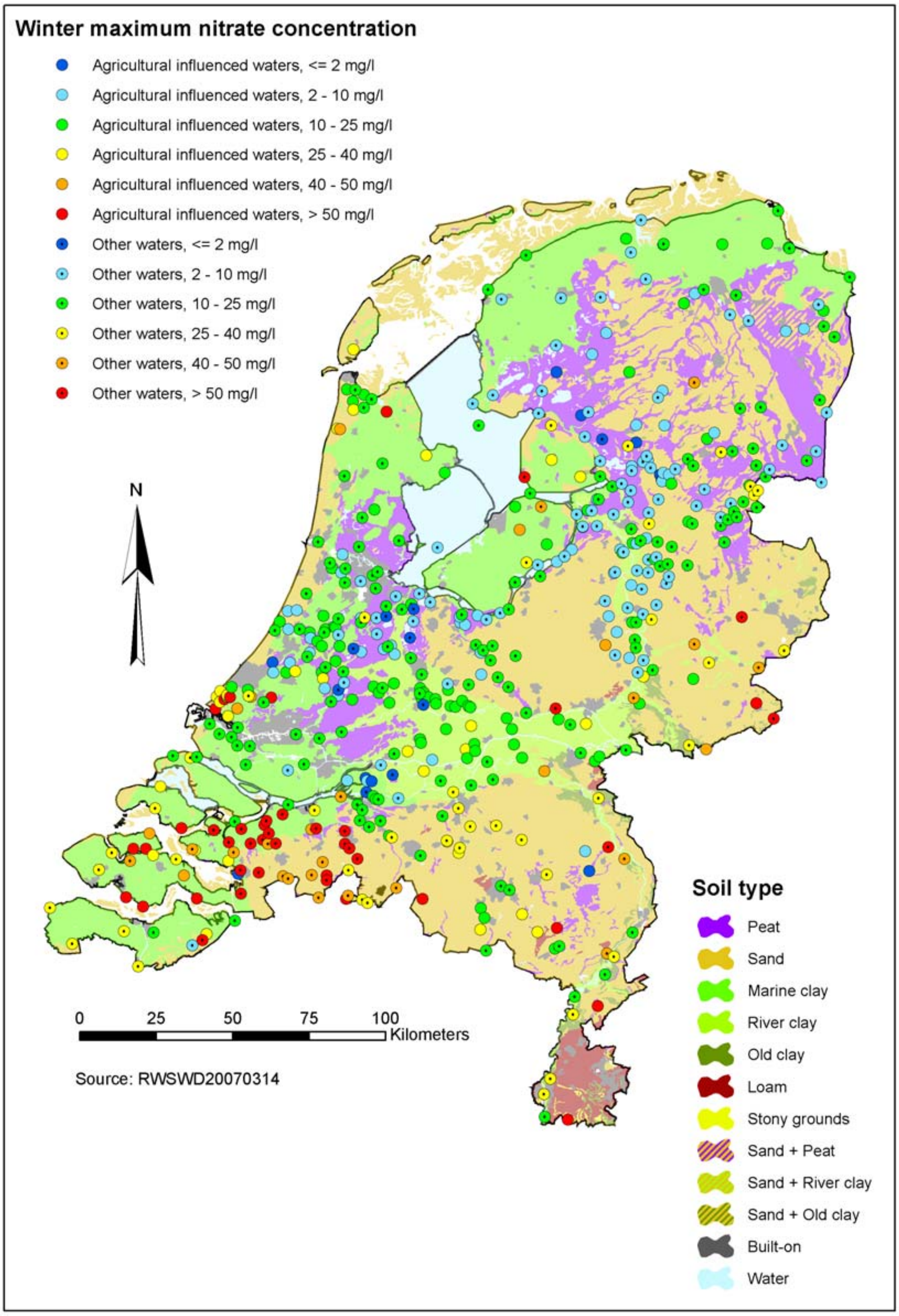


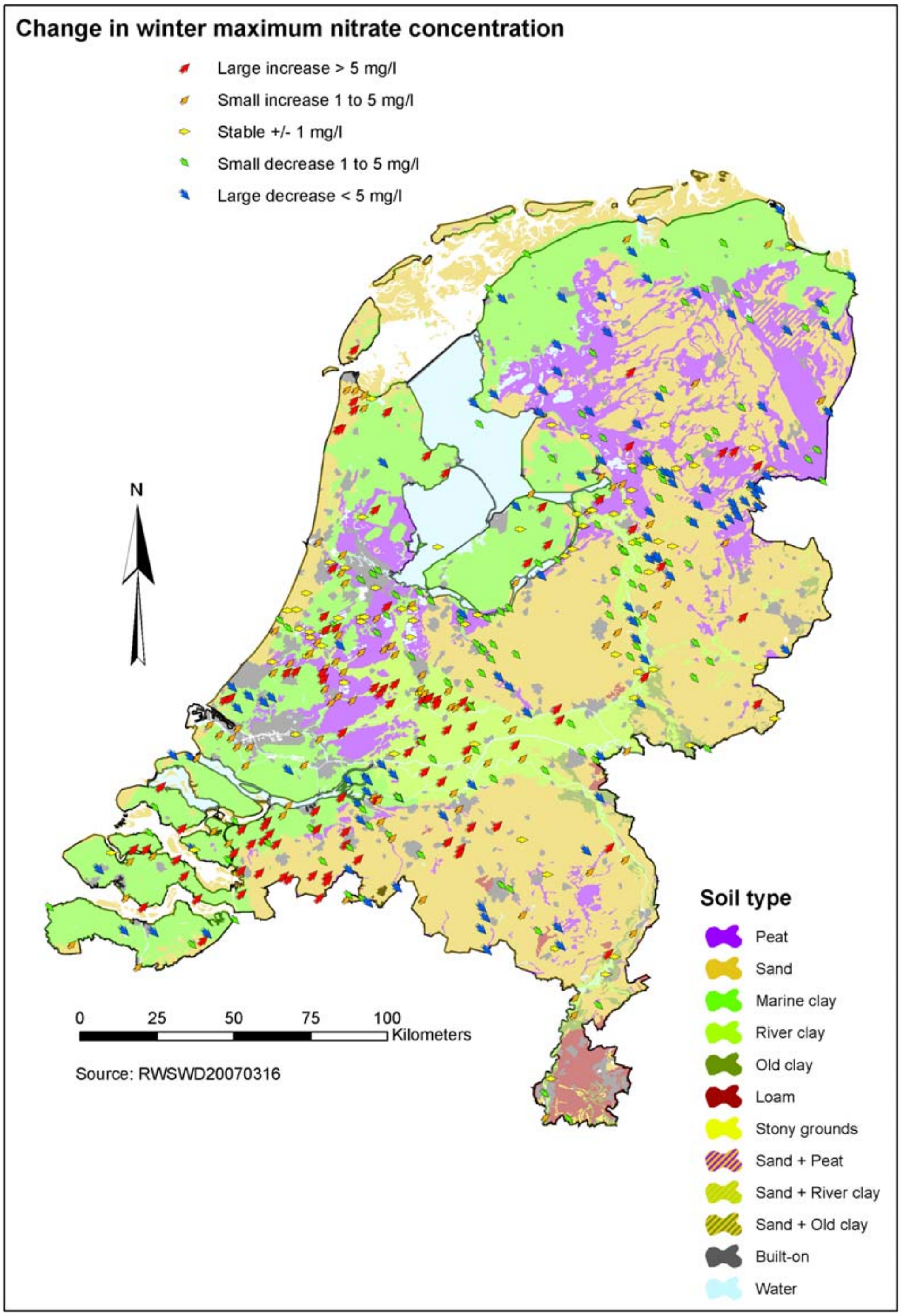
Map 12: Winter average nitrate 2004-2005-2006 (3rd period).



Map 13: Change in winter average nitrate between 2nd and 3rd period, i.e. 'period 2000-2001-2002-2003' and 'period 2004-2005-2006'.



Map 14: Winter maximum nitrate 2004-2005-2006 (3rd period).



Map 15: Change in winter maximum nitrate between 2nd and 3rd period, i.e. 'period 2000-2001-2002-2003' and 'period 2004-2005-2006'.

7 Marine and coastal water quality

7.1 Introduction

This chapter outlines the results of the monitoring activities on marine surface waters for the nutrients nitrogen and phosphorus.

Similarly to the chapter on freshwater, the next section (§7.2) is an overview of nitrogen and phosphorus loads in surface waters. The nitrate concentrations in the open sea and in coastal areas are described in §7.3. It should be noted that the results in this section are based solely on winter average (December – February) concentrations, since this period is characterised by the lowest biological activity and therefore the nitrate concentrations measured in winter are a better indicator of changes in nutrient load than those measured in summer. Interannual in-depth studies on trends in inorganic nitrogen concentrations, corrected for salinity, i.e. interannual differences in riverine water discharge, are presented as well (see §2.5.3). Results of the eutrophication state in marine waters are presented in §7.4, expressed as changes in summer average and maximum average concentrations of chlorophyll-*a*.

7.2 Nutrient load of marine and coastal waters

For the 2004-2006 period, the nutrient load of the North Sea and Wadden Sea via the Netherlands was calculated to be approximately 250 million kg nitrogen and 14 million kg of phosphorus (see Table 41). Direct discharge generally contributed little to the total load, with the bulk originating from riverine loads. The atmospheric contribution was about 10-18% of the total nitrogen load and remained stable.

Table 41: Total nitrogen and phosphorus load of the North Sea and Wadden Sea from and via the Netherlands in million kg for the 1992-2006 period[1] (source OSPAR, www.ospar.org).

	Nitrogen			Phosphorus		
	1992-1995	2000-2003	2004-2006	1992-1995	2000-2003	2004-2006
Discharge by rivers	481	284	244	26	16	13
Direct discharge	6	6	6	1	0.5	0.5
Total load from and via the Netherlands	487	290	250	27	16.5	13.5
Atmospheric deposition	50	48	43	n.a.	n.a.	n.a.

[1] Averages are presented for each period, i.e. 1992-1995, 2000-2003 and 2004-2006; for the first and third reporting periods data was only available for two years. Atmospheric deposition estimates by EMEP are only available for 1995 in the first period and 2004 in the last period.
Source: OSPAR (2007).

Nutrient loads can fluctuate quite drastically from year to year, largely as a result of fluctuations in precipitation. In the 2000-2003 period, nitrogen loads into marine waters via the Netherlands decreased on average by about 200 million kg compared to the 1992-1995 period and subsequently decreased by 14% to 250 million kg over the last period (2004-2006). The phosphorus load decreased by almost 50% between the periods 1992-1995 and 2000-2003 to 16 million kg, and in the 2004-2006 reporting period a decrease of 20% to 14 million kg was established.

Table 41 and Table 42 show that the total nitrogen and phosphorus loads to the Greater North Sea (see OSPAR, 2007) originated for about one-third from riverine discharges via the Netherlands. The relative importance however cannot be determined exactly since several riparian North Sea countries do not report on total nutrient loads.

Despite interannual fluctuations in nitrogen deposition rates, it seems that total Dutch nutrient loads and total atmospheric nutrient depositions to the North Sea are slowly decreasing.

Table 42: Total nitrogen and phosphorus load of the Greater North Sea (OSPAR Region II) in million kg for the 1992-2006 period[1].

	Nitrogen			Phosphorus		
	1992-1995	2000-2003	2004-2006*	1992-1995	2000-2003	2004-2006*
Discharge by rivers	980	738	578	53	42	40
Direct discharge	69	60	57	11	10	10
Total load via water	1049	798	635	64	52	50
Atmospheric deposition[2]	499	520	457	n.a.	n.a.	n.a.

[1] Averages are presented for each period, i.e. 1992-1995, 2000-2003 and 2004-2006.
[2] The atmospheric deposition data is only available for 1995 for the 1992-1995 period and 2004 for the last period. Atmospheric deposition consists of reduced and oxidized nitrogen.
n.a.: no data available.
* 2006 data not available for the last period.
Source: OSPAR (2007).

7.3 Nitrate concentration in marine and coastal waters

In this section, winter average nitrate concentrations in marine waters are presented, expressed as nitrate in milligram per litre. The winter period, in the figures denoted as 'winter year', is defined as the period from 1 December to the last day of February (see §2.5).

43 details the percentage of monitored locations, ranked according to different nitrate ranges, while Table 44 presents the percentages of monitored locations where an increase, a decrease or stability in concentrations was determined. When an absolute change of 1 mg/l nitrate was noted, monitoring locations were classified as either decreasing or increasing.

Nitrate concentrations remained stable over all three monitoring periods at all monitoring locations in the open sea areas, i.e. absolute changes in concentrations were less than 1 mg/l nitrate. For coastal waters, however, changes were noted over the last two monitoring periods. At more than half of all locations monitored, nitrate concentrations decreased between the last two periods, while the remaining locations monitored remained fairly stable.

Table 43: Winter average nitrate concentration in marine waters for the 1992-2006 period (%)[1].

Concentration range	1991	1992-1995	1996-1999	2000-2003	2004-2006
0-10 mg/l	87	87	92	88	95
10-25 mg/l	13	13	8	12	5
25-40-mg/l	0	0	0	0	0
40-50 mg/l	0	0	0	0	0
>50 mg/l	0	0	0	0	0
Number of sites	38	39	39	39	39

[1] Percentage of the monitoring locations with a winter period average within a given concentration range.

Table 44: Change in winter average nitrate concentration in marine waters for the 1992-2006 period (%)[1].

Rate of change	Open sea 1996/1999-2000/2003	Open sea 2000/2003-2004/2006	Coastal water 1996/1999-2000/2003	Coastal water 2000/2003-2004/2006
Large increase (>5 mg/l)	0	0	0	0
Small increase (1-5 mg/l)	0	0	66	0
Stable (± 1 mg/l)	100	100	34	38
Small decrease (1-5 mg/l)	0	0	0	59
Large decrease (>5 mg/l)	0	0	0	3
Number of sites	7	7	33	32

[1] Percentage of sites with given rates of change in concentration between the mentioned periods.

Figure 36 presents the trend in winter average nitrate concentrations over the 1991-2006 period in the open sea and coastal waters. The figure shows that, except for the drop in the 1995-1996 period, winter averages in the coastal zones have decreased slightly over the last seven years and have fluctuated between 3 and 6 mg/l nitrate. Concentrations in the open sea remained rather stable at far lower concentrations (< 0.5 mg/l). The lower nitrate concentration in 1996 is a consequence of previous relatively dry years.

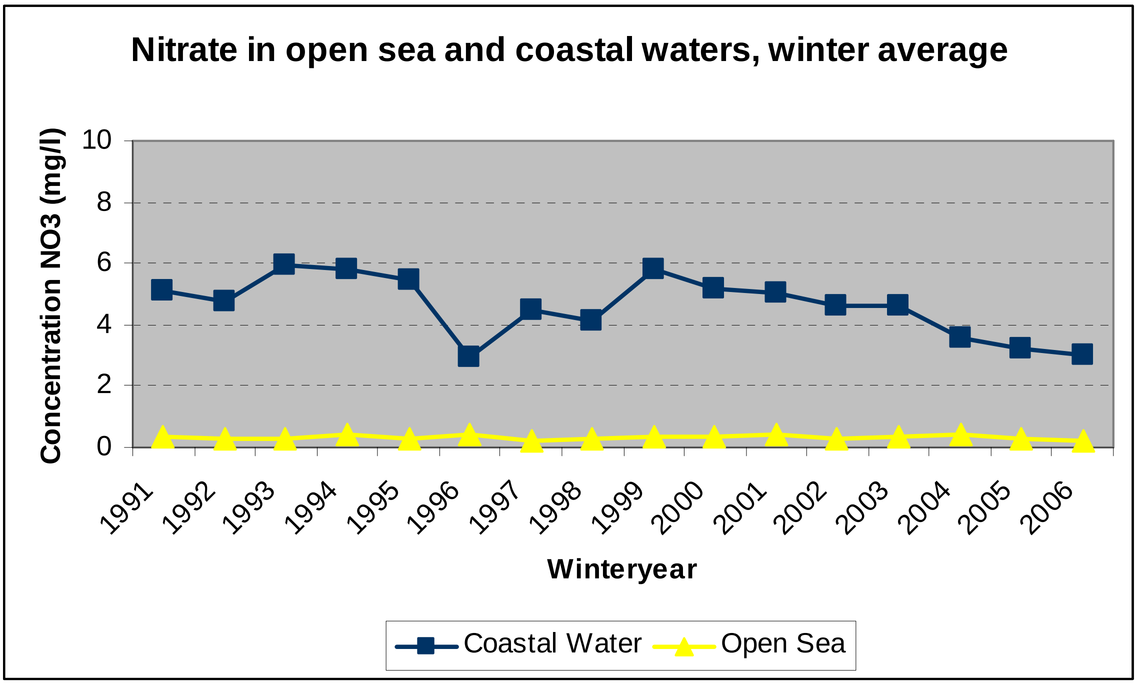


Figure 36: Winter average nitrate concentration (mg/l) in the open sea and coastal waters of the Netherlands for the 1991-2002 period.

Map 18 shows the variations in winter average nitrate concentrations in the open sea and coastal waters of the Netherlands for the 2004-2006 period. Winter average concentrations of nitrate only exceeded 10 mg/l in the Western Scheldt and the Ems-Dollard estuary. Other locations in the coastal zone were generally characterised by concentrations lower than 10 mg/l, whereas concentrations in open seawaters were lower than 2 mg/l.

The most pronounced decreases in winter average concentrations of nitrate were encountered during 2004-2006 in the Ems-Dollard estuary, the Western Scheldt and at some locations along the coast (see Map 17). At all other locations, concentrations remained virtually unchanged.

Table 45 presents the percentages of monitored locations at which various ranges of the maximum nitrate concentration were measured during the three different reporting periods. For the vast majority of locations, the maximum nitrate concentrations measured ranged from 0-10 mg/l. It seems that the number of locations in the lowest range of nitrate concentrations shows an increase between the first and second half of the 1990s.

Table 45: Winter maximum nitrate concentration in marine waters for the 1992-2006 period (%)[1].

Concentration range	1991	1992-1995	1996-1999	2000-2003	2004-2006
0-10 mg/l	84	81	88	85	92
10-25 mg/l	13	17	12	15	8
25-40-mg/l	3	2	0	0	0
40-50 mg/l	0	0	0	0	0
>50 mg/l	0	0	0	0	0
Number of sites	38	39	39	39	39

[1] Percentage of the monitoring locations with a period maximum within a given concentration range. Total percentage may exceed 100 because of rounding off.

Table 46 presents the percentages of monitored locations where an increase, a decrease or stability in winter maximum nitrate concentrations was determined. As in the previous section, only absolute changes of 1 mg per litre nitrate or more in the maximum nitrate concentrations determined the classification of monitoring locations as either decreasing or increasing. As noted earlier for winter average nitrate concentrations (Table 44), all monitoring locations in the open sea showed nitrate concentrations that were stable over all three reporting periods. For coastal waters however, changes were noted over the last two reporting periods. Nearly 70% of the locations showed a small decrease in winter maximum concentrations, while at the remaining locations the concentrations remained fairly stable. A very large decrease was observed at one location in the Western Scheldt.

Figure 37 presents the trend in the average winter maximum nitrate concentrations for the 1991-2006 period in the open sea and coastal waters. The figure generally shows that, except for the drop in concentrations during the 1996-1997 period, the winter maximum average in the coastal zones fluctuated between about 4 and 8 mg nitrate per litre, whereas concentrations in the open sea remained fairly stable at far lower concentrations (< 0.5 mg/l). Explanations for the lower maximum nitrate concentration in 1996 have already been given (see text to accompany Figure 36).

Map 18 shows the variations in winter maximum concentrations in Dutch open sea and coastal waters for the 2004-2006 period. In the Western Scheldt and the Ems-Dollard estuary, winter maximum concentrations of nitrate exceeded 15 mg/l. Other locations in the coastal zone were generally characterised by concentrations lower than 15 mg/l, whereas concentrations in open seawaters were lower than 10 mg/l.

Table 46: Change in winter maximum nitrate concentration in marine waters for 1992-2006 period (%)[1].

Rate of change	Open sea		Coastal water	
	1996/1999-2000/2003	2000/2003-2004/2006	1996/1999-2000/2003	2000/2003-2004/2006
Large increase (>5 mg/l)	0	0	0	0
Small increase (1-5 mg/l)	0	0	13	0
Stable (± 1 mg/l)	100	100	63	28
Small decrease (1-5 mg/l)	0	0	25	69
Large decrease (>5 mg/l)	0	0	0	3
Number of sites	7	7	32	32

[1] Percentage of sites with given rates of change in concentration between the mentioned periods. Total percentage may exceed 100 because of rounding off.

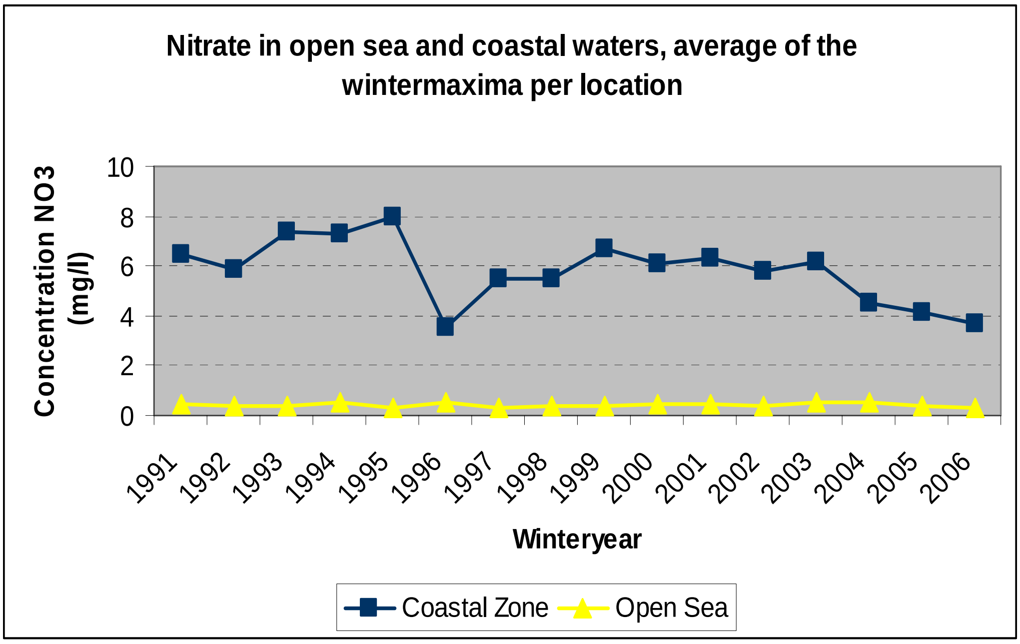


Figure 37: Winter maximum nitrate concentration (mg/l) in the open sea and coastal waters of the Netherlands for the 1991-2006 period.

The trends in winter maximum concentrations of nitrate encountered at the different locations during 2004-2006 are the same as for the average winter concentration. The concentration remained fairly stable in the open sea, while lower concentrations were seen in the estuaries (see Map 19).

The concentrations of nutrients in the coastal waters are determined by natural background concentrations and by direct and riverine discharges. During winter, biological activity is low and inorganic nutrient concentrations show a conservative behaviour and a negative linear relation with salinity. For a long-term analysis of changes in nutrient concentrations in relation to changes in nutrient loads, correction of the measured winter nutrient concentrations for changes in salinity at the fixed monitoring locations is required (see §2.5.3).

Here, salinity-normalized winter concentrations of dissolved inorganic nitrogen (DIN) at a salinity of 30 psu are presented for the 1985-2006 period for the Dutch coastal zone off Noordwijk (Figure 38). In Figure 39, the DIN concentrations are presented in comparison to 1985 (1985 is set at 1). The results show a slow but gradual decrease in dissolved inorganic nitrogen concentrations since 1990. The concentration in 2006 is approximately 34% lower than in 1985. It seems that concentrations have remained stable since 2000.

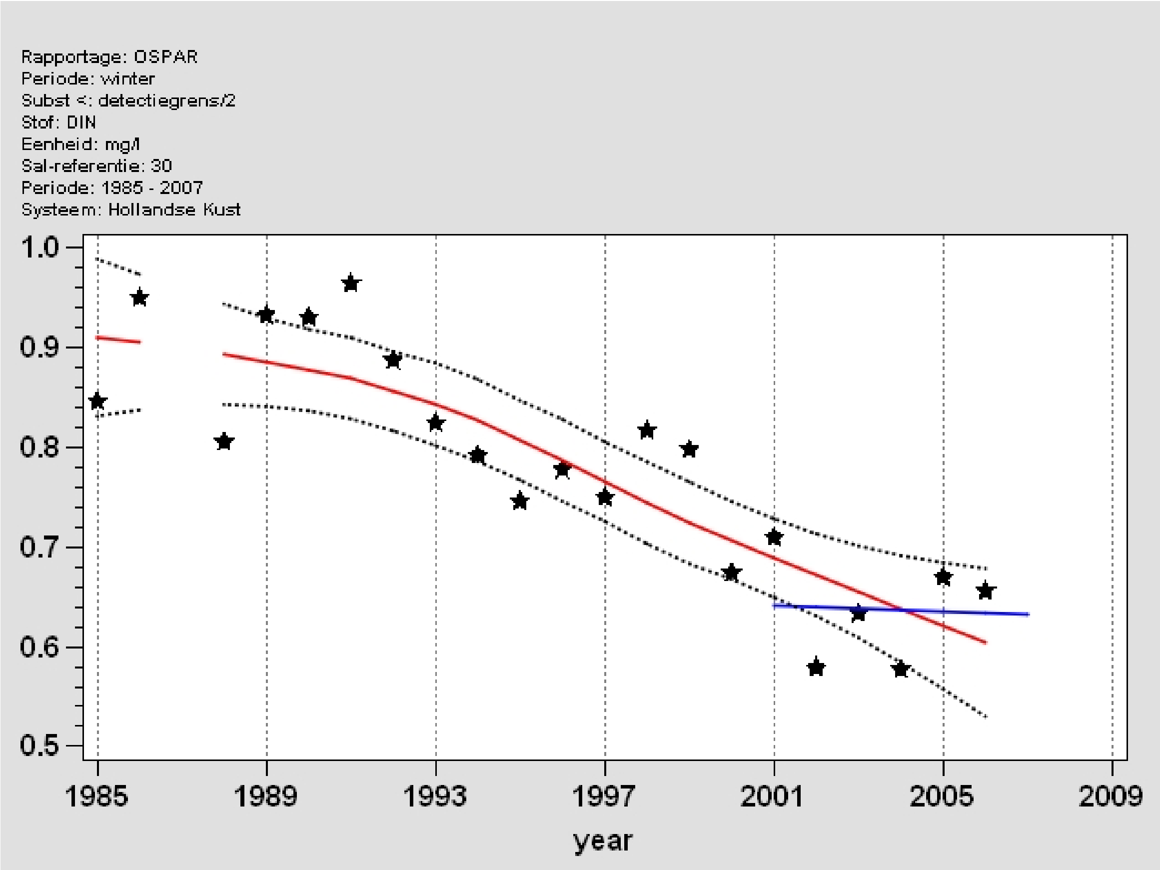


Figure 38: Winter average dissolved inorganic nitrogen concentrations (DIN, N mg/l), standardised to a salinity of 30 psu, for the Dutch coastal zone off Noordwijk for the 1985-2006 period. The red line is the smoothed trend line and the dashed lines indicate the 95% confidence interval of the trend line. The blue line is the trend line of the last seven years.

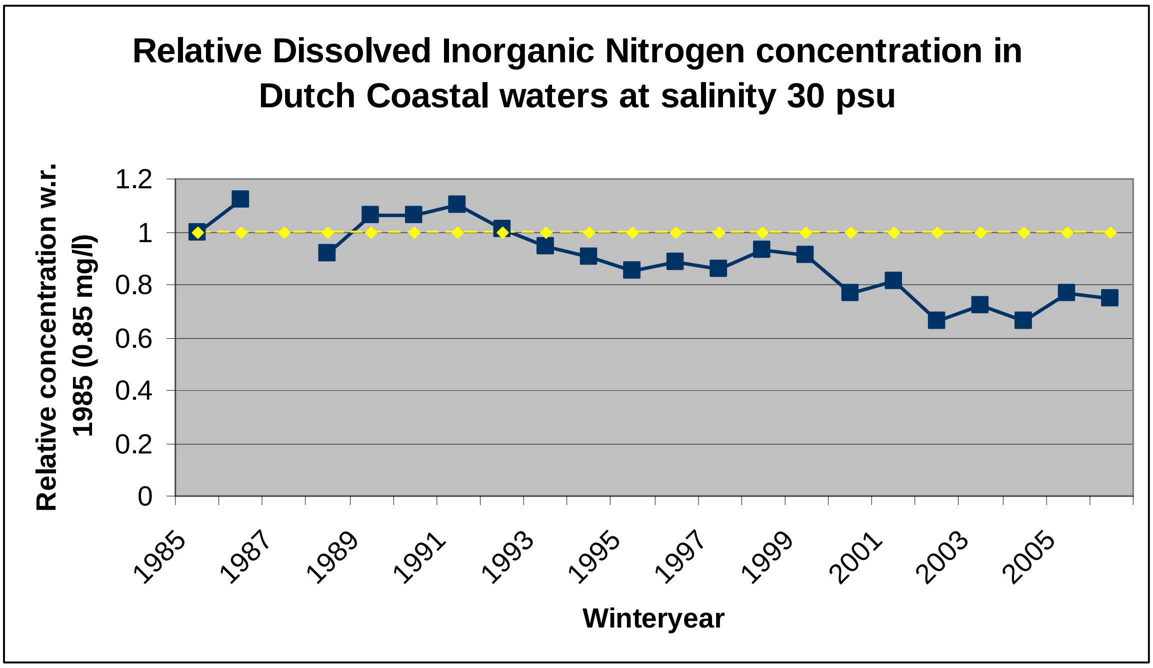


Figure 39: Relative winter average dissolved inorganic nitrogen concentrations (DIN), standardised to a salinity of 30 psu, for the Dutch coastal zone off Noordwijk for the 1985-2002 period. DIN concentrations in comparison to concentration in 1985 (0.85 mg/l, is set at 1).

7.4 Eutrophication status of marine and coastal waters

Eutrophication is a major topic within OSPAR (The Convention for the Protection of the Marine Environment of the Northeast Atlantic). Following a 2002 assessment of Dutch marine waters, it was concluded that the entire Dutch coastal zone was eutrophic (i.e. an eutrophication problem area). The larger part of the offshore waters was classified as a potential problem area, pending further research. An area is classified as a problem area if the concentration of nutrients and chlorophyll is above a region-specific elevated level. This level for winter average DIN in open sea (salinity >34.5 psu) is defined as > 15 µMol/l and (< 34,5 psu) > 21-36 µMol/l for the coastal zone. The elevated level of the summer average chlorophyll-*a* concentration for the respective regions is >4.5 and >15.

In this section, summer average chlorophyll-*a* concentrations are used as a measure of algal abundance to determine the occurrence of eutrophication phenomena. The summer is defined as the period from 1 April to 30 September. Table 47 shows the percentages of all locations for which the average chlorophyll-*a* concentrations observed were in the given range, during the reporting period and preceding periods.

The percentage of locations in marine waters with a summer average chlorophyll-*a* concentration higher than 25 µg/l showed a decline, whereas the number of locations with concentrations ranging from 2.5 to 8.0 µg/l seemed to increase (see Table 47). In general, however, conditions over the whole remained fairly stable. Similar conclusions can be drawn from Table 48. This table presents the results of possible changes in chlorophyll-*a* concentrations during the reporting period for open sea areas as well as coastal waters. It seems that, for both open sea and coastal waters, the summer average chlorophyll is more or less stable. A large increase could be seen at one location in the coastal water, while two locations showed a small decrease between the last two reporting periods.

Table 47: Summer average chlorophyll-*a* in marine waters for the 1992-2006 period (%)[1].

Concentration range	1991	1992-1995	1996-1999	2000-2003	2004-2006
0-2.5 µg/l	13	15	15	14	15
2.5-8.0 µg/l	28	17	28	26	41
8.0-25-µg/l	56	62	52	57	40
25-75 µg/l	3	6	5	3	4
>75 µg/l	0	0	0	0	0
Number of sites	39	40	35	34	34

1 Percentage of the monitoring locations with a period average within a given concentration range. Total percentage may exceed 100 because of rounding off

Table 48: Change in summer average chlorophyll-*a* concentration in marine waters in the 1992-2006 period (%)[1].

	Open sea		Coastal water	
Rate of change	1992/1995-2000/2003	2000/2003-2004/2006	1992/1995-2000/2003	2000/2003-2004/2006
Large increase (>10 µg/l)	0	0	0	4
Small increase (5-10 µg/l)	0	0	4	0
Stable (± 5 µg/l)	100	100	75	89
Small decrease (5-10 µg/l)	0	0	21	7
Large decrease (>10 µg/l)	0	0	0	0
Number of sites	6	6	28	28

1 Percentage of sites with given rates of change in concentration between reporting periods 1992-1995 and 2000-2003 and between 2000-2003 and 2004-2006.

Figure 40 shows the summer average chlorophyll-*a* concentration in the open sea and coastal waters. Although chlorophyll-*a* concentrations appear to have been elevated during the early 1990s, a small decline can be seen in the summer average chlorophyll-*a* concentrations in the last years. These concentrations varied from 10-17 µg/l in the coastal water, while in open sea areas concentrations varied between 1 and 4 µg/l, which is below the elevated levels of OSPAR.

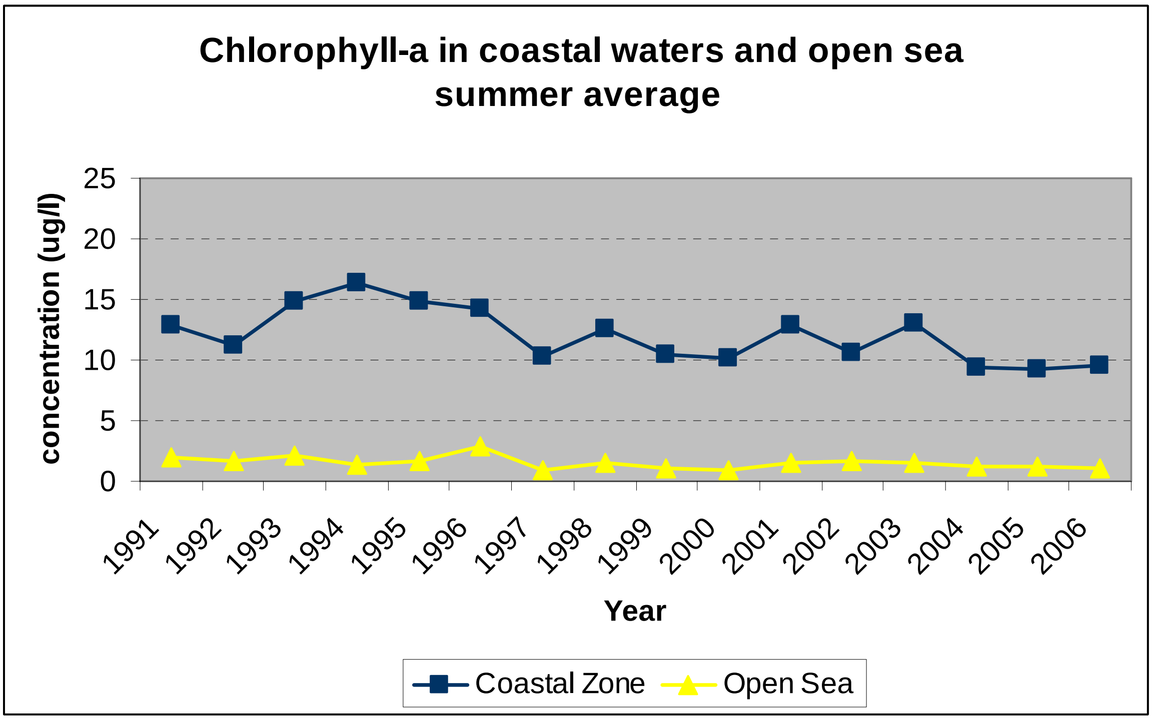


Figure 40: Summer average chlorophyll-*a* concentration (µg/l) in the open sea and coastal waters of the Netherlands in the 1991-2006 period.

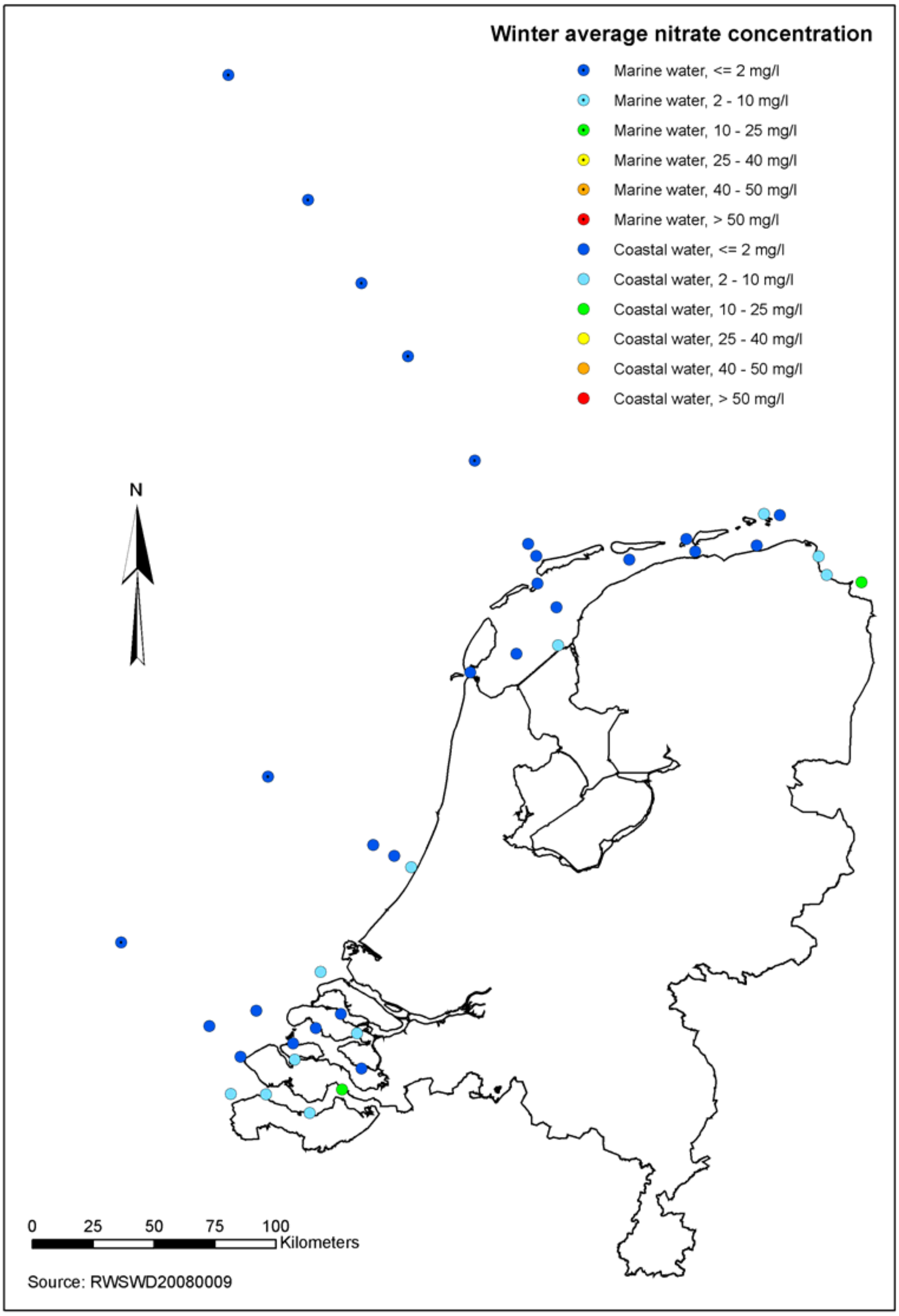
7.5 Conclusion

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: concentrations in 2006 are approximately 34% lower than those in 1985. Chlorophyll-*a* concentrations show a small decreasing trend in marine waters and remained stable in the open sea.

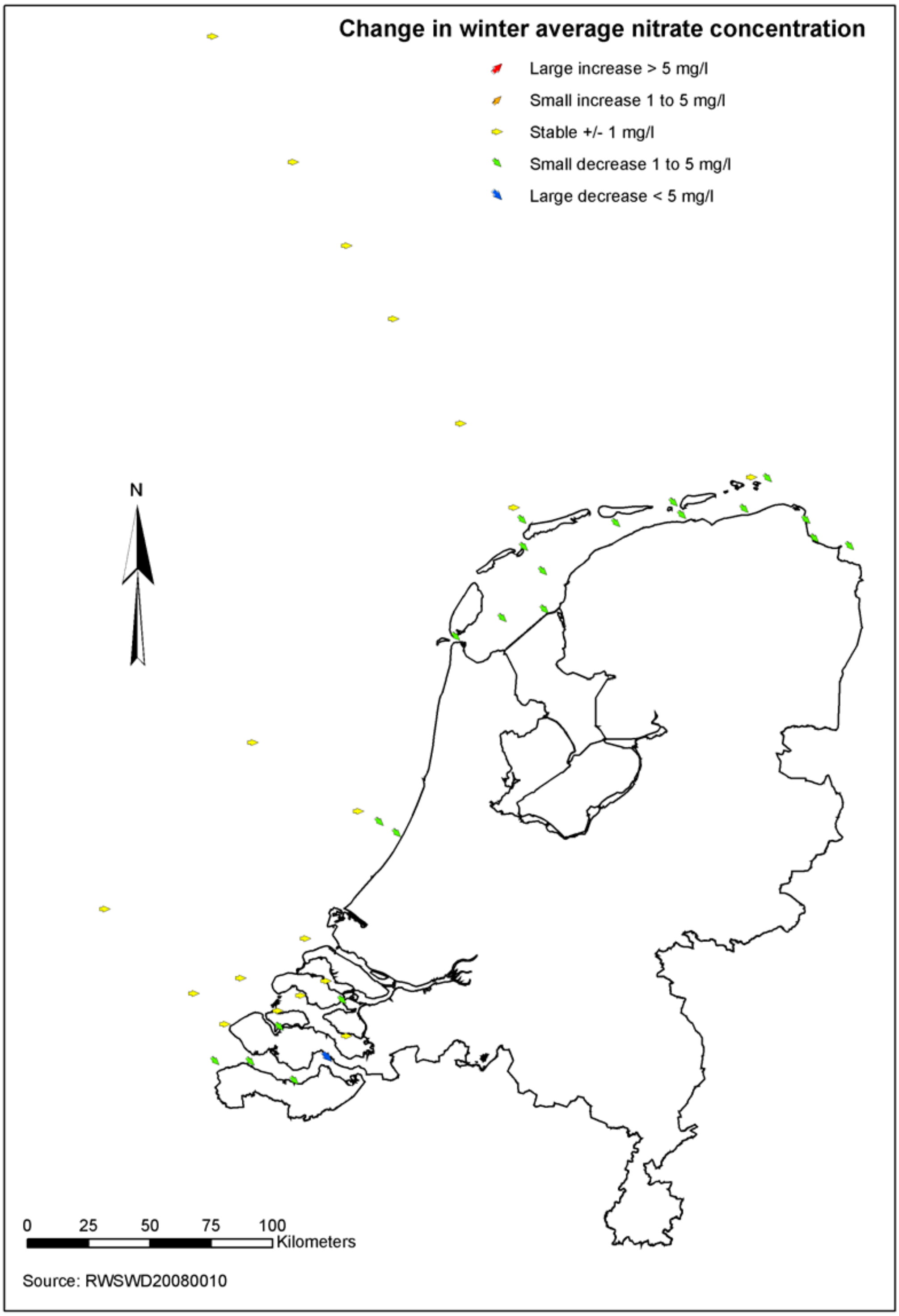
A further reduction of indirect and direct nutrient loading is necessary to achieve the OSPAR target of 2010, i.e., 'to achieve and obtain a healthy marine environment where eutrophication does not occur'.

7.6 Literature

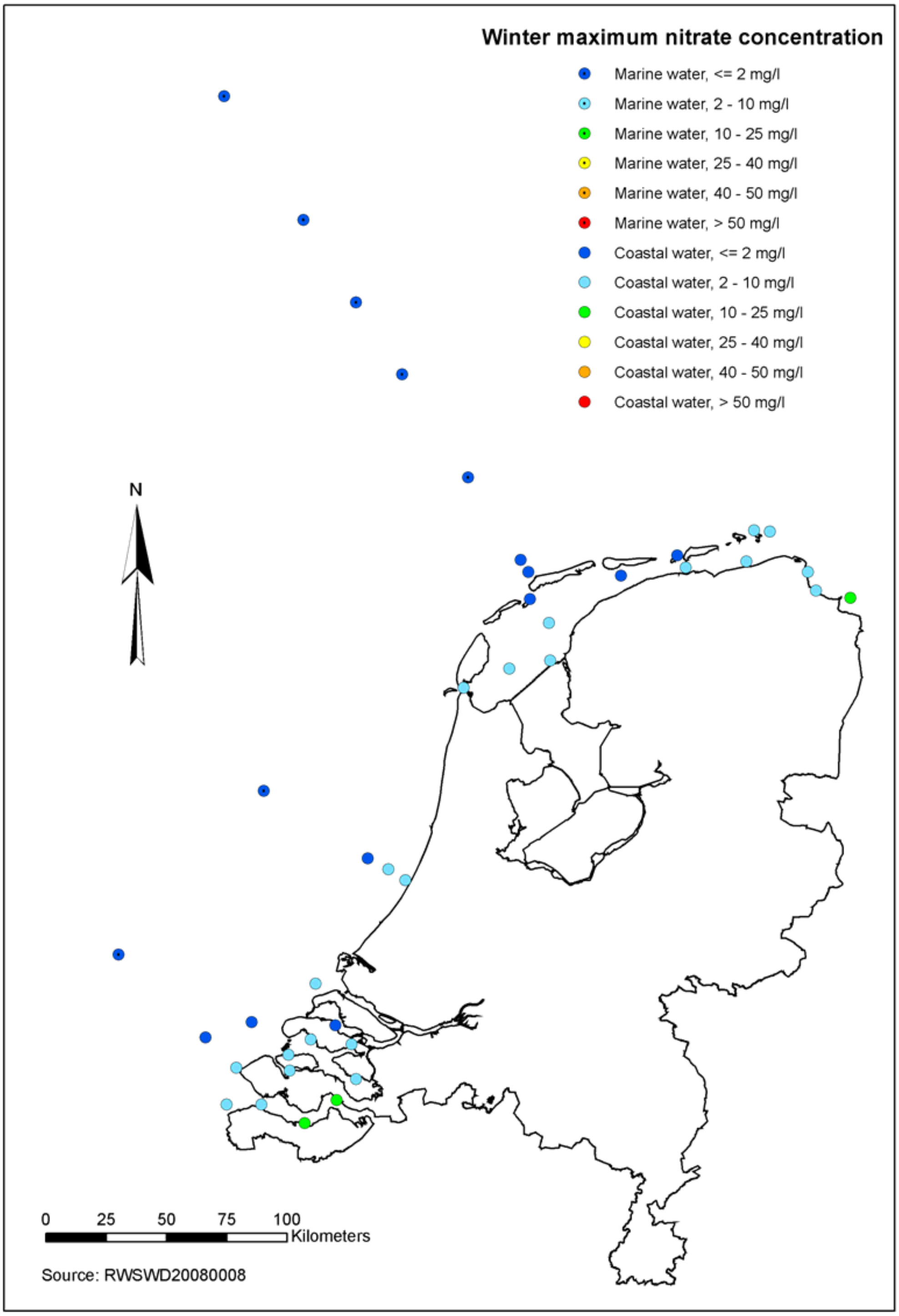
OSPAR 2007, unpublished data, www.ospar.org. atmospheric deposition: http://www.emep.int/publ/ospar/2007/index.html.



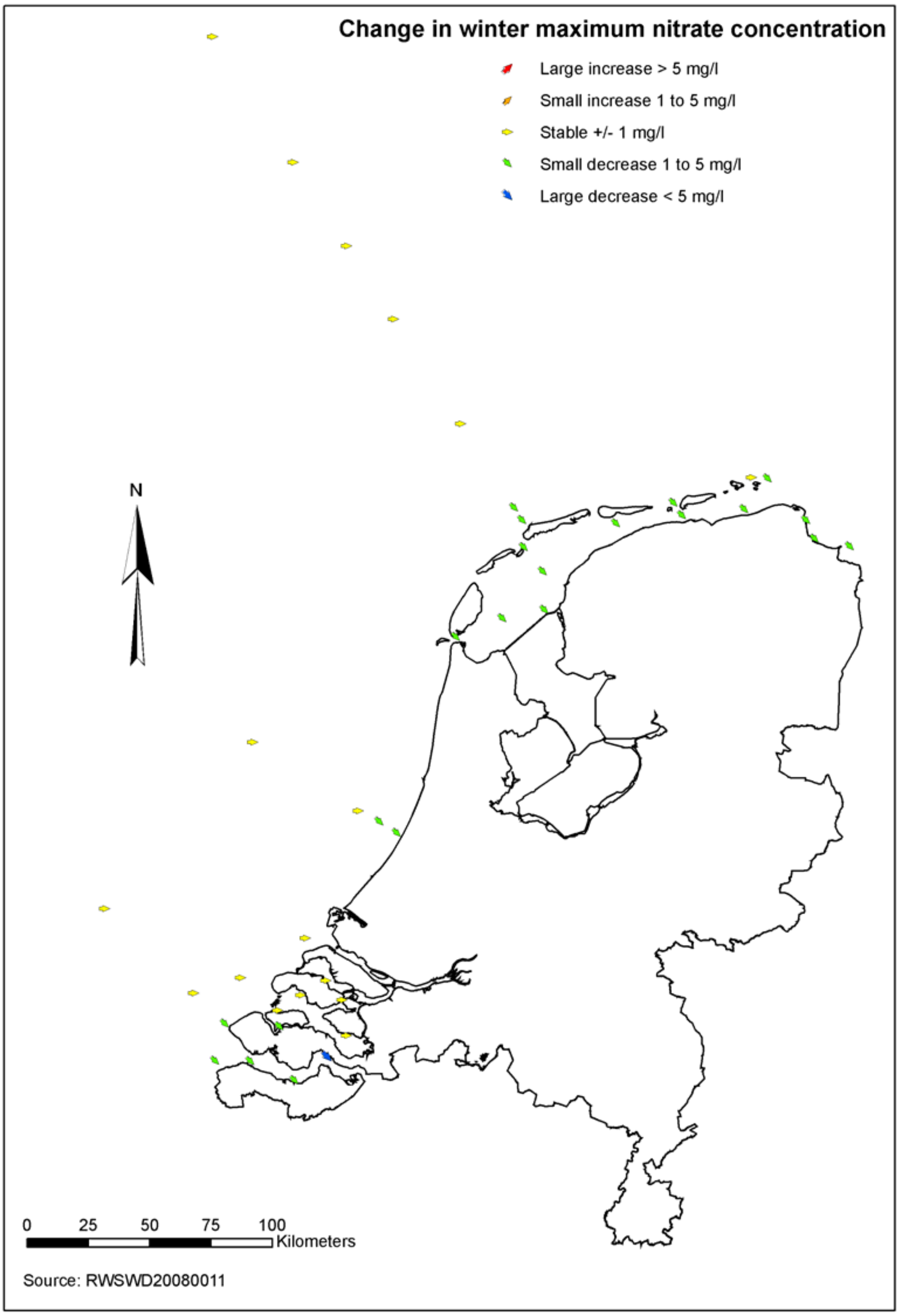
Map 17: Winter average nitrate concentration in Dutch marine and coastal waters in the 2004-2006 period.



Map 18: Change in winter average nitrate concentration in Dutch marine and coastal waters in the 2004-2006 period.



Map 19: Winter maximum nitrate concentration in Dutch marine and coastal waters for the 2004-2006 period.



Map 20: Change in winter maximum nitrate concentration in Dutch marine and coastal waters in the 2004-2006 period.

8 Future water quality development

8.1 Assessment of ability to forecast

An assessment of the time scale for change in water quality as a consequence of changes in farm practice is riddled with uncertainty. Groundwater travel times increase with depth and show a large variation at a given depth. Moreover, biological processes (e.g. denitrification and ammonification) and physical processes (e.g. dispersion, diffusion and dilution) change water quality in time and space due to large variations in the physico-chemical characteristics of the vadose zone, aquifers and aquitards. Regional surface waters receive groundwater from different origins (agriculture, nature and urban areas) and of different ages and are also fed by rainwater and sometimes effluents of, for example farmyards, wastewater plants or even industrial plants.

Travel times of on-farm waters sampled in the LMM 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 third Action Programme measures (2004-2007) on on-farm water quality will become apparent between 2008 and 2013.

Travel times of groundwater in the sand regions at a depth of 5-15 m are on average 12 years, but range from less than 5 years to over 30 years (Meinardi, 1994) (see Figure 41). Travel times of groundwater at a depth of 15-30 m are on average 36 years, and range from less than 25 years to over 80 years (Meinardi, 1994) (see Figure 42). In clay and peat regions, travels times are usually much longer as aquifers are often confined or semi-confined.

At least a decade will pass before we are able to see the effects of measures on nitrate concentrations in groundwater at a depth of 5-15 m. Due to the large variation in travel times at a specific depth, nitrate concentrations will decrease slowly. In areas with confined aquifers and/or a high aquifer denitrification capacity, nitrate concentrations are already low and there will be no change.

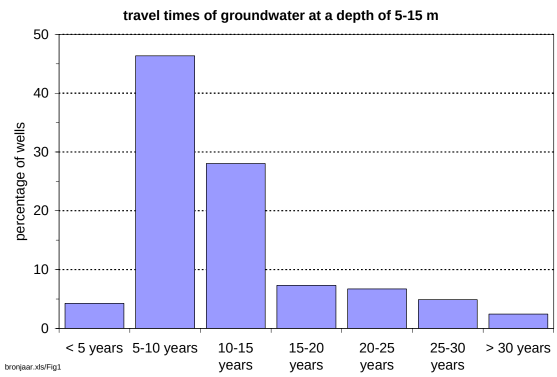


Figure 41: Travel time distribution of groundwater in the sand regions in the Netherlands at a depth of 5–15 m.

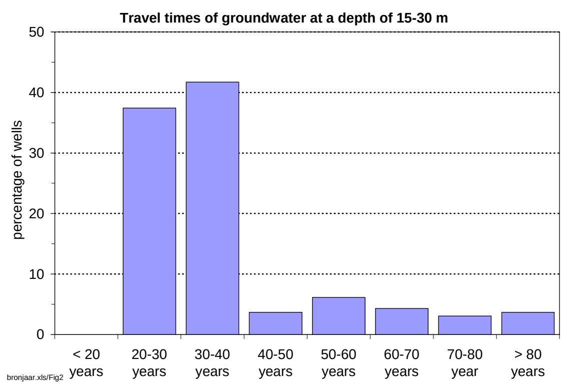


Figure 42: Travel time distribution of groundwater in the sand regions in the Netherlands at a depth of 15-30 m.

At least several decades will pass before we are able to see the effects of measures on nitrate concentrations in groundwater at a depth of more than 15 m, and certainly at a depth of more than 30 m. Nitrate concentrations will change slowly due to the large variation in travel times at a specific depth.

Lags in the observation of the effects of measures on nitrate concentrations in fresh surface waters are assumed to be relatively short compared with groundwater at a depth of more than 5 m and to be in the same order of magnitude as on-farm waters. Surface water quality in clay and peat regions will be similar to that in on-farm waters and will also show the same effects of the third Action Programme. The contribution of recent (1-5 year old) groundwater to surface water in the sand regions varies from less than 10% to more than 70%. This suggests that the effects of the Action Programme will become visible at any time between 2008 and 2013.

It is therefore assumed that the effects of measures from the third Action Programme (2004-2007) on nitrate concentrations in fresh waters will become apparent between 2008 and 2013. As a result of mixing, it will probably be hard to distinguish the effects of the measures on nitrate concentrations from the effects of natural variations in nitrate concentrations. This is due to factors such as the variation in precipitation.

Estimating future evolution in relation to agricultural practice is for eutrophication even more difficult than for nitrate concentrations. The main reasons for this are:
1. the differences in surface waters with regard to their sensitivity to eutrophication;
2. phosphorus levels and other factors such as hydromorphology, which also play an important part in the eutrophication process;
3. the contribution made by other sources of nutrient input, notably urban wastewater and transboundary rivers;
4. the very poor predictability of the response lag of aquatic ecosystems to a substantial reduction in nutrient inputs and nutrient concentrations.

In addition to source-oriented measures, regional effect-oriented measures such as fish stock management have been taken in several cases where prospects were good and will be pursued further. In some cases, the ecological restoration process was accelerated substantially (for example, for the Veluwe border lakes). However, as Figure 32 and Figure 39 show, the ecological restoration processes in Dutch surface waters are seen to take place at a relatively slow pace and a general, clearly observable acceleration of these restoration processes is not expected.

8.2 Future water quality development

In the report ‘Werking van de Meststoffenwet 2006 *(Effectiveness of Manure legislation 2006)*’ (MNP, 2007) a very careful assessment of future development is made, using simulation modeling. The figure below shows the prediction of the nitrate concentration in the first meter of groundwater under farmland in sand areas (most vulnerable) without assessing weather effects.

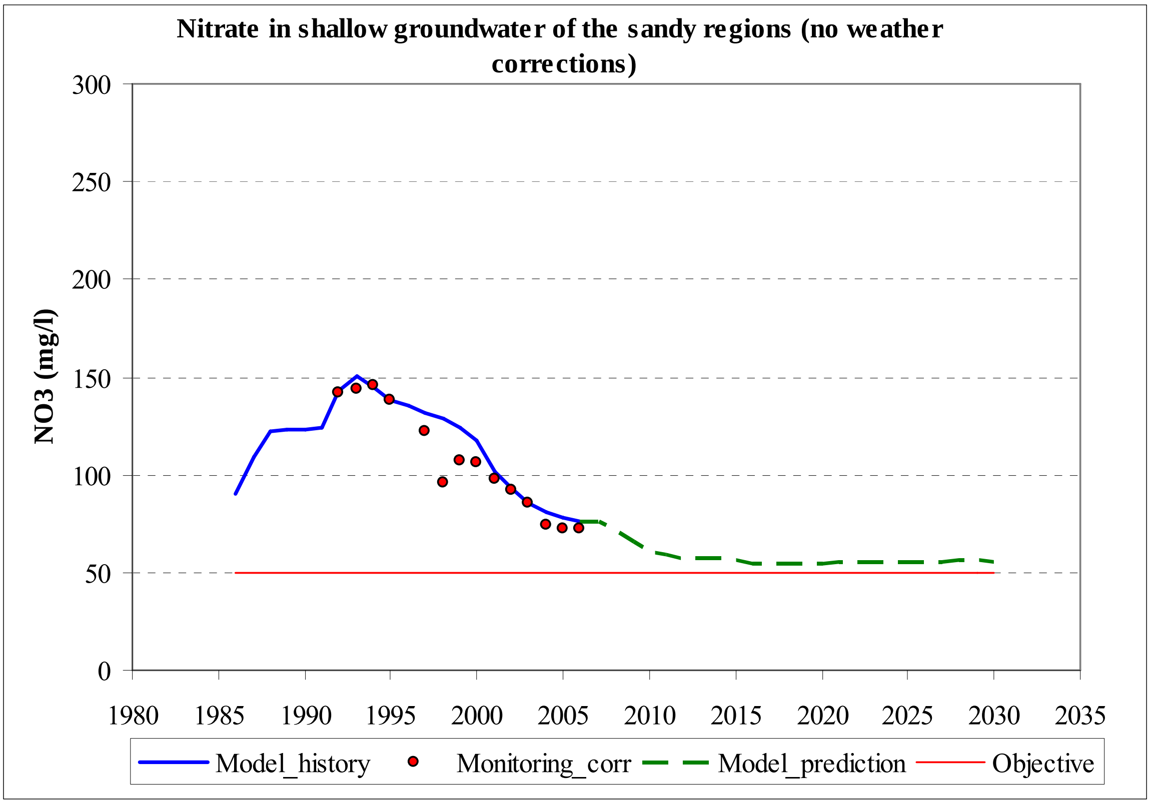


Figure 43: Reconstruction of measured nitrate concentration in the top meter of groundwater in sandy areas and estimations of nitrate concentrations with a 10% reduction on the nitrogen usage standards after 2008 (compared with 2006) for arable and horticultural areas, most sensitive to leaching. In the model used, weather effects are made constant.

Source: MNP, 2007.

Both nitrate content and eutrophication are decreasing. However, it takes several years before the effects of policy measures taken by farmers are seen in the water quality. It is therefore expected that it will be some years before the effects of recent policy measures from the current action programme (2004-2009) are seen in the water quality and that water quality will therefore only show further improvement in the 2010-2015 period. In Figure 44 an estimation of future water quality for different groundwater bodies is given. For motivations is refered to the report 'Werking van de Meststoffenwet 2006 *(Effectiveness of Manure legislation 2006)*' (MNP, 2007).

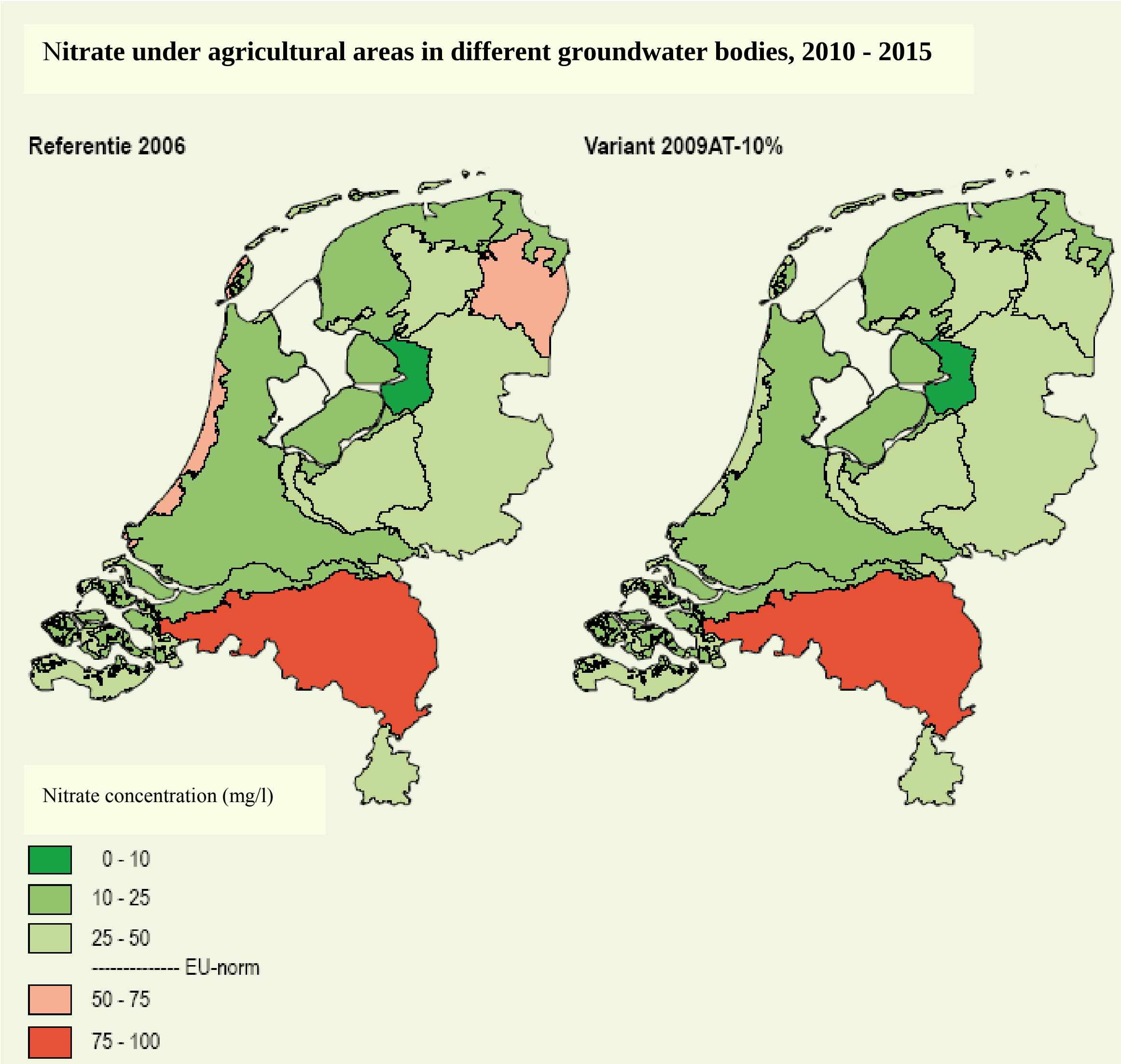


Figure 44: **Estimation of nitrate concentration in 2010-2015 under agricultural areas for the different groundwater bodies.**

Source, MNP, 2007.

8.3 References

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Meinardi C.R., Van den Eertwegh G.A.P.H. and Schotten C.G.J. (1998a). Grondwateraanvulling en oppervlakkige afstroming in Nederland. Deel 2: De afwatering van kleigronden [Groundwater recharge and surface run-off in the Netherlands. Part 3: Drainage of clay soils. Stromingen, 4 (4): 5-19.

Meinardi, C.R., Schotten, C.G.J., De Vries, J.J. (1998b). Grondwateraanvulling en oppervlakkige afstroming in Nederland. Langjarig gemiddelde voor de zand- en leemgebieden [Groundwater recharge and surface run-off in the Netherlands. Long term average for sand and loess areas]. Stromingen, 4 (3): 27-41.

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MNP (2007). Werking van de Meststoffenwet 2006. Overgang van verliesnormenstelsel naar gebruiksnormenstelsel; Evaluatie werking in het verleden (1998-2005), heden (2006-2007) en toekomst (2008-2015). MNP publicatie 500124001.

Annex 1:

Table: Acreage (kha) per farm type per year per soil type region.

Sand regions	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Dairy farms	472	472	468	467	461	459	460	452	441	441	446	444	439	433	421
Arable farms	131	125	121	126	126	125	126	126	127	119	112	127	130	127	123
Factory farms	21	22	22	23	23	26	26	28	31	32	33	28	29	32	32
Remaining	157	162	164	163	173	164	171	161	162	165	166	157	162	164	163

Clay regions	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Dairy farms	232	235	234	233	227	226	229	225	227	226	224	232	235	234	233
Arable farms	313	313	306	304	304	300	295	291	291	293	283	313	313	306	304
Remaining farms	74	75	79	84	88	89	95	94	95	95	95	74	75	79	84

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