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

Agricultural practice and water quality in *the Netherlands:* status (2012-2014) and trend (1992-2014)

Monitoring results for Nitrates Directive reporting

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RIVM Report 2016-0019

Publication details

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This investigation was conducted by order and for the account of the Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs as part of the Fertiliser Policy Support Project (project no. M/250030).

Published by:
National Institute for Public Health and the Environment (RIVM)
Postbus 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.nl

Synopsis

Agricultural practices and water quality in the Netherlands; status (2012-2014) and trend (1992-2014)
monitoring results for Nitrates Directive reporting

Nitrogen and phosphate are essential substances in manure used at farms to improve production. Nevertheless, too much nitrogen or phosphate is harmful. The difference between supply and removal of nitrogen at farms in the Netherlands – the so-called nitrogen surplus – has halved between 1992 and 2014. The phosphate surplus has almost ceased to exist. The nitrate concentration in on-farm groundwater and surface water has diminished, and the quality of the surface waters in the Netherlands has improved. However, compared with the previous monitoring period (2008-2011), the improvement of the water quality is small. According to expectations, nutrient concentrations will further decrease, but the desired quality of groundwater will not be achieved everywhere. In addition, the quality of surface waters will often remain insufficient.

Water quality 2012-2014
The improvements in water quality are a result of the measures implemented in the Netherlands pursuant to the European Nitrates Directive. One example is the requirement to apply less manure. In the 2012-2014 period, at most farms the nitrate concentrations in on-farm waters in the Clay and Peat Region were lower than the standard (50 mg/L). In the Sand Region, this was the case for about half of the farms, and in the Loess Region for less than half of the farms.

The nitrate concentrations in regional surface waters which are mainly supplied from agricultural areas are almost always lower than the standard. In surface waters designated for the Water Framework Directive (WFD), this standard is not exceeded. Nevertheless, nitrate, other nitrogen substances and phosphate have a negative impact in the majority of surface waters. It turns out that the nitrate standard that is implemented to protect drinking water resources is not sufficient to avert this impact. The nitrogen and phosphorus concentrations in summer, which have a large impact on flora and fauna in surface waters (ecological water quality), have decreased since the beginning of the 1990s.

Keywords: Nitrates directive; fertiliser policy; agricultural practices; groundwater and surface water quality; nitrate; eutrophication

Publiekssamenvatting

Landbouwpraktijk en waterkwaliteit in Nederland; toestand (2012-2014) en trend (1992-2014).
Resultaten van de monitoring voor de Nitraatrichtlijn.

Stikstof en fosfaat zijn essentiële stoffen in mest die landbouwbedrijven gebruiken om de productie te bevorderen. Het verschil tussen de aan- en afvoer van stikstof naar en van landbouwbedrijven in Nederland, het zogeheten stikstofoverschot, is tussen 1992 en 2014 gehalveerd. Het fosfaatoverschot is nagenoeg verdwenen. De nitraatconcentraties in het water op landbouwbedrijven zijn gedaald en de kwaliteit van het oppervlaktewater is verbeterd. Ten opzichte van de vorige monitoringsronde (2008-2011) zijn de verbeteringen in de waterkwaliteit echter beperkt. De nutriëntenconcentraties zullen naar verwachting wel blijven dalen, maar de gewenste situatie zal in het grondwater niet overal worden bereikt. Ook zal de kwaliteit van het oppervlaktewater veelal onvoldoende blijven. Dit blijkt uit een inventarisatie van de grond- en oppervlaktewaterkwaliteit en de landbouwpraktijk.

Waterkwaliteit 2012-2014
De verbeteringen in de waterkwaliteit zijn een gevolg van maatregelen die in Nederland vanwege de Europese Nitraatrichtlijn zijn genomen. Een voorbeeld daarvan is het voorschrift om minder mest te gebruiken. De nitraatconcentraties in het water op landbouwbedrijven in de Klei- en Veenregio zijn van 2012 tot en met 2014 op de meeste plaatsen lager dan de norm (50 mg/l). In de Zandregio geldt dit voor iets meer dan de helft van de bedrijven en in de Lössregio voor minder dan de helft.

De nitraatconcentraties in regionale oppervlaktewateren die vooral vanuit landbouwgebieden worden gevoed, zijn bijna altijd lager dan de norm. In de oppervlaktewateren die zijn aangewezen voor de Europese Kaderrichtlijn Water, wordt deze norm niet overschreden. Desondanks veroorzaken nitraat, andere stikstofverbindingen en fosfaat ongewenste milieueffecten in het merendeel van de oppervlaktewateren. De norm voor nitraat, die is ingevoerd om het drinkwater te beschermen, blijkt niet voldoende om deze effecten te voorkomen. De stikstof- en de fosforconcentraties in de zomer, die grote invloed hebben op de flora en fauna in het oppervlaktewater (ecologische waterkwaliteit), zijn sinds begin jaren negentig gedaald.

Het RIVM heeft de inventarisatie uitgevoerd met het Centraal Bureau voor de Statistiek (CBS), Rijkswaterstaat Water, Verkeer en Leefomgeving (RWS/WVL), LEI Wageningen Universiteit en Research Centrum (WUR) en de Rijksdienst voor Ondernemend Nederland (RVO.nl). De rapportage hiervan is een vierjaarlijkse Europese verplichting.

Kernwoorden: nitraatrichtlijn, mestbeleid, landbouwpraktijk, grondwater- en oppervlaktewaterkwaliteit, nitraat, eutrofiëring

Foreword

This report was produced by order and for the account of the Ministry of Infrastructure and the Environment (I&M) and the Ministry of Economic Affairs (EZ). It was prepared in order to comply with Article 10 of the EU Nitrates Directive, which requires Member States to report every four years to the European Commission on their progress in achieving the objective of the Directive. The objective of the Nitrates Directive is to reduce water pollution caused or induced by nitrates from agricultural sources, and to prevent further pollution. The Directive obliges Member States to take a number of measures to realise this objective. This report provides a summary of the policy implemented, an overview of the results of the monitoring programmes for assessing their effectiveness and a forecast of the effects of the current Fifth Action Programme for the Nitrates Directive in which the proposed policy has been established for the period 2014-2017.

A number of terms are used in the report which are not widely known or which can also be used in a different sense. For this reason, a definition of terms is provided.

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Definition of terms

Action Programme (Nitrates Directive): A programme which every country must produce in order to comply with the objective of the Nitrates Directive; a number of sections are obligatory

Application standard: Standard for the maximum quantity of livestock manure or the maximum total quantity of nitrogen or phosphate that may be used per year per hectare

Artesian groundwater: Groundwater in a permeable layer that is confined at both the top and bottom by a less permeable layer; as a result, the pressure head in the aquifer is higher than the upper limit of the aquifer (this is therefore also referred to as confined groundwater)

Derogation (Nitrates Directive): Permission to deviate from the obligation under the Nitrates Directive to use no more than 170 kg of nitrogen from livestock manure per hectare per year in specific, precisely defined situations and under certain conditions

Eutrophic: Excessively nutrient-rich water the biology of which does not comply with the desired situation because of the high levels of nutrients (excess of nitrogen and/or phosphorus)

Feed conversion ratio: A measure of the efficiency with which animals convert feed into higher body weight

Leaching water: Water that leaches from the root zone of a plot of land; this could be water that is discharged into a ditch with tile drainage, the water in the top metre of groundwater, or the moisture in the soil layer just below the root zone if the groundwater is too deep (more than five metres below surface level)

Loss standard: A standard for the maximum nutrient surplus per hectare per year, with no levy payable on the surplus

Nutrient surplus: The difference between inputs and outputs of nutrients, taking differences in stocks into account

Phreatic groundwater: Groundwater in a permeable layer which is not confined at the top by a less permeable layer; the groundwater has a free groundwater table

Plant-available nitrogen: The amount of nitrogen in livestock manure which is absorbed by the crop as efficiently as artificial fertiliser nitrogen, plus the amount of artificial fertiliser nitrogen

Potentially eutrophic: Nutrient-rich water the biology of which complies with the desired situation despite the fact that the water is too rich in nutrients (excessive nitrogen and/or phosphorus)

Spreading period: Period within a year in which the application of manure is permitted

Storage capacity: The amount of space in which livestock manure can be stored in an accountable manner, usually expressed as the number of months a farms can store the manure produced by the animals present on the farm

Summary and conclusions

Introduction
This report was prepared in order to comply with Article 10 of the EU Nitrates Directive, which requires Member States to report every four years to the European Commission on their progress. The purpose of the Nitrates Directive is to reduce water pollution caused or induced by nitrates from agricultural sources, and to prevent further pollution. This Member State report must be submitted to the European Commission before 1 July 2016. The contents of this Member State report for the Netherlands conform to the guidelines published in November 2011. The report describes developments in the period 1992-2014, with the emphasis on developments between this reporting period (2012-2014) and the previous one (2008-2011). Where available, pre-1992 data and data for 2015 are also provided.

The report provides an overview of current agricultural practices and groundwater and surface water quality in the Netherlands and outlines the trends in groundwater and surface water quality. It also describes the implementation and impact of the measures taken as part of the Action Programmes. Furthermore, the report includes a forecast of the future development of water quality.

Policy measures
Legislation regulating the use of fertilisers was adopted in the Netherlands before the implementation of the Nitrates Directive in 1991. The system of manure bookkeeping (introduced in 1987) was replaced in 1998 by a system of minerals accounting, known as MINAS. This was based on the mineral balance of nitrogen (N) and phosphate (P_2O_5) ("farm gate balance"). Under this system, limits were set for the permitted levels of the nitrogen and phosphate surpluses on farms (MINAS loss standards), the surplus being the difference between supply and removal. For arable farmers, MINAS actually boiled down to an application standard, in other words, regulating the amount of fertiliser that can be used. The loss standards have gradually been tightened. On 1 January 2002, the Manure Transfer Contracts (MAO) system came into force to ensure compliance with the application standards for livestock manure under the Nitrates Directive. Livestock farmers who produced too much manure were obliged to enter into manure transfer contracts with arable farmers, other less intensive livestock farmers, or manure processors. In October 2003, the European Court of Justice rejected MINAS on the grounds of it being an improper implementation of the Nitrates Directive, following which the Dutch government decided to abandon MINAS and the MAO system. In January 2006, the Netherlands adopted a new fertiliser policy based on application standards instead of loss standards. Application standards for nitrogen in livestock manure and application standards for the total amount of (plant-available) nitrogen and phosphate were introduced. The application standards were tightened during the period 2006-2015, the application standards for phosphate being made dependent on the phosphate status of the soil in 2010. In addition, other measures were introduced or tightened, such as shortening the spreading period for livestock manure, increasing the

minimum storage capacity for this manure to seven months in 2012, and increasing the nitrogen availability coefficient of pig manure on sandy soil in 2014. The latter means that where pig manure is used on sandy soils, the amount of nitrogen that can be given together with other fertilisers was reduced in 2014 in order to ensure compliance with the nitrogen application standard.

Practice in agricultural areas

Agriculture in the period 2012-2015

In the period 2012-2015, the area under cultivation in the Netherlands totalled 1.84 million ha, corresponding to 55% of the country's land surface. The area under cultivation comprises 54% grassland (78% permanent), 12% silage maize, and 28% other arable crops. The rest is used for horticulture. There are more than 66,000 farms, including 53% farms with grazing animals, 18% arable farms, 16% horticultural enterprises (including permanent crops), and 13% factory farms and mixed farms.

In 2012-2015, the livestock population comprised an average of 4 million head of cattle, 12.3 million pigs, 100.7 million poultry, and 1.4 million sheep and goats. This livestock produced manure containing about 480 million kg of nitrogen (N) and 169 million kg of phosphate (P_2O_5). Cattle manure was responsible for some 58% of the nitrogen and 51% of the phosphate during this period. Of the phosphate in the manure, around 25% is exported or used for non-agricultural purposes; for nitrogen, this amount is about 17%. During the period 2012-2015, nitrogen input to soil was on average 299 kg/ha, of which 163 kg/ha was via manure, 103 kg/ha via artificial fertiliser, and 33 kg/ha via atmospheric deposits and other sources. The loss of nitrogen to the soil – i.e. the input minus the output via crops – averaged approx. 100 kg/ha. Phosphate input to agricultural land in this period was on average 77 kg/ha, of which 68 kg/ha was via manure, 5 kg/ha via artificial fertiliser, and 4 kg/ha via other sources. The loss of phosphate to the soil was on average 6 kg/ha.

Trends in agricultural practices

The area under cultivation in 2012-2015 was almost 3% lower than in 2008-2011. This area declined by more than 7% between 1992 and 2015. The number of farms was almost 9% lower than in the previous period, while this number has fallen by more than 43% since 1992. By comparison with 2008-2011, the number of cattle has increased by 2.3%, pigs by 0.8%, and poultry by 2.8%. However, the number of cattle and pigs is still more than 15% lower than in the period 1992-1995. The number of poultry is 7% higher than in 1992-1995.

Despite the increase in the number of animals, excretions of nitrogen and phosphate from livestock manure was lower in 2012-2014 than in 2008-2011, with reductions of 1.2% and 3.6% respectively. By comparison with 1992-1995, the reduction was more than 31% for nitrogen and 27% for phosphate. The reduction since 1992 is due to the combined effect of a reduction in the number of livestock and in the amount of mineral excretion per animal. The reduction since 2008 is due to a further reduction in the amount of mineral excretion per animal brought about by lower nitrogen and phosphate content in fodder and improved feed conversion.

As a result of the reduction in excretion and a steep decline in the use of artificial fertilisers, the nutrient surplus in Dutch agriculture between 1992 and 2014 has halved in the case of nitrogen and has virtually disappeared in the case of phosphate (Figure S1). The nutrient surplus is the difference between input and output of nutrients, taking differences in stock on farms into account.

Compared with the previous reporting period (2008-2011), the net output of manure (the difference between input and output) increased further in some areas, while input in areas with a net input fell. Disposals of manure outside the Dutch agricultural sector in 2012-2014 were about 9% higher than in 2008-2011.

Ammonia emissions from agricultural sources into the atmosphere continue to decrease, and are almost 8% lower than in 2008-2011 and 58% below the level for the period 1992-1995.

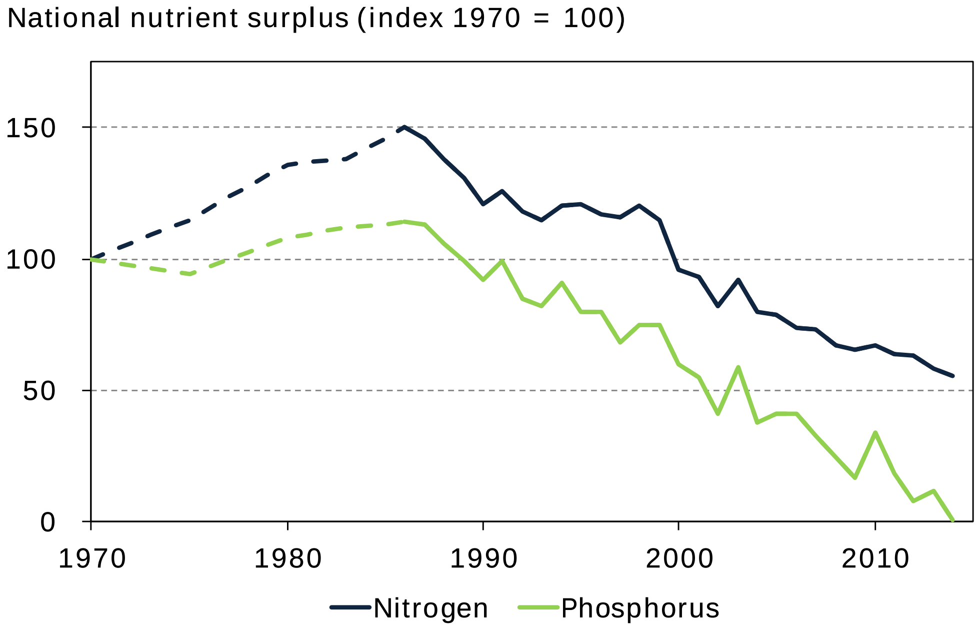

Figure S1: Trends in the relative nitrogen and phosphate surpluses in Dutch agriculture in the period 1970-2014, with 1970 values defined as 100; annual observations from 1986

The storage capacity for manure increased significantly by comparison with the period 2008-2011, after the mandatory minimum storage capacity was increased by one month to seven months in 2012. In 2014, 88% of dairy farms, 90% of pig farms and 77% of veal calf farms had storage facilities sufficient for at least seven months of manure production. Farms that can demonstrate that the excess is removed or used responsibly are not required to have seven months' worth of storage capacity.

Quality of groundwater and surface waters

Nitrate concentrations in the period 2012-2014

Changes in agricultural practices have the most rapid impact on water leaching from the root zone of an agricultural plot (leaching water). For this reason, the Dutch government decided to monitor the effects of the Action Programmes in the top metre of groundwater, in tile drain water or in the moisture of soil layers just beneath the root zone of the plot. However, this report also includes the data from nitrate measurements in deeper groundwater and surface waters.

Nitrate concentration decreases the further it is measured from the source, i.e. agricultural activities (see Table S1). This applies to groundwater as regards depth (of measurement) and to surface water as regards distance. In recent years, nitrate concentrations in fresh national waters were slightly higher than in regional waters. The cause of this is still not certain. However, it is known that a large proportion of the total quantity of nitrogen in Dutch surface waters comes from cross-border rivers. The overview below shows the different types of surface water according to nitrate concentration, from the highest to the lowest: agricultural ditches > agriculture-specific regional waters > WFD fresh national waters > WFD fresh regional waters > transitional waters > coastal waters > open sea.

Two important factors influence this falling concentration. The first is the conversion of nitrates (denitrification) into gaseous nitrogen (N_2) and nitrogen oxides such as nitrous oxide (N_2O, a greenhouse gas) during transport, and the second is the mixing with water with lower nitrate concentrations (dilution). In the case of groundwater, two additional factors play a role: time and the hydrological conditions. Water leaching from a root zone is young water (1 to 5 years old). In sand areas, groundwater at a depth of 5 to 15 metres has an age of approximately 10 years, and groundwater at a depth of 15 to 30 metres an age of approximately 40 years. Hence, groundwater at a depth of 15 to 30 metres reflects agricultural practice of at least 40 years ago. The groundwater at depths of 5-15 and 15-30 metres in clay and peat areas is generally even older. Hydrological factors (flow paths) play a key role here, as the groundwater in aquifers in clay and peat areas to a depth of 5 to 15 metres as well as 15 to 30 metres is often wholly or partly confined by a weakly permeable clay aquifer. In such areas, the precipitation surplus drains away through the soil surface to the surface water. Wholly and partly confined aquifers also occur locally in sand areas.

In the Peat Region, nitrate concentrations in leaching water and groundwater are lower than in the Clay Region, the concentrations here in turn being lower than in the Sand Region (see Table S1). The cause is differences in denitrification rates. The Sand Region has the lowest denitrification capacity, the Clay Region comes next, and the Peat Region has the highest.

Table S1: Average nitrate concentrations measured (in mg/l) and exceedances of the 50 mg/l standard (as a percentage of the number of monitoring wells) in groundwater and surface water for the period 2012-2014[1]

Water type	Sand	Clay	Peat	Loess	All types
Leaching from root zone (agriculture)	54 (46%)	19 (7%)	8 (0%)	75 (64%)	
Groundwater at a depth of 5-15 metres (agriculture)	33 (20%)	2 (2%)	<1 (0%)		20 (13%)
Groundwater at a depth of 15-30 metres (agriculture)	6 (4%)	2 (2%)	< 1 (0%)		5 (3%)
Groundwater at a depth exceeding 30 metres (phreatic extraction)	7 (0%)				
Fresh surface water[2]					
Agricultural ditches	28 (19%)	10 (1%)	4 (0%)		
Agriculture-specific waters	17 (2%)	11 (2%)	4 (0%)		14 (2%)
WFD regional waters					9 (0%)
WFD national waters					13 (0%)
Marine surface water[2]					
Transitional waters					8 (0%)
Coastal waters					2 (0%)
Open sea					1 (0%)

[1] The percentages in brackets show the relative numbers of breaches of the EU water quality standard of 50 mg/l in the period 2012-2014. For water leaching from a root zone (under 5 metres in depth) and agricultural ditches (both based on data for 2012-2015), the percentage is the relative number of farms that exceeded the 50 mg/l standard. For groundwater at a depth exceeding 5 metres, the percentage is the relative number of wells, and for surface water, the relative number of monitoring locations.

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

Eutrophication state of surface waters in the period 2012-2014

A large part of the surface waters covered by the Water Framework Directive (WFD) are eutrophic or potentially eutrophic. “Eutrophic” means that the biological status is poor, and the nutrient concentrations do not meet the water quality standards for these waters under the WFD. “Potentially eutrophic” means that the biological status of these waters is good, but the nutrient concentrations do not meet the water quality standards for these waters under the WFD. It is not only nitrates but the total amount of nitrogen and phosphorus in the water that is the main reason for high nutrient levels in the water. In addition, the EU water quality standard for nitrates of 50 mg/l, which is designed to protect drinking water, is too high to achieve good (ecological) water quality for the WFD and a good eutrophication status for surface water. This nitrate standard is therefore not determinative in the water quality targeted by the WFD.

Sixty percent of fresh water in the Netherlands is eutrophic. Slightly more than a quarter of the waters are non-eutrophic, and a small proportion of the waters are potentially eutrophic.

The picture is different when it comes to marine waters, where the eutrophication effects in the biology are limited (less than 10%), but the nutrient concentrations (dissolved nitrogen) are too high in more than 80% of waters. This probably means that there are other factors causing the algal biomass not to indicate eutrophic conditions, such as light limitation, grazing by plankton, or other nutrients apart from nitrogen.

Trends in the quality of groundwater and surface water
Nitrate concentrations
Nitrate levels in the Sand, Clay and Peat Regions rose during the period 2012-2015 (see Figure S2). However, the average nitrate concentrations in this period are lower than or equal to those in the previous period (2008-2011). The average concentration in the Sand Region fell from 58 mg/l in 2008-2011 to 54 mg/l in 2012-2015. Regarding nitrate concentrations in the Loess and Peat Regions, there has been no change between the previous and the latest reporting periods.

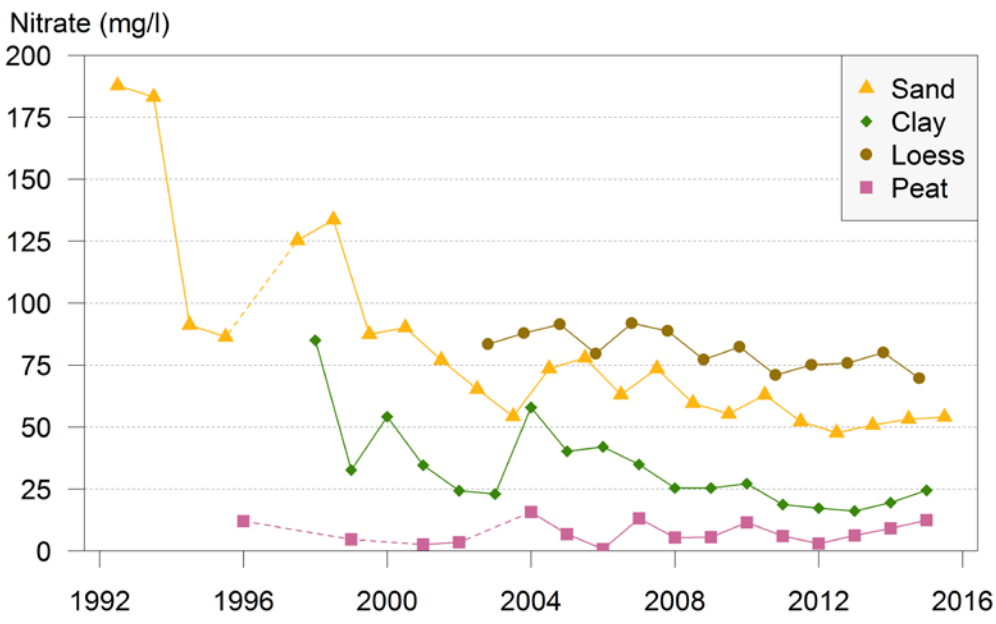

Figure S2: Nitrate concentrations in water leaching from root zones on farms by region in the period 1992-2014; annual averages of measured concentrations

In the period 1992-2014, nitrate concentrations in water leaching from root zones on farms (Figure S2) decreased. This was also the case with the number of farms with nitrate concentrations in excess of 50 mg/l (see Figure S3).

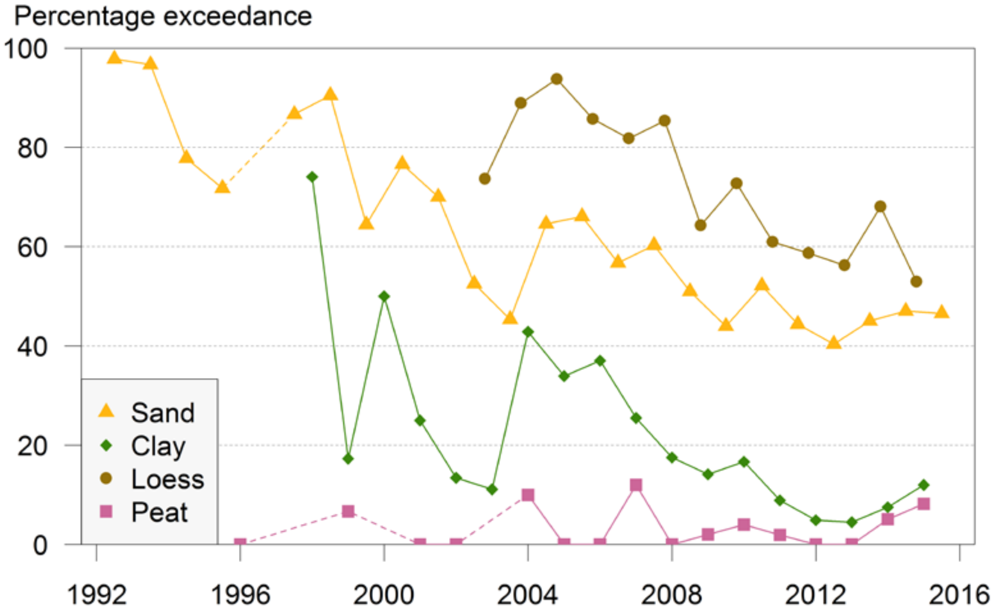

Figure S3: Percentage of farms with nitrate concentrations above 50 mg/l in the water leaching from the root zone on farms per region in the period 1992-2014

The average annual nitrate concentrations in groundwater at depths of 5 to 30 metres showed no trends in the period from the start of the groundwater monitoring network in 1984 to 2014, except in the Sand Region. In the shallow groundwater under agriculture in the Sand Region (5-15 metres below surface level), there was an increase from 38 mg/l to 46 mg/l between 1984 and 1996. Thereafter, the concentration dropped to an average of 33 mg/l in the period from 2008 to 2011, and has been stable since then. The average concentrations in the deeper groundwater (15-30 m below surface level) also decreased slightly, from 10 mg/l in 1988-1991 to 6 mg/l in 2012-2014. Nitrate concentrations in raw water in phreatic groundwater extracted for drinking water (at a depth of more than 30 m in the Sand Region) were stable and low (average < 8 mg/l) in the period 1992-2014, and stable and very low (< 2 mg/l) in artesian water extracted.

The nitrate concentration in the fresh surface waters, averaged over the leaching season (winter), has been dropping since 1992. This decline occurs in both agriculture-specific regional waters and in the measurement points in the waters designated for the WFD. The decline is also visible in (marine) transitional waters. In coastal waters and the open sea, the average nitrate concentration in the winter period from 1992 to 2014 was more or less the same. Adjusted for the variation in output via rivers, the average inorganic nitrogen concentrations (nitrate, nitrite, and ammonium) in transitional and coastal waters in winter showed a decrease between 1992 and 2002. After 2002, the inorganic nitrogen concentration stabilised for coastal waters, while the decline has continued for transitional waters. Concentrations in seawater are stable.

Eutrophication
Eutrophication of the waters under the WFD methodology could only be assessed for the period 2011-2013. However, it is clear that the average chlorophyll-a and phosphorus concentration in WFD fresh waters during the summer season (the season in which eutrophication may occur) in 2012-2014 hardly changed compared to the period 2008-2011. The total summer average nitrogen concentration has improved slightly, however. These concentrations declined significantly between 1992-1995 and 2008-2011. The picture for transitional, coastal and marine waters is the same, with a clear decline between 1992-1995 and 2008-2011, and an almost unchanged situation in 2012-2014 compared with 2008-2011.

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

The quality of the water on farms (ditch water as well as leaching from the root zone of agricultural plots) will exhibit the fastest and greatest response to measures that have been implemented as part of the Action Programmes. For the above reasons, the measures in the Fifth Action Programme (2014-2017) will only impact fully on the quality of the water on farms in the first five years following its full implementation.

The effects on the quality of phreatic groundwater at a depth of more than 5 metres will not manifest themselves until after one or more decades. Moreover, these effects will be difficult to detect owing to the mixing of groundwater of different ages and origins, as well as to the physical-chemical processes in the subsoil.

The consequences of the Fifth Action Programme for the quality of agriculture-specific regional surface waters will probably also only manifest themselves in the first five years following its full implementation, as is the case with the water quality on farms. The effects will be difficult to demonstrate – and then only after a long time – in the larger regional and national waters, both marine and fresh water. This is the result of these waters mixing with water originating elsewhere and of chemical processes in the groundwater and surface water.

For an ex-ante evaluation of the draft River Basin Management Plans (pursuant to the WFD), model calculations were carried out to establish the effects of the Fifth Action Programme on nitrate concentrations and nitrogen and phosphorus leaching and run-off in the longer term. These model calculations show that the average nitrate concentrations in the upper groundwater have been falling since 2014 due to the tightening of measures such as the nitrogen application standards up to 2017, mainly affecting a number of crops on sandy soil, and lower artificial fertiliser use as a result of the application of a higher availability coefficient for pig manure. For the entire Sand Region, the average nitrate concentration has fallen to a level of 50 milligrams per litre. The calculations also indicate that the nitrate objective for the Sand North and Sand Central areas will, on average, easily be reached. The groundwater quality is improving in Sand South, but achieving the nitrate target is not yet in sight.

The model calculations show that the total load on Dutch surface water from run-off and leaching is not decreasing at all for nitrogen and only very slightly for phosphorus. In the case of nitrogen, however, there is reduced run-off and leaching into surface water in sand areas, but this is being cancelled out by an increase in load in clay areas.

Forecasting the evolution of eutrophication due to agricultural activities is even more difficult than it is for nitrate concentrations, the main reasons being:

- The differences in surface waters with regard to their sensitivity to eutrophication
- Phosphorus concentrations and other factors such as hydromorphology, which also play an important part in the eutrophication process
- Contributions from other sources of nutrient input, such as urban wastewater and cross-border rivers
- The extreme difficulty with predicting the response times of aquatic ecosystems to a substantial reduction in nutrient inputs and concentrations

Conclusions

The years 1950 to 1987 saw the growth of nitrogen and phosphate surpluses in Dutch agriculture. Since 1987, however, the Netherlands has been successfully reducing them. The nitrate concentration in on-farm groundwater and surface waters has diminished, and the quality of the surface waters in the Netherlands has improved. This is a result of measures taken in Dutch agriculture on account of the EU Nitrates Directive, such as using less manure and for a shorter time each year.

The nitrate concentrations in the water that leaches from the root zone of land on farms in the Sand and Clay Regions were lower in the period 2012-2014 than in the previous period, 2008-2011. The nitrate concentrations in the groundwater have been stable since 1992 (Clay and Peat Regions) or falling (Sand Region). Despite improvements in water quality, nitrate concentrations higher than 50 mg/l are still occurring in 2012-2014, mainly in the Sand and Loess Regions. Moreover, 60% of the fresh surface waters are eutrophic, which means that the biology of the water is not at the desired level. Slightly more than a quarter of fresh water is non-eutrophic, and a small portion is potentially eutrophic because its biological status is good but the nutrient concentrations do not meet the WFD water quality standards for the various waters. Slightly more than 10% of marine waters are eutrophic. Nutrient concentrations (dissolved nitrogen) are too high in over 80% of marine waters, as a result of which these waters can be classified as potentially eutrophic.

The expectation is that water quality will improve in the first five years following full implementation of the Fifth Action Programme (2014-2017), owing to the measures that have been and are being taken during this Action Programme, and those taken in previous programmes. It will probably be a few more decades before the nitrate concentration in deep groundwater is fully impacted. Concerning eutrophication, the quality of fresh and marine water is expected to stabilise or improve slightly in the near future.

1 Introduction

1.1 General

This report is part of the Netherlands Member State reporting under Article 10 of the Nitrates Directive and has to be submitted to the European Commission by 1 July 2016 at the latest. The report provides an overview of current agricultural practices, and of groundwater and surface water quality in the Netherlands, describes the trends in these waters, and assesses the time scale for the change in water quality due to changes in the aforementioned practices. It deals with the implementation and impact of the measures taken as part of the Action Programmes, covering the period 1992-2014. Where available, the data for 2015 are also presented.

This introductory chapter summarises the objective of the Nitrates Directive and the main obligations arising from it (Section 1.2). The two obligations relevant to this report, namely reporting (Section 1.3) and monitoring (Section 1.4), are discussed in detail. The 2016 Member State report covers the sixth reporting phase. A review of the first five reports is given in Section 1.5, with a detailed description of the sixth report's contents given in Section 1.6. References (Section 1.7) are included at the end of this and every chapter.

1.2 The Nitrates Directive

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

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

The Netherlands has not designated any Nitrate Vulnerable Zones. However, it informed the European Commission in 1994 that it would prepare an Action Programme for the entire territory of the Netherlands, in conformity with the Nitrates Directive. According to a study in 1994 (Working Group Designating NVZ, 1994), agriculture is a major source of nitrate emissions into groundwater and/or fresh surface waters and/or coastal waters. The working group therefore concluded that an Action Programme had to be carried out for the whole country. This conclusion was confirmed in a study carried out in 2010 in connection with the Snijder motion on the designation of NVZs (Schoumans *et al.*, 2010).

1.3 Reporting obligations

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

Reporting obligations:

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

This report concentrates on items 4d and 4e of the reporting obligations, with the results being presented so that the effectiveness of the Action

Programmes as a whole can be assessed. Reporting on the results of the monitoring for the derogation is done separately and, moreover, annually (Lukacs *et al.*, 2015, 2016; Hooijboer *et al.*, 2013, 2014; Buis *et al.*, 2012; Zwart *et al.*, 2009, 2010, 2011; Fraters *et al.*, 2007a, 2008).

1.4 Monitoring obligation

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

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

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

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

In 1998 the European Commission sent a draft guideline for the monitoring process, in accordance with Article 7 of the Directive, to the Member States for comment. Revised versions were submitted in 1999, 2003 and 2004, but no final version has been published so far. A guideline is not binding. The purpose of the monitoring guideline is to define all types of monitoring and suggest possible ways in which Member States might carry them out. In addition, the Commission aims to ensure that the monitoring regimes of the Member States are comparable. An especially large effort has gone into the monitoring relating to the Water Framework Directive (KRW) and the Groundwater Directive (GR), for which guidance documents were published. In addition, several years ago a study on the harmonisation of the monitoring and reporting relating to the WFD, Nitrates Directive (ND) and the State of the Environment (SoE) was carried out, although this has produced no concrete results so far.

1.5 The first five Member State reports of the Netherlands

The first Member State Report of the Netherlands was submitted to the Commission in 1996 (LNV, 1996). This report covered the period 1992-

1995 (or more precisely, 20 December 1991 to 20 December 1995). It did not include any monitoring data to demonstrate the effectiveness of the first Action Programme, as this only came into effect on 20 December 1995. The report provided an overview of the operational monitoring programmes.

The second Member State report of the Netherlands was submitted to the Commission in 2001 (LNV, 2001). This report covered the period 1996-1999. Like later reports, it contained the results of the monitoring programmes for assessing the effectiveness of the Action Programme and was based on the report of the Working Group - Monitoring Nitrates Directive (Fraters *et al.*, 2000). The report, which contained monitoring data up to 1998, indicated that there was a stabilisation, but not yet a substantial improvement of the environmental quality. This lack of improvement was anticipated because, on the one hand, measures had not yet been fully implemented, and on the other, the measures would only bring about a change in the quality of groundwater and surface water in the longer term.

The third Member State report of the Netherlands was submitted to the Commission in 2004 (VROM, 2004). This report covered the period 2000-2003. As in 2000, it was based on the report of the Working Group - Monitoring Nitrates Directive (Fraters *et al.*, 2004). The report, which contained monitoring data up to 2002, concluded among other things that due to policy measures taken since 1987, the water quality had improved in the reporting period. This applied to both nitrate concentrations and eutrophication. By comparison with previous periods, the nitrate concentration in the upper groundwater on farms had clearly decreased between 2000 and 2002. This was related to the reduction in the use of nitrogen since 1998. Nitrate concentrations in deep groundwater (> 30 meters) were still increasing, which was attributed to the increase in nitrogen surpluses in the period before 1987.

The fourth Member State report of the Netherlands was submitted to the Commission in 2008; this was the report of the Working Group - Monitoring Nitrates Directive (Zwart *et al.*, 2008). This report covered the period 2004-2007 and contained monitoring data up to 2006. The report concluded that nitrate concentrations in the water on farms were significantly lower in the period 2004-2006 than in preceding periods. This was attributed to the reduction in nitrogen use since 1998. Nitrate concentrations in deep groundwater (> 30 m deep) were continuing to increase, however.

The fifth Member State report of the Netherlands was submitted to the Commission in 2012 (Baumann *et al.*, 2012). This report, which contained monitoring data up to 2010, showed a further decline in the nitrogen and phosphate surpluses as well as a further decrease in nitrate concentrations in the water on farms. Nitrate concentrations in deep groundwater (> 30 m) were stable by comparison with the preceding reporting period.

1.6 The sixth Member State report and this report

1.6.1 Definition and accountability

The Member States have to submit their Nitrates Directive Member State reports to the European Commission in mid-2016. The sixth Member State report covers the period from 20 December 2011 to 20 December 2015. It also needs to contain the results of the monitoring programmes for assessing the effectiveness of the Action Programme (item 4d of Section 1.3), as well as the assumptions made by the Member States about the likely time scale within which the designated waters are expected to respond to the measures in the Action Programme (item 4e of Section 1.3).

The Ministries responsible for the reporting by the Netherlands (see Section 1.3) once again requested the Working Group - Monitoring Nitrates Directive (WGMND) to report on the two above-mentioned topics. The present report represents the results of the Working Group's activities.

The starting point for preparing this report was a combination of the reporting guidelines published by the Commission in 2011 (EC/DGXI, 2011). The 2000 guidelines contain a request for the monitoring period results to be published on the basis of three years' monitoring for each period. Because the guidelines have not been revised in this respect, it is not clear whether results for only two monitoring periods have to be given or for all periods (in this case six). It is just as unclear as regards which periods have to be used for comparing results, as prescribed in the guidelines.

For the fourth Member State report (2008), the WGMND recommended (Fraters *et al.*, 2007b) that, in order to provide an informative overview of the status and trends of agricultural practice and the aquatic environment, the first and last two periods should be presented in the form of tables. This method is used again in this report for preparing the sixth Member State report. It means that the results of the 1992-1995, 2008-2011 and 2012-2014 monitoring periods are presented in tables. In addition, graphs are provided showing yearly averages for the 1992-2014 period. Moreover, where earlier data are available, often going as far back as the mid-1980s, these are presented as well. To limit the number of maps in the report, only those showing the water quality for the period 2012-2014 and the change in water quality between 2008 and 2014 (fifth and sixth periods) will be included.

1.6.2 Structure of the report

This report consists of an introduction (this chapter), a description of the monitoring programmes and an explanation of the data and methods used (Chapter 2), a summary of the main policy developments and measures taken in the context of the fertiliser policy since 1987, as well as the developments in agriculture and agricultural practices (Chapter 3), the results of the monitoring programmes for assessing the effectiveness of the Action Programmes (Chapter 4), the results of the monitoring programmes for assessing the development of water quality (Chapters 5 to 7), a forecast of how the quality of water bodies will evolve in the future (Chapter 8) and a summary of the results from the preceding chapters, together with conclusions drawn from them. For the convenience of the reader, this summary 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.

The effectiveness of the Action Programmes is monitored by observing both the developments in agricultural practices and water quality on farms. Water quality is determined from measurements of the nitrate concentration in the water leaching from the root zone and concentrations in the ditch water on these farms. As stated above, the effect of changes in agricultural practices on water quality on these farms is described in Chapter 4.

In Chapters 5 to 7, the status of and trends in the aquatic environment are described: groundwater in Chapter 5, fresh surface waters in Chapter 6, and marine surface waters in Chapter 7.

Groundwater nitrate concentrations are given for three depths: 5-15 metres, 15-30 metres and > 30 metres below the soil surface. Measurements are taken at different depths, because nitrate concentrations vary considerably with depth. Other important environmental factors considered when measuring nitrate concentrations in groundwater are land use, soil type and aquifer type.

Nitrogen and phosphorus emissions are given for surface waters, along with a description of the water quality. Water quality is described in terms of nitrate concentrations (for the winter) and eutrophication parameters (for average summer concentrations of nitrogen, phosphorus and chlorophyll-a). Three types of water are distinguished for fresh surface waters: agriculture-specific regional waters, regional WFD waters and national WFD waters. They are given here in order of decreasing impact of agriculture on water quality. Other sources affecting water quality are, for example, effluent from wastewater and sewage treatment plants, sewage overflow during heavy rainstorms, and atmospheric deposits. Marine waters are divided into transitional waters, coastal waters and open sea, making clear the differences in nutrient emissions, which are mainly from rivers, rather than the result of direct discharge.

The forecast of future water quality (Chapter 8) is based on the ex-ante evaluation of the Dutch plans for the Water Framework Directive (Van Gaalen *et al.*, 2016) and the calculation of the consequences of the Fifth Action Programme on future nitrate concentrations in groundwater and surface water and on nitrogen and phosphorus leaching into surface water that was performed for it (Groenendijk *et al.*, 2015).

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2 National monitoring programmes

2.1 Introduction

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

This chapter provides a brief description of the organisation of and measurement efforts in these programmes. It also includes a general description of the data collection and processing methods. Details of the data collecting and processing are given in the publications in the list of references at the end of this chapter.

2.2 Monitoring agricultural practice

2.2.1 General

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

2.2.2 Data collection

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

Agricultural Census

Statistics Netherlands (CBS) collects general information about all farms, such as areas of cultivated land, the number of farm animals and data on organic farms (CBS StatLine, 2016). This annual collecting of data is referred to as the “Agricultural Census”.

Farm structure surveys have been held for more than 100 years and have taken place annually since World War II. The Agricultural Census was originally a Statistics Netherlands survey and later became a joint survey by Statistics Netherlands and the Ministry of Agriculture. Since 2002 it has been part of the Combined Data Collection (GDI) carried out by the Netherlands Enterprise Agency (RVO), formerly Dienst Regelingen (the Regulatory Service).

Until the end of 2009, the economic size of a farm was expressed in NGEs (Dutch Magnitude Units). As from the beginning of 2010, this was replaced by the concept of Standard Revenue (SO). SO is a standardised measure of the economic size of a farm, based on the average annual revenue per crop or animal category. SO standards are set separately for each type of crop and animal category. They are based on five-year averages and updated every three years. The SO of a farm is the sum of all its SOs for crops and animals. The farm type is established based on the SO proportions of the various crops and animals in the SO total.

The threshold value for inclusion of farms in the publication of the Agricultural Census changed from 3 NGEs to 3,000 euro SO in 2010. With the threshold value of 3,000 euro SO (formerly 3 NGEs), only very small farms are excluded, such as, for example, farms with only one dairy cow or 100 m^2 of peppers. In fact the change in the threshold value had virtually no impact on the size of the population. The part not counted in the Agricultural Census is of a negligible economic size.

In 2010 the classification of farms by type and acreage also changed. In addition to a different basis and a slightly different calculation method for determining the farm type, tree nurseries are no longer counted as permanent crop farms. Tree nurseries now fall under horticulture. On the other hand, vegetables grown on open fields are no longer classified as horticulture. Acreages of field-scale vegetables are included in the arable crop area.

The changes were implemented in StatLine in 2010 from reporting year 2000 onwards. The series on StatLine were compared sequentially by recalculating the Agricultural Census data from 2000 to 2009. In this report, particularly in Chapter 3, pre-2000 data have also been amended so that the series can be compared.

Farm Accountancy Data Network
LEI Wageningen University & Research Centre (LEI) collects information of a more specific nature about farm economics and technical management, via the Farm Accountancy Data Network (FADN) (Lodder and De Veer, 1985; Vrolijk, 2002; Poppe, 2004). This farm management information includes environmentally relevant data such as nutrient balances (inputs and outputs of nutrients, including changes in stock), the use of pesticides, water and energy consumption, use of artificial fertilisers, and grazing frequency.

The FADN represents 1500 farms from the Agricultural Census, selected by stratified random sampling, thus forming a representative sample of Dutch agriculture. The FADN network is part of a larger EU network (EU Council Regulation 79/65/EEC). Farms included in the FADN were visited each year. Up to 2006, between 15% and 20% of farms would be replaced every year. Since 2006 this replacement has been limited to farms that stop operating, move to another region, or cease to participate for some other reason. As a result, the annual replacement of farms is no more than 3-5%.

The FADN represents about 75% of the total number of farms and about 90% (both in NGEs and SO) of the registered agricultural production in the Netherlands. Due to the switch from NGEs to SO units, the NGE will continue to be used as the unit for economic measurement in reports utilising FADN data up to 1999 and the SO from 2000.

To ensure the representative nature of the FADN, farms smaller than 16 NGEs or 25,000 SO, where agriculture is generally not the main activity, are excluded from the network. Farms larger than 1200 NGEs (mostly greenhouse nurseries) are not completely suitable for data collection and are therefore also excluded. The upper size limit was abolished with the introduction of the SO. Currently, the FADN covers more than 90% of Dutch agricultural area (Van der Veen *et al.*, 2014). Past years show similar results.

Monitoring compliance with the regulations
For the implementation of the new fertiliser policy, order enforcement is utilised. Current policy is based on the following standards and rules, which differentiate between three types of standards:

1. Primary standards
   a. Nitrogen application standard
   b. Phosphate application standard
   c. Livestock manure application standard

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

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

Administrative checks
The Netherlands Enterprise Agency (RVO) inspects farms on the basis of registered data over the various calendar years. Compliance with the primary standards and the duty of accountability is monitored annually. This concerns two main target groups: farmers and manure transporters (intermediaries). Within these groups, a further distinction is made between aspects such as the location of the farms (programmatic enforcement). If the Netherlands Enterprise Agency does not have sufficient information at its disposal, additional information is requested from the farms.

Different approach to inspections
In 2012, the Netherlands Enterprise Agency started changing its enforcement strategy to focus more on the result and the impact of the surveys and less on the numbers.

Random checks on application standards and accountability
The Netherlands Enterprise Agency inspected the registered data of randomly checked farms for compliance with the application standards and the duty of accountability. If the information was incomplete, supplementary information was requested from the party concerned.

Selected administrative checks
In addition to the random checks, farms are checked because they have met one of the following three criteria:

1. Farms that have applied for derogation but that do not meet one or more derogation conditions
2. Farms with land and manure input during the spreading period
3. Farms with several branches

2.2.3 *Data processing*

Nitrogen and phosphorus balances

Each year, Statistics Netherlands calculates the nitrogen and phosphorus balances of the agricultural sector.

When drawing up and analysing balances, input flows in both cultivated land and at livestock farm level must be in balance with output flows, including loss flows (see Figure 3.2). In the livestock farming balance, the use of roughage and concentrates should be in balance with mineral excretions from the livestock and in the animal production records. The figures for the balance items were obtained using the method of the Manure and Mineral Figures Standardisation Working Group (Van Bruggen, 2015). In the cultivated land balance, the “loss to the soil” output flow is equal to the difference between the input flows and the other output flows. The figures for this correspond to the soil surface balance figures in StatLine (CBS StatLine, 2016).

The original method for compiling the balances was described by Statistics Netherlands (CBS) more than 20 years ago (CBS, 1992) and still forms the basis for the current nitrogen and phosphorus balances.

The method is adjusted occasionally as insights progress. For example, the input of artificial fertilisers now only includes the share used in agriculture, as a result of which artificial fertiliser use is now about 4-8% lower. An adjustment on a similar scale concerns the switch to a different estimation method for determining “manure disposed of to destinations outside Dutch agriculture”. This is now consistent with the approach used in NEMA (National Emission Model Agriculture) (Van Bruggen *et al.*, 2015). NEMA is the model used for calculating ammonia, greenhouse gas and fine particulates emissions in Dutch agriculture.

In addition to adjustments to the method, changes are regularly made to the source statistics, such as when a new time series on airborne nitrogen emissions from the 1990 reporting year onwards was compiled via the Emissions Registration, for example. The deposition figures from 1990 onwards have also been revised. Other input no longer includes nitrogen fixation by free-living bacteria in the soil, although nitrogen fixation by clover/grassland, alfalfa and legumes is included.

The data on the nitrogen and phosphorus balances are published by Statistics Netherlands via StatLine and the *Environmental Data Compendium*. Statistics Netherlands also submitted a detailed set of data to Eurostat (series from 1990 onwards, including metadata) in 2013 and 2015. The two-yearly submission was compiled in accordance with a manual (Eurostat/OECD, 2013) produced in consultation with EU Member States. These figures (StatLine, *Environmental Data Compendium,* Eurostat) are consistent with each other and correspond to the balance data in Chapter 3 of this report.

All these adjustments result in minor changes to the items on which the balances are based, especially in the case of the nitrogen balance; in other words, compared with the data published in previous reports. Nevertheless, the resultant picture of developments in the nutrient surplus and losses into the soil and air is no different and the trends are in line with those in previous reports.

Nutrient excretion and production
Statistics Netherlands also calculates the manure and mineral production of the livestock based on a nutrient balance per animal category in combination with the number of animals per animal category in the Agricultural Census. This method is based on the excretion factors calculated for N and P on the basis of the balance, i.e. defined as the difference between the intake via feed and the retention in animal products.

The basis for the calculation of the excretion factors is made up of technical data, i.e. data on the use of animal feed and animal production per animal category. Wherever possible, these are based on annually updated statistical information.

The results are made available through StatLine and *Environmental Data Compendium*, including an annual publication on the standardised calculation method and the starting points used (Van Bruggen, 2015).

Manure storage capacity
Manure storage capacity on livestock farms has been included in the Agricultural Census for only a few years of the monitoring periods (1993, 2003, 2007, 2010 and 2014). Part of the questionnaire deals with the storage capacity for animal manure on the farm itself. Here the answers have to be in the form of the storage capacity in months for different types of manure. The data for liquid manure are shown by livestock farm type in Figure 3.4.

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

Processing of data in the Farm Accountancy Data Network
The calculation of the nitrogen and phosphate surpluses and the method of calculating nutrient use via livestock manure, as stated in Chapter 4, are described in Section 2.3.3.

2.3 Monitoring effectiveness of the fertiliser policy

2.3.1 General
The effects of the Action Programme are monitored via standard programmes for groundwater and surface water, and a special programme known as Minerals Policy Monitoring Programme (LMM; in Dutch *Landelijk Meetnet effecten Mestbeleid*), based on a national network for measuring the effects of the fertiliser policy. LMM was developed to measure the effect of the Dutch fertiliser policy on nutrient

emissions, especially nitrate emissions, from agricultural sources into groundwater and surface water and to monitor the effects of changes in agricultural practices on these emissions. Consequently, LMM can also identify the impact of the Action Programmes.

The LMM programme monitors both water quality and farm management, i.e. agricultural practice. The Dutch policy measures have the aim of changing farm management in such a way that water quality improves. The quality of groundwater and surface waters is generally affected not only by agricultural practice, but also by other sources of pollution and by environmental factors such as the weather. To exclude other, diffuse sources of pollution as much as possible, the quality of water that leaches from root zones and ditch water is monitored on farms. This type of water reveals the effects of recent agricultural activities (carried out less than four years ago). To distinguish between the effects of measures on water quality and the effects of confounding factors, such as weather, these factors are monitored as well (see De Goffau *et al.*, 2012). The next Section (2.3.2) provides more details on LMM data collection, followed in Section 2.3.3 by a discussion of the data processing.

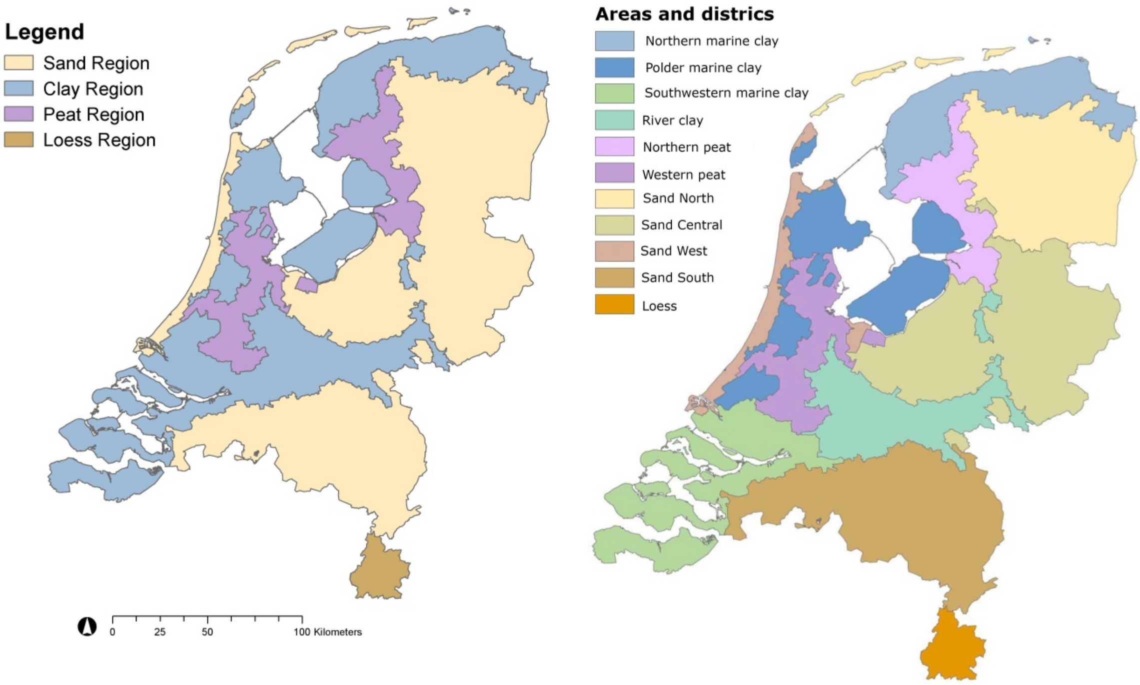
2.3.2 *Data collection*

LMM and FADN

When the LMM monitoring programme commenced in the Sand Region in 1992, it was decided that linking LMM and FADN (see Section 2.2.2) would have many advantages. Linking the two networks would make both farm management and water quality data available of all participating farms. In 1996, after the evaluation of the initial four-year period, it was decided to continue this collaboration. Because of the nature of Dutch agriculture and the high level of dynamics, the advantages of linking the FADN and the LMM to each other were obvious. The decision to use a sample of farms with a changing composition for the FADN was taken in the mid-1960s. Monitoring a fixed sample within LMM independent of the FADN would mean doubling the FADN's activities. The dynamism of the Dutch farming sector ensures that even a fixed sample would result in an LMM population with a changing composition. Account needs to be taken of the fact that both the FADN and LMM exclude some farms from participation. To keep the selection of participants representative, farms smaller than 16 NGEs or larger than 1200 NGEs or smaller than 25,000 SO are not included in the FADN (see Section 2.2.2). In addition to these FADN thresholds, LMM uses a minimum participation criterion of 10 hectares of land per farm for inclusion in its network.

The monitoring network was expanded in 2006 owing to the EU granting derogation for the application per ha of 250 kg of nitrogen in the form of livestock manure. Not all farms in the derogation monitoring network meet the conditions for inclusion in the standard monitoring programme (basic monitoring network). These farms are not suitable because they are not randomly selected. Both the basic monitoring network and the derogation monitoring network have had a fixed composition since 2006, except for changes arising from farm-specific developments.

Main soil type regions
The Netherlands applies the Nitrates Directive Action Programme to its entire territory. Even so, legislation distinguishes between main types of soil, with measures based on soil vulnerability to nitrate leaching. The monitoring programmes therefore focus on the most important Dutch main soil type regions: the Sand, Loess, Clay and Peat Regions (Map 2.1, left).



Map 2.1: LMM classification into main soil type regions (left) and into 11 areas and districts (right), the classification into the four sand areas in the Sand Region being based on provincial borders; classification into districts in the Clay and Peat Regions is in line with the standard LMM classification

Between the date of this report and the previous report in 2012, the classification of these regions has been improved with retrospective effect. The regions are now classified based on postcode districts, whereas they were previously based on municipal boundaries. These 4-digit postcode districts have the advantage of being much more stable than municipal boundaries. When municipal boundaries were used, the map had to be regularly revised to take account of boundary changes. The classification based on postcode districts is also more refined, so fewer discrepancies occur between the dominant farm soil type and the main soil type of the region. This new classification has been taken into account in the selection of farms since the 2012/2013 winter programme. Due to the retrospective amendment of the classification of regions, some minor differences in farm numbers have arisen compared with the previous report in 2012 on account of farms being classified in a different region.
The status of the aquatic environment on farms is described for the four regions (each named according to the dominant soil type). Each region comprises one or more areas or districts (see Map 2.1, right). The

classification of the Sand Region into four sand areas – North, Central, West and South – is based on the provincial borders:

Sand North	Friesland, Groningen and Drenthe
Sand Central	Overijssel, Gelderland and Utrecht
Sand South	Noord Brabant and Limburg
Sand West	Noord Holland, Zuid Holland and Zeeland

This is in line with the classification of sandy soils in the Implementing Regulation on Fertilisers (EZ, 2014).

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

Sampling and other data collection methods
The water quality on farms is monitored by sampling the water leaching from root zones and ditch water (if present). Leaching water is measured by taking samples from different types of water: from soil moisture in the unsaturated zone beneath the root zone, at a depth of between 1.5 and 3.0 metres below the surface if the groundwater is more than 5 metres below the surface; from the top metre of phreatic groundwater if the groundwater is less than 5 metres below the surface; and from drain water if the plots of land are drained by tile drains. Supplementary data on environmental parameters, such as the quantity of precipitation and evapotranspiration, the percentage of land area for each soil type and groundwater trap, are collected and utilised, with the aid of models, to explain the effect of these parameters on the measurements (see Section 2.3.3 and De Goffau *et al.*, 2012).

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

Sampling frequency
Sampling frequency varies according to programme and region. The sampling frequency depends on the expected change in water quality over time, and on the variation in quality by time and space. For groundwater and surface waters, changes in nitrate concentrations over time need to be relatively large if the targets are to be reached. The current sampling frequency in the LMM is based on a statistical analysis of the results of research conducted in the period 1992-2002. This comprises research into the Sand Region in the period 1992-1995 (Fraters *et al.*, 1998), and in the Clay (Fraters *et al.*, 2001) and Peat Regions (Fraters *et al.*, 2002) in the period 1995-2002. In these periods, samples were taken from farms every year. The ideal sampling frequency was again reviewed in 2010 (Ferreira, 2010).

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

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

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

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

Until 2006, the number of farms in the FADN that were potentially eligible for participation in the LMM programme was large. In the Sand, Loess and Peat Regions, it was found that the most productive and cost-effective method was to take samples from LMM farms only in their first, fourth and seventh years of participation. In the Clay Region, where most water drains away artificially through tile drains, and samples are taken from the drain water, it was found to be more productive and cost-effective to take the samples from farms each year.

This was a changed in 2006 owing to the European Commission granting derogation for the use of more than the limit in the Nitrates Directive of 170 kg nitrogen per hectare in the form of livestock manure. Since that year, samples have been taken annually from every participating farm.

Since the start of the LMM, the information on agricultural practices from all participating farms has been recorded each year. Owing to various circumstances, however, information is not always available from the year preceding the one in which the samples were taken.
The relationship over time between the information about agricultural practices collected in the FADN and the actual sampling period per region is illustrated by Table 2.1.

Table 2.1: Relationship between the information on agricultural practice in a specific year and the water sampling period with data associated with this agricultural information for all regions in the LMM

Month	Jan-Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Agricultural information	■	■	■	■													
Soil moisture in Loess Region													■	■	■	■	■
Groundwater in Sand Region (total)								■	■	■	■	■	■				
Groundwater in Sand Region in Low Netherlands		■	■	■	■	■	■										
Groundwater in Clay Region[1]		■	■	■		■	■										
Groundwater in Peat Region[1]			■	■	■	■	■										
Drain + ditch water, all regions		■	■	■	■	■	■	■									

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

Loess Region
The Loess Region has been part of the LMM since 2001, the first year in which data on agricultural practices in this region were recorded in the FADN for the purposes of the LMM. The first data on groundwater quality date from 2002. Water-quality data from the Provincial Soil Moisture Network for Limburg is also included in this Article 10 report in order to obtain a picture of changes over a longer period. Instead of the farm as sampling unit, the Provincial Soil Monitoring Network uses the parcel. As such, the design differs from that of the LMM (IWACO, 1999; Voortman *et al.*, 1994). Apart from crop types, no information on agricultural practices is available for the parcels in question.

Sample size
To make optimum use of the information in the FADN, the presentation of agricultural practice also includes farms in the FADN that do not take part in the LMM. The farms in the FADN are selected by means of a stratified, disproportionate sample, as a result of which weighting is required (Van der Veen *et al.*, 2014). The standard weighting in the FADN is less useful for the agricultural practices described in this report because, for example, it does not take account of the location.

Statistical matching is now used for weighting purposes (Vrolijk *et al.*, 2005). Two datasets are created as input. The first dataset contains the farms in the sample population (in this case the farms in the Agricultural Census within the upper and lower limits, with a minimum of 10 ha of cultivated land and falling within the LMM farm-types) with characteristics suitable for matching. The second dataset contains the sampled farms with the same characteristics (also available from the Agricultural Census). The characteristics of farms, also known as imputation variables, form the basis for comparing and matching the sampled and target population farms.

The imputation variables vary slightly between farm types: for example, the share of grassland is one of the imputation variables for dairy farms, and the share of cereals for arable farms.
With statistical matching, the farm characteristics that are available in both the sample and the sample population are used to obtain a number of "most similar" sample farms for every farm in the sample population. A distinction can be made between characteristics that (should) exactly match (e.g. type) and characteristics of the sample farm that should be as similar as possible (e.g. the proportion of grassland) to the farm in the sample population. Characteristics that are "as similar as possible" can be distinguished further by relevance by means of different weightings. Each farm from the sample population is matched with a number of farms from the sample. This gives each of the sample farms a weighting, adding up to 1. The closest matching farm is given the highest weighting (it is unlikely that each one of the closest matches is equally similar to the sample population farm).

For the same reason as the reason why all suitable FADN farms are included in the description of agricultural practice even if their water quality has not been sampled (this is done in order to use available information wherever possible), all farms belonging to the basic monitoring network were used for water quality reporting, along with randomly selected dairy farms forming part of the derogation monitoring network. The results of the samples taken were included even if there were no agricultural practice data available in the preceding year. The number of farms used for agricultural practice purposes therefore differs from the number used for water quality. Between 1992 and 2006, the number of participating farms in respect of water quality varied from year to year in all regions (see Table 2.2). Since 2007, the number of farms per region has been reasonably stable. Moreover, data on both agricultural practices and water quality are available for almost all farms. In total, approximately 5,100 farm year samples were taken for evaluation purposes at representative farms in the period 1992-2014. Ditch water sampling was performed on all farms in the Clay and Peat Regions. However, only a small number of farms in the Sand Region have ditches. For this reason, ditch water was sampled on approximately 60 farms (Table 2.4).

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

Table 2.2: Number of farms in the LMM where water quality was measured in the period 1992-2015

	Sand Region			Clay Region			Peat Region	Loess Region		
Year	Dairy farms	Arable farms	Other farms	Dairy farms	Arable farms	Other farms	Dairy farms	Dairy farms	Arable farms	Other farms
1992	66	18	7	0	0	0	0	0	0	0
1993	66	19	5	0	0	0	0	0	0	0
1994	33	0	3	0	0	0	0	0	0	0
1995	64	18	3	0	0	0	0	0	0	0
1996	1	0	0	1	0	0	17	0	0	0
1997	17	10	3	2	4	0	0	0	0	0
1998	20	11	11	15	11	1	0	0	0	0
1999	24	8	13	22	26	4	15	1	0	0
2000	28	8	11	27	27	4	2	1	0	0
2001	37	8	5	27	25	4	10	1	0	0
2002	36	10	13	23	22	7	20	9	6	4
2003	43	18	25	36	16	2	6	8	6	4
2004	57	14	26	30	35	5	10	6	7	3
2005	76	21	36	24	27	5	19	7	5	2
2006	127	15	44	24	27	3	17	22	14	8
2007	138	36	50	52	25	21	50	19	13	9
2008	131	34	49	55	24	18	50	18	14	10
2009	137	33	46	56	28	15	49	20	16	8
2010	137	32	52	59	28	15	50	20	12	9
2011	135	34	37	59	29	13	52	22	17	7
2012	133	38	34	59	32	11	51	21	19	8
2013	143	37	34	67	32	12	58	21	18	8
2014	146	38	36	62	31	13	59	23	19	9
2015	136	35	33	57	30	13	57	- [1]	-	-

[1] Sampling data for 2015 from the Loess Region were not yet available when this report was prepared.

Table 2.3: Number of farms in the LMM where water quality was measured in the period 1992-2015 and sampling frequency[1]

Year	Sand Region			Clay Region			Peat Region	Loess Region		
	Dairy farms	Arable farms	Other farms	Dairy farms	Arable farms	Other farms	Dairy farms	Dairy farms	Arable farms	Other farms
1992-1995	72 (3.2)	19 (2.9)	7 (2.6)							
1996-1999	54 (1.1)	28 (1)	27 (1)	23 (1.7)	29 (1.4)	4 (1.2)	17 (1.9)			
2000-2003	93 (1.5)	32 (1.4)	42 (1.3)	53 (2.1)	38 (2.4)	8 (2.1)	24 (1.6)	9 (2.1)	6 (2)	5 (1.6)
2004-2007	168 (2.4)	46 (1.9)	93 (1.7)	71 (1.9)	44 (2.6)	24 (1.4)	55 (1.7)	24 (2.2)	19 (2.1)	12 (1.8)
2008-2011	147 (3.7)	42 (3.2)	66 (2.8)	64 (3.6)	32 (3.4)	19 (3.2)	56 (3.6)	22 (3.6)	21 (2.8)	12 (2.8)
2012-2015[2]	158 (3.5)	41 (3.6)	47 (2.9)	69 (3.6)	34 (3.7)	14 (3.5)	60 (3.8)	23 (2.8)	20 (2.8)	10 (2.5)

[1] The figure in brackets is the average number of years in which samples were obtained from a farm in the period shown in the “Year” column.
[2] Sampling data for 2015 from the Loess Region were not yet available when this report was prepared.

Table 2.4: Number of farms in the LMM in the Sand Region where ditch water sampling was carried out

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number	25	29	52	52	60	62	62	60	63	59	60

2.3.3 *Data processing*

Nutrient surpluses

The nitrogen and phosphate surpluses referred to in Chapter 4 were calculated by a method derived from that used and described by Schröder *et al.* (2004, 2007) and as described in Annex 2.4 of the 2013 Derogation Report (Lukacs *et al.*, 2015). This means that in addition to the imported quantities of nitrogen and phosphate in organic and artificial fertilisers, and the exported quantities of nitrogen and phosphate in crops, consideration is also given to other input categories such as net mineralisation of organic matter in peat and wetland soils, nitrogen fixation by legumes, and atmospheric deposition.

A state of equilibrium is assumed when calculating nutrient surpluses on the soil surface balance. It is assumed that, in the long term, fixation of organic nitrogen in the soil in the form of crop residues and organic manure (immobilisation) is equal to the annual decomposition (mineralisation). An exception to this rule is made for peat soils and reclaimed peat soils ("*dalgronden*"). With these types of soil, an input due to net mineralisation is taken into account: 160 kg of nitrogen per hectare for grassland on peat soils, and 20 kg of nitrogen per hectare for grassland or other crops on peat soils and reclaimed peat soils. It is known that net mineralisation occurs on these soils as a result of groundwater level management, which is necessary in order to use the land for agriculture. Schröder *et al.* (2004, 2007) determine the surplus to the soil as the difference in the release of nutrients to the soil (partly calculated and partly recorded) and the nutrient yield of the crops (also partly calculated and partly recorded). In this study the surplus to the soil is calculated from the difference between inputs and outputs at the farm level (Lukacs *et al.*, 2015) with inputs and outputs largely derived from registrations.

Nitrogen in livestock manure

For the calculation shown in Chapter 4 to determine the nutrient usage via livestock manure, the production of manure on the farm concerned is calculated first. For nitrogen, this is the net production after subtraction of gaseous nitrogen losses from housing and storage. The manure production from grazing livestock is calculated by multiplying the mean number of animals present by the statutory excretion allowance (Netherlands Enterprise Agency; RVO, 2015 and other years). This method does not apply to farms that use the guidance document issued for this purpose (Lukacs *et al.*, 2015, Annex 2.4). Manure production by housed animals is calculated using the "stable balancing method", except where insufficient data are available or in the case of third party animals. In that case, the numbers for housed animals are multiplied by the national excretion allowance established by the Working Group for the Standardisation of Manure and Mineral Figures (Van Bruggen, 2015). For more details, please refer to Lukacs *et al.* (2015).

Furthermore, the quantity of nutrients is registered for all stock and fertiliser inputs and outputs (artificial fertiliser, livestock manure and other organic fertilisers). In principle, the quantity of nitrogen and phosphate in all imported and exported fertilisers is recorded by means of sampling. If sampling has not taken place, allowance levels per fertiliser type are used (RVO, 2015). Opening and closing stocks are calculated with contents from the stable balance and/or from the guidance document, if these are used, otherwise via allowances (RVO, 2015).

The total quantity of fertiliser used at farm level is then calculated using the following formula:

Quantity of fertiliser used on farm = Production + Opening stock level – Closing stock level + Input – Output

The quantity of fertilisers used on arable land is directly registered in the FADN.

The type of fertiliser, the quantities applied, and the time of application are all documented. The fertiliser use on grassland is subsequently calculated as:

Fertiliser use on grassland = Fertiliser use on farm - Fertiliser use on arable land

With less than 25% grassland in the total acreage of cultivated land, the quantity of fertilizers on grassland registered in the FADN is taken as fertiliser use on grassland. Fertiliser use on arable land is thus:

Fertiliser use on arable land = Fertiliser use on farm - Fertiliser use on grassland

The quantity of fertiliser used on grassland comprises spread fertilisers and manure excreted directly by grazing animals on grassland (grassland manure). The quantity of nutrients in grassland manure is calculated per type of animal by multiplying the percentage of time on an annual basis that the animals graze by the excretion allowance (RVO, 2015).

For more details, please refer to Lukacs *et al.* (2015).

Calculating annual averages

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

Statistical analyses and observed effects

For the statistical analysis of the relationship between farm management and the nitrate concentration in water that leaches from root zones, the residual maximum likelihood (REML) method is used (Payne, 2000). This method is used to correct or index for the effects of the annually changing natural conditions and changing samples on the measured nitrate concentrations (Boumans *et al.*, 2001; 1997), so that the impact of the policy is expressed more clearly. This method is available for the programmes in the Sand and Clay Regions. How the correction for the environmental parameters used in the method is made more accurate, is described in Boumans and Fraters (2011). The method was further improved in 2016 through the use of detailed precipitation and evaporation data and by first indexing the measured nitrate leaching instead of the measured nitrate concentration. For this purpose, the measured nitrate concentration is divided by the set precipitation surplus in which it is dissolved. The indexed nitrate leaching is then calculated back into an indexed nitrate concentration.

2.4 Monitoring status and trends in groundwater

2.4.1 General

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

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

2.4.2 Data collection

The National Groundwater Quality Monitoring Network (LMG), established between 1979 and 1984, comprises about 350 monitoring sites spread throughout the Netherlands (Van Duijvenbooden, 1987). The main criteria for site selection were type of soil, land use and hydrogeological conditions. At each location, groundwater is sampled at depths of 5-15 metres and 15-30 metres below ground. Table 2.4 shows the number of wells sampled for this study, broken down by soil type, land use and sampling depth.

Table 2.5a: Number of wells for which complete[1] data series are available for the period 1984-2014, broken down by soil type, land use and sampling depth

Land use	Depth (m)	Sand	Clay	Peat	Other
Agriculture	5-15	121	61	32	5
	15-30	120	60	32	4
Nature	5-15	55	4	4	3
	15-30	52	4	4	2
Other	5-15	37	19	2	8
	15-30	37	18	2	12

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

Table 2.5b: Number of wells for which complete[1] data series are available for the period 1984-2014 for farmland and sandy soil, broken down by sand area and sampling depth

Depth (m)	Sand North	Sand Central	Sand South	Outside sand region
5-15	35	33	35	18
15-30	35	33	34	18

[1] Series were complete, or sufficient data were available to make estimates for locations that were 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 reduced for certain combinations of soil types and depths. Shallow monitoring wells in sandy soils are still sampled every year, whereas in other regions (clay and peat), they are sampled every two years. Deep wells are sampled every four years, as are shallow well screens at monitoring sites with a high chloride concentration (above 1000 mg/l due to marine effects). Finally, wells dominated by local conditions are eliminated (for example, wells near rivers and local sources of pollution). As a result, the number of wells sampled each year has been reduced from 756 to about 350. RIVM manages the network and is responsible for both interpreting and reporting the data.

2.4.3 Data processing
LMG sites (observation wells) that are affected by river-bank infiltration are not included in the analysis.

Owing to the design of the LMG, there are locations that are not sampled each year. In order to avoid spurious trends that are a consequence of the network's design, an estimate is made of all missing data by interpolating from the data that is available. For data missing at the beginning and end of a series, the initial and final available values respectively are used to estimate them. Annual average concentrations are calculated by simply averaging the measured concentrations. Period average concentrations are calculated by averaging the period averages per location. The classification into regions and districts is also in line with the LMM (see Section 2.3.2 and Map 2.1). The average of the LMG wells in the Sand Region was determined separately for each of the Sand North, Sand Central and Sand South areas.

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

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

2.5.2 *Data collection*

Since July 2010, drinking water in the Netherlands has been supplied by ten drinking water companies (ILT, 2015). About 55% of the drinking water originates from groundwater (Vewin, 2015). A distinction is drawn between phreatic and artesian groundwater. A phreatic aquifer is not enclosed by a less permeable layer above it and has a free water table. Artesian water is bordered above and below by a less permeable layer. As a result, the pressure head in the aquifer is higher than the upper limit of the aquifer (this is therefore also referred to as confined groundwater). In 2014, there were 145 drinking water production sites utilising groundwater. Of this number, 82 were using phreatic groundwater and 63 artesian groundwater. There are 16 sites where drinking water is produced from riverbank groundwater, dune infiltration water and surface water (see Table 2.6). The average depth of the groundwater from phreatic aquifers utilised for drinking water production is 45 metres; the average depth of the screens is between 30 and 65 metres. Of these sources, 70% are at an average depth exceeding 30 metres, and 30% are at a depth of less than 30 metres.

Concentration is measured per string of wells, with one string consisting of several wells. A monitoring site often comprises multiple strings. For each monitoring site, the minimum, maximum and average values of the strings are determined. Measurements are taken at each site several times a year (between once and four times), but also monthly or weekly.

Table 2.6: Number of drinking water production sites in the Netherlands in the period 1992-2014

Year	Phreatic groundwater	Artesian groundwater	Surface water	Dune infiltration	River bank infiltration
1992	127	86	10	8	13
1993	126	85	11	9	14
1994	125	87	11	8	14
1995	123	86	12	8	15
1996	123	86	12	8	14
1997	121	87	11	7	14
1998	120	86	11	6	13
1999	117	86	11	7	13
2000	117	87	11	5	12
2001	113	82	9	5	12
2002	105	84	7	4	13
2003	108	82	7	4	13
2004	106	81	5	4	13
2005	102	78	3	5	12
2006	102	78	4	4	13
2007	101	78	4	4	12
2008	94	74	4	4	12
2009	98	74	4	4	11
2010	95	74	4	4	9
2011	96	72	9	8	9
2012	94	72	10	7	8
2013	91	72	10	7	8
2014	82	63	5	5	6

2.5.3 Data processing

For processing the data on drinking water, a supplementary database was created to tackle the issue of the changing number of drinking water production sites in the period 1992-2014. This was carried out with a Restricted Maximum Likelihood Procedure, REML (Payne, 2000). The REML model in the R programme was used to calculate an approximate concentration of nitrates per year, the pumping station being a random effect and the sampling year being a fixed effect. The result is an estimated nitrate concentration per annum in which the effect of the existence or absence of a pumping station in that year is modelled. This is a method for dealing with unbalanced data (in this case, data from samples not taken from the same monitoring sites each year).

The drinking water data are used in the section on groundwater for the production facilities that utilise phreatic and artesian groundwater (see Chapter 5, in particular Section 5.4).

For this report, the annual average per drinking water production site was determined based on the average of the strings as the maximum. The annual maximum of a site is the highest maximum value of the strings. Annual averages and maxima for the 1992-2010 period are based on the supplementary database. Each annual average and annual maximum is the average of averages and the average of maxima, respectively, of all drinking water production sites, for a particular year.

The tables and maps showing the status for each period and the trends between periods are derived from the original database. For each drinking water production site an average value was calculated per period, the value being based on between one and three annual averages or maxima. Only the sites monitored in both these periods (2008-2011 and 2012-2014) were used for comparison purposes.

2.6 Monitoring status and trends in surface water quality

2.6.1 General

There are several monitoring networks operating in the Netherlands. In ascending order from small to large waters, these are:

- Minerals Policy Monitoring Programme (LMM) in ditches on farms (see Section 2.3)
- Agriculture-specific Surface Water Monitoring Network (MNLSO) in regional waters
- Monitoring networks for water authorities in regional waters designated as Water Framework Directive (WFD) waters
- Rijkswaterstaat (RWS) monitoring network in national WFD waters
- RWS monitoring network in WFD transitional and coastal waters
- RWS monitoring network in the open sea

The surface water monitoring networks comprise the monitoring networks for regional and large freshwater bodies, as well as those for transitional, coastal and marine waters. The classification of freshwater bodies and transitional and coastal waters is in line with the Water Framework Directive. The measurement data from all WFD monitoring sites in both regional and national waters are used in this report, thus meeting the requirement of the Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs to comply as far as possible with the reporting on water quality under the Water Framework Directive. Rijkswaterstaat and the water authorities are responsible for sampling, analysing and reporting on these Water Framework Directive monitoring sites in national and regional waters respectively. In addition, Rijkswaterstaat is responsible for water quality monitoring in the open sea. Unlike the LMM monitoring sites, the regional WFD monitoring sites typically cover a much wider catchment area than one single farm. These regional WFD monitoring sites are also affected by other anthropogenic nutrient emission sources apart from agriculture, such as discharges from urban areas.

To exclude other human sources as far as possible and to focus on the impact from agriculture, monitoring sites in the MNLSO are also used. This monitoring network was set up in 2010-2012 to monitor water quality with regard to nutrients in agriculture-specific surface water. All water authorities' existing monitoring sites at which agriculture is the sole human source of nutrients were selected for the monitoring network. In addition, the occurrence of minimal seepage and minimal impact on nutrient load from inlet water were taken into account in the selection of these monitoring sites. This monitoring network is managed by the water authorities.
If the waters from the various monitoring networks are compared with each other, the contribution made by agriculture in the nutrient load in

the recipient water drops step by step in relative terms, in the following order: leaching from root zones and ditch water, regional agriculture-specific waters > WFD fresh regional waters > WFD fresh national waters > WFD transitional water > WFD coastal water > open sea. The ever-increasing distance between the site where the agricultural activities take place and the site where the water quality is sampled will also dramatically reduce the causality between the agricultural activity and monitoring of the water quality.

2.6.2 *Data collection*

To meet the desire to better comply with the water quality status description in the Water Framework Directive, it is possible that the data presented in this report may deviate slightly from the data presented in the 2012 report (Baumann *et al.*, 2012). This may occur at the regional WFD and MNLSO monitoring sites in particular. The same WFD monitoring sites were used for this report as in 2011-2014. Where available, monitoring data from 1990 were also used for these sites (Van Duijnhoven *et al.*, 2015). For waters affected by agriculture, all MNLSO monitoring sites were used (Klein and Rozemeijer, 2015). In previous reports, a different selection of regional monitoring sites was used, some of which are the same as the WFD and MNLSO sites.

In principle, nitrate and chlorophyll-a are measured at all sites. In addition, phosphorus (P) and nitrogen (N) are measured in fresh waters, with dissolved inorganic nitrogen concentration (DIN) and salinity being measured in marine waters. Furthermore, phytoplankton (lakes, coastal and transitional waters) and phytobenthos (rivers) are often measured at WFD sites.

Monitoring sites in national waters

Rijkswaterstaat (RWS) collects data from 40 monitoring sites at sea (including the Zeeland estuary) and from around 35 locations in large national fresh waters, such as large rivers, canals and lakes. At sea, the frequency of sampling is once a month in winter and twice a month in summer. Fresh surface waters are generally sampled every four weeks.

The RWS Water, Traffic and Environment department is responsible for the collection and presentation of marine water data and fresh surface water data.

Regional monitoring networks

The 22 water authorities have their own regional monitoring networks, comprising several thousands of monitoring sites in regional fresh water bodies. The frequency of sampling varies but is usually once every four weeks. Not all of these monitoring sites are used in this report: it only covers WFD and MNLSO monitoring sites.

Just under 700 regional WFD monitoring sites are involved, giving a good picture of the water quality in the regional WFD water bodies. This number has doubled since 1990. The number of MNLSO monitoring sites grew from 60 to around 170 in the period 1990-2014. Agriculture is the sole source of nutrients in these locations. This monitoring network gives a good picture of the status of the water quality in relation to the nutrient concentrations in agriculture-specific waters. About half of these

MNLSO monitoring sites currently have a measurement series of more than 10 years, making it possible to identify trends in nutrient concentrations. The same applies to the regional WFD monitoring sites, and a trend can be determined in 90% of monitoring sites in national WFD waters.

2.6.3 *Data processing*

Calculation of averages and trends

Annual averages are calculated only at those sites with at least 10 observations per year. Winter and summer averages and maxima are based on sites for which at least five measurements in the season concerned are available. The winter and summer averages and maxima for all sites are the averages of the winter and summer averages and the winter maxima of all monitoring sites in surface waters respectively, which comply with the minimum number of set measurements.

The only sites used to determine trends are those with at least 10 years of measurements available, of which five must be post-2004, and with at least 10 measurements per year. If the measurement series is longer than 10 years, years with less than 10 measurements per year are also included.

For the trend monitoring sites in the WFD monitoring network and the MNLSO, a LOWESS trend line is calculated (Van Duijnhoven *et al.*, 2015; Klein and Rozemeijer, 2015). A LOWESS trend line can be used to detect whether a trend becomes steeper or levels off over the course of time. These LOWESS trend lines for each monitoring site have been aggregated into a new LOWESS trend line and a 25th- and 75th percentile LOWESS trend line have also been calculated. The 25th percentile LOWESS shows the trends for the lower concentration range and the 75th percentile LOWESS shows those for the higher concentration range. Together, the 25th and 75th percentile LOWESS show the bandwidth within which 50% of the sites are situated in terms of concentration levels.

Definition of summer and winter

The six summer months, from April to September, are the most critical period with respect to eutrophication. The EU water quality standard of 50 mg/l for nitrates (EU standard) is primarily aimed at assessing the effects of agriculture on water quality. In this context, the winter months, when leaching plays a significant role, are of particular importance. The winter period as regards fresh surface waters lasts from October to March inclusive.

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

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

In the present analysis of trends in nutrient concentration, no salinity correction has been made. Consequently, the conclusions that are based on trends in nutrient concentration are affected by year-to-year differences in river outflows (because of differences in precipitation, etc.). For a number of monitoring sites in Dutch coastal waters, additional figures are provided on inorganic nitrogen concentrations for which a correction has been made for salinity. Dissolved inorganic nitrogen (DIN) is the sum of nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N) and ammonium nitrogen (NH_4-N), with DIN standardised to a salinity of 30 psu (practical salinity units). The water in the Dutch part of the North Sea contains on average about 3.5% sodium chloride (NaCl), the equivalent of 35 psu. This presentation of data is in accordance with the OSPAR Procedure, and shows the long-term trend in inorganic nitrogen concentrations corrected for the effects of precipitation.

Characterisation of eutrophication
Previous article 10 reports only reported the status and trends in the eutrophication indicators, such as the summer average for chlorophyll-a, phosphorus (P) and nitrogen (N). In the previous report (Baumann *et al.*, 2012), eutrophication was characterised using a simple existing method developed by the OECD. This OECD method lacks differentiation when it comes to shallow lowland waters such as those in the Netherlands and is therefore unsuitable, because the Netherlands only has very shallow lowland water systems, and the water is furthermore calcareous, so natural background concentrations are relatively high by comparison with the OECD assessment. The OECD assessment does not take this sufficiently into account. Furthermore, with the European intercalibration of biological quality elements for the Water Framework Directive, an overall European picture has emerged for major eutrophication-sensitive parameters such as phytoplankton (chlorophyll-a and algal blooms) and phytobenthos. The intercalibrated assessments are also water type specific and take natural background values into account.

In addition to the eutrophication indicators of chlorophyll-a, phosphorus and nitrogen, this report specifically includes a characterisation of eutrophication which complies with EU requirements on the assessment and classification of eutrophication (Reporting Guidelines, Section 5.3.2 Eutrophication in freshwater and marine water: EC/DGXI, 2011); where applicable, these comply with the EU Commission Decision on intercalibration (2013/480/EU). The yardsticks for natural waters have been adjusted to reflect the applicable quality elements in accordance with this decision.

To obtain a picture of the degree of eutrophication of the waters, only the data and information from all Water Framework Directive waters in the fresh, coastal and transitional waters were used. Information from various biological quality elements is used to assess eutrophication: phytoplankton (lakes, coastal and transitional waters), phytobenthos (rivers), and, if not present, the element of other aquatic flora (rivers), total N (rivers and lakes), dissolved inorganic N (coastal and transitional waters), and total P (rivers and lakes). The water body assessments were supplied by water managers to Informatiehuis Water for the report on the 2015-2021 WFD River Basin Management Plans. These data generally relate to the period 2011-2014.

The Water Framework Directive does not assess eutrophication as a parameter or a quality element. Instead, it assumes a slight deviation in the status of waters not affected by human activity. Eutrophication is one of the effects.

The amount of nitrogen and phosphorus in the water is a significant cause of high water nutrient levels. Phytoplankton and phytobenthos are parameters the quality of which is vulnerable to high nutrient levels in the water. In natural conditions, water type specific exceedances of these parameters indicate eutrophication. The Netherlands has developed assessment systems for these parameters. Where there is no data on phytobenthos, the general “other flora” quality element provides the best possible estimate of the eutrophication status. The assessment systems are available in *Referenties en maatlatten voor natuurlijke watertypen 2015-2021* (Van der Molen *et al.*, 2012).

For many artificial and heavily modified water bodies, comparable assessment systems have been developed based on the yardsticks for natural waters which take the heavily modified properties of the water into account. However, the standards for eutrophication-sensitive parameters barely differ at all. There may be a larger deviation in certain cases, for example if the higher nutrient concentrations are the consequence of the heavily modified properties of the water body. One example of this is low polders with old marine sediments or peat soils: because the water level is kept unnaturally low (heavily modified property), for example to allow for agriculture, nutrient concentrations are much higher. A different standard for nutrients will apply in these specific waters. All differing standards and assessments are available for each water body and are explained and justified. They are available in the fact sheets which form part of the 2016-2021 Water Framework Directive water and River Basin Management Plans (Informatiehuis Water, 2016).

For the purpose of the Water Framework Directive, the European Commission has defined and adopted internationally harmonised classification boundaries for both phytoplankton and phytobenthos in its intercalibration decision: “high”, “good”, “moderate”, “poor” and “bad”. The Member States are responsible for drawing up their own standards for nutrients on this basis. The definition of “eutrophic” or “potentially eutrophic” water is used to show that waters do not meet the criteria of “good” to “high” for the above-mentioned parameters. Waters in which the biological quality elements (including phytoplankton and phytobenthos) score less than “good” are “eutrophic", regardless of the score for N or P. Waters in which the biological quality elements are rated as “good” and N and P both score less than “good” are potentially eutrophic. Waters in which both the biology and one of the nutrients score “good” are “non-eutrophic”.

The results are reported for each water body.

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3 Agricultural practice

3.1 Introduction

This chapter deals with the development of agricultural practice in the Netherlands in general, and with use of nitrogen and phosphorus in Dutch agriculture in particular, for the period 1992-2014. The main topics discussed are the changes in areas such as land use, number of farms and livestock resulting from policy measures as well as from autonomous developments (Section 3.2). The nitrogen and phosphorus balances of agriculture are discussed in Section 3.3, followed by a description of the other developments in agricultural practice in Section 3.4. Section 3.5 contains an overview of the results of projects that looked at the cost effectiveness of measures designed to reduce nitrogen leaching and improve water quality. With respect to the tables, the sum of the items in a table column or row is sometimes higher of lower than the total given in the table because of rounding off.

To begin with, a summary is given of the Dutch policy measures taken in the framework of fertiliser policy since 1997, with the focus on the four Action Programmes carried out since 1995 (1995-1999, 1999-2003, 2004-2009, 2010-2013) and the current Fifth Action Programme (2014-2017). In this context, three periods can be distinguished that do not exactly coincide with the Action Programme periods: 1987-1997, 1998-2005 and 2006-2017.

Policy measures 1987-1997

Legislation regulating the use of fertilisers was adopted in the Netherlands before the implementation of the Nitrates Directive in 1991. From 1987 onwards, measures were taken by way of fertiliser legislation to limit the use of livestock manure. For this purpose, application standards for phosphate (P_2O_5) were drawn up that set a maximum level for the use of livestock manure. These application standards have been tightened almost every year since 1990 (see Table 3.1). In this way, the maximum quantity of nitrogen deposited on the land via livestock manure was also further limited.

Table 3.1: Livestock manure application standards in the period 1987-2000 in kg phosphate (P_2O_5) per ha

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

Source: LNV (2001b, 1997, 1993b)

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

- Maximum quantities for minerals that were allowed to be applied with livestock manure (application standards, Table 3.1)
- Designated time of the year when the application of manure was prohibited because of the risk of nitrogen leaching (Table 3.2) and as prescribed in Annex III (1) (1) of the Nitrates Directive
- Prescribed method for applying manure to reduce ammonia emissions (low-emission application)
- Covering of manure storage facilities to reduce ammonia emissions

Table 3.2: Period in which spreading of slurry (liquid manure) is permitted[1]

Soil type	Sand and Loess		Clay and Peat	
Years	Grassland	Arable land	Grassland	Arable land
1988-1990	1/1 – 30/9	1/11 - harvest	whole year	whole year
1991-1994	1/1 – 31/8	1/1 – 31/8	1/1 – 30/9	-
1995-1997	1/2 – 31/8	1/2 – 31/8	1/2 – 31/8	-
1998-2004	- [2]	-	1/2 – 15/9	-
2005	-	-	-	1/2 – 30/11
2006-2009	-	-	-	1/2 – 15/11
2010-2011	-	-	-	1/2 – 15/9
2012-2017	15/2 – 31/8	1/2 – 31/7 [3]	15/2 – 31/8	1/2 – 31/7 [3]

[1] Different periods sometimes apply to farmyard (solid) manure.
[2] "-" means no change compared with previous years.
[3] Slurry may be used on all types of soil until 1 September if green manure is grown by no later than 31 August of the same year or bulbs are planted in the autumn.

Source: RVO (2014c, 2009a, 2009b), LNV (2005b, 1996)

Policy measures 1998-2005

In 1998, the Dutch government introduced MINAS, the farm-level system for mineral accounting, based on the mineral balances of nitrogen (N) and phosphate (P_2O_5) (farm gate balance) for livestock farms. Arable farms were permitted to work with legal fixed nutrient contents in exported crops, so there was a *de facto* application standard in place for those farms. Under this system, limits were set for the permitted levels of nitrogen and phosphate surpluses on farms (MINAS loss standards). MINAS did not regulate artificial fertiliser and fixation separately, but performed accounting for the overall flow of minerals (including feed, livestock, animal products, etc.). Farmers could therefore switch between the various components, provided they kept to the loss standards. In this way, the system regulated the nitrogen and phosphate surplus of farms (farm gate balance). A certain nitrogen and phosphate surplus was considered acceptable and was free of levy. The loss standards for nitrogen were tightened in the period 1998-2005 (Table 3.3). If a farmer had a surplus exceeding the loss standard, he had to pay a levy, with the levies increasing progressively between 1998 and 2003. The MINAS system was implemented in stages. On its introduction in 1998, it initially applied to livestock farms with a high animal density (above 2.5 LU/ha). In 2001, MINAS was extended to all farms. In that year lower loss standards were set for arable land on sand and loess soils, which are more vulnerable to nitrogen leaching than clay and peat soils (Map 3.1).

Table 3.3: Nitrogen loss standard for 1998-2005, in kg N/ha for arable land and grassland on clay, peat, sand and loess soils[1]

	Grassland		Arable land	
Year	All types	Sand/Loess	All types	Sand/Loess
1998-1999	300	300	175	175
2000	275	275	150	150
2001	250	250	150	125
2002-2003	220	190	150	110/100[1]
2004	180	180/160[1]	135	100/80[1]
2005	180	180/140[1]	125	100/80[1]

[1] Lowest standard applies to sand and loess soils vulnerable to nitrate leaching (Map 3.2).

Source: LNV (2004a, 2001b, 1997)

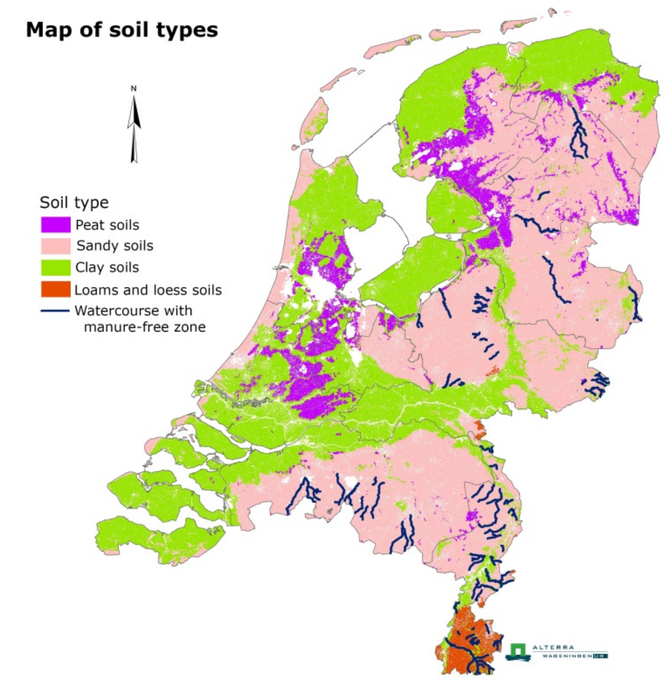
The MINAS system also included the regulation of inorganic-fertiliser nitrogen and nitrogen fixation by legumes (arable land only). In 2002, special lower nitrogen loss standards were introduced for farms with soils prone to nitrate leaching. Overall, 140,000 ha of land were designated as having soil prone to nitrate leaching (see Map 3.2).

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

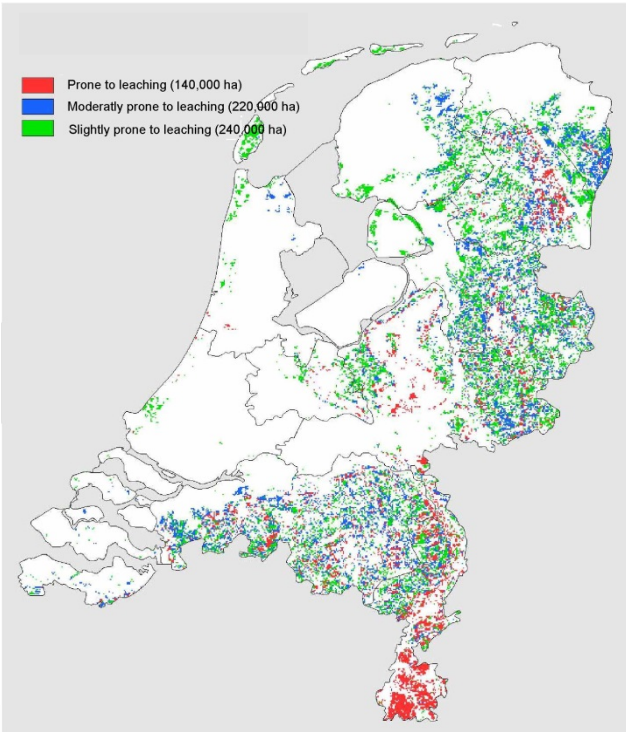
Policy measures 2006-2017

In January 2006, the Netherlands adopted a fertiliser policy based on application standards instead of loss standards (LNV, 2005b). Compared with MINAS, the new fertiliser policy imposes more restrictions on the use of nitrogen and phosphate. The Dutch fertiliser policy in force since 2006 applies to all manure from animals kept for professional purposes or for profit. This policy has a wider scope of application than the pre-2006 policy; for example, horse manure is also subject to the new legislation. For grassland, the transition from MINAS to the new system initially meant that more artificial fertiliser could be used. There are also new and additional regulations governing the application methods for livestock manure and artificial fertiliser:

- The further restriction of the period in which the application of manure is permitted.
- The introduction of a mandatory minimum storage capacity for livestock manure, as prescribed in Annex III (point 1(2)) of the Nitrates Directive.
- The obligation to follow ploughing up grassland with growing a crop with a high nitrogen requirement which is fertilised based on a soil analysis. Ploughing up of grassland on sandy and loess soils is only permitted in spring (1 February - 10 May). Both of these obligations arise from the derogation decision of the European Commission (EU, 2005) and relate to Annex II (B) (7) and (8) and Annex III (1) (3.ii) of the Nitrates Directive.
- The obligation to grow a catch crop after the cultivation of maize on sandy and loess soil to limit nitrogen leaching. This obligation also arises from the derogation decision of the European Commission (EU, 2005) and relates to Annex II (B) (8) of the Nitrates Directive.



Map 3.1: Map of soil types in the Netherlands and natural watercourses in High Netherlands on which a crop-free buffer zone or a no-fertiliser, no-spray grass buffer zone of 5 metres must be allowed
Source: Alterra (2006)



Map 3.2: Map of areas with soil prone (red), moderately prone (blue) or slightly prone (green) to nitrate leaching
Source: LNV (2001a)

To supplement its policy, the Netherlands provides an assurance for the European Commission in the Third Action Programme (2004-2009) that nitrogen and phosphate levels in national livestock manure production will not exceed 2002 levels (in accordance with the obligation in the derogation decision; EU, 2005). Specifically, the excretion of nutrients must not exceed 173 million kg phosphate and 504 million kg nitrogen (including losses in the form of gas). The reason referred to in the Action Programme is that a system of application standards can only operate properly if manure production and manure deposit capacity are in balance. The latter being the total amount of livestock manure that can be applied to the agricultural land given the application standards for nitrogen or phosphorus. The limiting of manure production is regarded as an Article 5 (5) measure (the Nitrates Directive requires Member States to take additional measures as soon as necessary).

The period in which manure may be spread has been reduced by between 1 and 4 months, from 7-7½ to 6½-7 months for grassland and from 7-10 to 6 months for arable land (Table 3.2). From winter 2005-2006 onwards, any farm producing livestock manure was required to have at least six months' storage capacity. As of 2012, when the spreading period was also reduced, the mandatory minimum storage capacity was increased by one month to at least seven months. Farms that can demonstrate that any manure produced in excess of their actual storage capacity will be removed from the farm or used in an environmentally-friendly way are excluded from this rule (LNV, 2005c). This could promote storage at the place of use (arable areas) and has a number of potential benefits:

- Transportation is spread more evenly over the year.
- The arable farmer has the manure close to the field if he wants to apply it.
- The farmer has more time, and therefore more opportunities, to put together a mixture of livestock manures that suits his requirements.

Since 2006 the fertiliser policy has also included application standards for nitrogen in livestock manure, as set out in the Nitrates Directive (EU, 1991) and the derogation decisions (EU, 2014, 2010, 2005), and for artificial fertiliser as required for inclusion in the Action Programme in accordance with Annex III (1) (3) of the Nitrates Directive. The current system of application standards does not distinguish between sandy soils in terms of vulnerability to nitrate leaching on the basis of Map 3.2, owing to the complexity of implementation and enforcement. To compensate for this non-designation, it was agreed with the Commission in negotiations on the third Action Programme that the nitrogen application standards for the whole sand and loess area would be tightened to a limited extent. The application standards are established on the basis of a weighted average, assuming 25% of soils prone to leaching (LVN, 2004b). Application standards for phosphate were also introduced in 2006.

The policy provides for different limits on the use of nitrogen from livestock manure, on the use of total nitrogen, and on the use of total phosphate. The application standard for nitrogen from livestock manure is 170 kg N per ha. Farms with grazing animals can use an exemption rule (derogation) if they meet certain conditions with regard to manure from grazing livestock. The derogation does not apply to manure from other animals on these farms. These conditions were tightened up in 2014 and the maximum application standards for livestock manure now depend on the location of the farm and the soil types occurring on it (Table 3.4) (EZ, 2014). Farms with at least the prescribed percentage of grassland may adhere to a standard of 230 or 250 kg N per ha, provided they follow a fertilising plan according to set rules. The phosphate status of the soil must also be determined at least once every four years. Since 2014, farms that make use of the derogation may no longer apply phosphate-containing fertilisers.

Table 3.4: Nitrogen application standard for livestock manure in kg nitrogen (N) per hectare for farms registered for derogation and the required minimum percentage of grassland in the period 2006-2017 for arable and grassland in the various areas in the Netherlands[1]

Period	Area	Arable land N standard	Grassland N standard	Grassland % grassland
2006-2013	All areas	170	250	70
2014-2017	CS, SS, LO[1]	170	230	80
	Other	170	250	80

[1] This concerns sandy and loess soils in the CS (Central Sand Area; provinces of Utrecht, Overijssel and Gelderland), SS (South Sand Area; provinces of Noord Brabant and Limburg) and LO (Loess Region).
Source: EZ (2014)

Various application standards apply to the use of total plant-available nitrogen depending on the crop and soil type, and these also vary over time: after 2006, these nitrogen application standards were tightened on occasions (see examples in Table 3.5 for grassland and Table 3.6 for arable land). The complete table spans several pages, so the reader is referred to the Netherlands Enterprise Agency website for full details (RVO, 2015a, 2015b and 2011a). The crop availability of nitrogen in organic fertilisers is laid down in law by means of the N availability coefficient (NAC), which varies from 10% to 80% of the availability of inorganic nitrogen fertiliser (NAC = 100%). For farmyard manure and farm slurries, the values are between 30% and 60% and between 45% and 80% respectively (RVO, 2011b). In 2014, the NAC for pig slurry on sand increased from 70% to 80% (EZ, 2014; RVO, 2014b), meaning that where pig slurry is used on sandy soils, the amount of nitrogen that can be given together with other fertilisers was reduced in 2014 in order to ensure compliance with the nitrogen application standard.

Table 3.5: Nitrogen application standard in kg plant-available nitrogen (N) per ha for grassland in the period 2006-2017, with grazing and without grazing[1]

	With grazing		Without grazing	
Soil type	2006	2014-2017	2006	2014-2017
Sand/Loess	300	250	355	320
Clay	345	345	385	385
Peat	290	265	330	300

[1] "Without grazing" means that the grassland may only be grazed by young cattle under two years old or only mowed.
Source: PBL (2016), LNV (2007), RVO (2015a, 2015b)

There are various application standards for phosphate on grassland and arable land, the application standards for phosphate being dependent on the phosphate status of the soil since 2010 (Table 3.7). The application standards are expressed in kg phosphate (P_2O_5) per hectare. In the period 2010-2014 the application standards were tightened, especially for arable land with a phosphate status of neutral and high (Table 3.7). In 2015 all application standards were further reduced by 5 kg, with the exception of grassland with low phosphate status.

Table 3.6: Nitrogen application standard in kg plant-available nitrogen (N) per ha in the period 2006-2017 for the main arable crops[1]

Soil type	Clay		Sand and Loess	
Crop	2006	2014-2017	2006	2014/2017[4]
Table potatoes[2]	250-300	225-275	240-290	210-260[3]
Starch potatoes	265	240	240	230
Winter wheat	245	245	190	160[3]
Sugar beet	165	150	150	145
Maize (derogation)	160	160	155	140
Maize (other)	205	185	185	140

[1] This represents more than 80% of the area of cultivated land in 2014.
[2] The level of the standard depends on the variety's nitrogen requirements; lower standards apply to early potatoes.
[3] In loess soil, the standard is 5 kg lower for table potatoes and 30 kg higher for winter wheat.
[4] Since the beginning of 2015, the 2014 standard has been reduced by 20% in the South Sand Area and the Loess Region.
Source: PBL (2016), LNV (2007), RVO (2015a, 2015b)

Table 3.7: Phosphate application standard in kg phosphate (P_2O_5) per ha in the period 2006-2017 for grassland and arable land according to the phosphate status of the soil[1]

Crop	Status	2006	2009	2010	2011	2012	2013	2014	2015/2017
Grassland	Low	110	100	100	100	100	100	100	100
	Neutral	110	100	95	95	95	95	95	90
	High	110	100	90	90	85	85	85	80
Arable land	Low	95	85	85	85	85	85	80	75
	Neutral	95	85	80	75	70	65	65	60
	High	95	85	75	70	65	55	55	50

[1] The phosphate status of grassland is expressed in the PAL value, and for arable land in the Pw value.
Source: RVO (2014a, 2009c), LNV (2009, 2006)

3.2 Developments in agriculture

3.2.1 Land use

The Action Programmes apply to the whole of the Netherlands. Land use is therefore reported at the national level (see Table 3.8). The Netherlands has a total land surface area of 3.37 million ha, of which 1.84 million ha (55%) is cultivated (CBS StatLine, 2016). The area of cultivated land is gradually decreasing. The declining trend in cultivated land goes hand-in-hand with an increase in other land use (including the expansion of urban areas and road building). The total grassland area, and in particular permanent grassland, continues to decline. The area of temporary grassland has been fluctuating at around 200,000 ha since 2003. The area under other arable crops has also shown a downward trend over the past 10 years. The area under permanent crops (fruit trees) has stabilised at around 20,000 ha.

Table 3.8: Land use in the Netherlands (x 1,000 ha)

	1992-1995	2008-2011	2012-2015*
Grassland	1068	1005	993
Permanent	1032	821	775
Temporary[1]	36	184	217
Silage maize	223	236	228
Other arable crops	598	547	518
Horticulture[2]	65	79	78
Permanent crops	24	20	19
Fallow land	11	7	8
Total cultivated area	1989	1994	1843
Nature and forest areas[3]	452	486	490
Other land use[3]	948	990	1034
Total land surface area[3]	3388	3370	3368

[1] Grassland less than five years in use by a farm
[2] Tree nurseries are classified under horticulture and not under permanent crops. Horticulture does not include field-grown vegetables such as leeks, chicory root, broad beans and French beans).
[3] Data available for only 1993, 2008, 2010 and, provisionally, 2012
* Reporting year 2015 is provisional. Previous years are definitive.
Source: CBS StatLine, 2016

3.2.2 *Number of farms*

The total number of farms shrank by 43% during the period 1992-2015, from 117,100 to 66,400 farms (Table 3.9). The extent of the decrease depends on the type of farm (arable farms -23%, dairy farms -44%, horticultural farms -58%, and factory farms -61%). Because the number of farms is declining much more rapidly than the area of cultivated land (-43% compared with -7%), the size of the average farm has increased over the past 20 years from 17.0 to 27.7 ha.

Table 3.9: Number of farms broken down by main farm type (x 1000)

	1992-1995[2]	2008-2011	2012-2015*
Arable farms	15.8	11.9	12.1
Horticultural farms[1]	20.5	10.6	8.7
Permanent crop farms	3.0	1.8	1.7
Farms with grazing animals	54.0	37.9	35.4
of which dairy farms	30.0	17.6	16.8
Factory farms	13.7	6.6	5.3
Combination farms	10.1	4.0	3.2
All farm types	117.1	72.7	66.4

[1] Tree nurseries are classified under horticulture and not under permanent crops.
[2] The figures for 1992-1995 have been adjusted to reflect the farm classification used for 2008-2011 and 2012-2015*.
* Reporting year 2015 is provisional. Previous years are definitive.
Source: CBS StatLine, 2016

At present, 2.1% of all farms are organic. At the turn of the century the figure was 1%. The proportion of organic land out of the total area of cultivated land is currently 2.7% (49,000 ha). The size of the average organic farm is currently 34 ha.

The largest increase in the number of organic farms was in the 1990s (see Figure 3.1). Since 2001, the number of organic farms has stabilised at between 1200 and 1500. Enthusiasm for organic farming waned between 2003 and 2007, although it increased again with the introduction of new support measures in 2007, which once again made it worthwhile for small and very small farms to register as organic farms with Skal, the certification body. The associated downturn and subsequent upturn is most clearly evident in organic horticultural farms in the period 2000-2010.

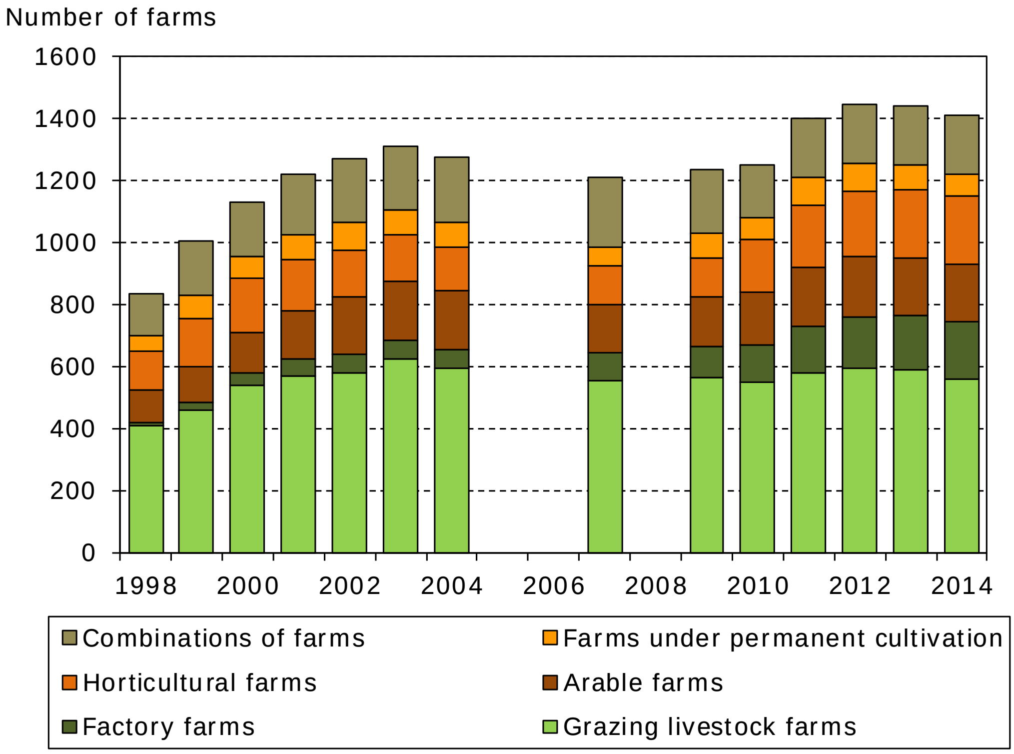


Figure 3.1: Number of organic farms in the Netherlands (including farms in the process of switching)
Source: Indicator Biologische landbouw (Environmental Data Compendium); observation: via a separate Statistics Netherlands survey in 1998-2004, and via an additional questionnaire in the Agriculture Census in 2007 and from 2009 onwards

3.2.3 *Livestock population*

Between 1992 and 2015, the number of cattle and pigs fell by 16% and 15% respectively. By contrast, poultry numbers rose by 7% (Table 3.10). In addition to the increase in the number of chickens, a striking development is the recent increase in the number of cattle. This is primarily the result of the almost 10% increase in the milk quota between 2007 and 2013, including an adjustment in the fat correction (see Section 2.2 in LEI, 2014).

Table 3.10: Number of farm animals (in millions)

	1992-1995	2008-2011	2012-2015*
Cattle	4.8	3.9	4.0
Pigs	14.5	12.2	12.3
Poultry	94.2	97.9	100.7
Sheep and goats	1.9	1.5	1.4

* Reporting year 2015 is provisional. Previous years are definitive.
Source: CBS StatLine, 2016

3.2.4 *Nitrogen and phosphorus excreted in livestock manure*

In the period 1992-2014, the annual nitrogen excreted per animal decreased across all animal species (see Table 3.11). The situation in respect of phosphorus excretions is similar (see Table 3.12). This is mainly due to a combination of lower nitrogen and phosphorus content in fodder and improved fodder conversion efficiency. The feed track project that started in 2011 aims to reduce phosphorus excretions from pig and cattle farms by improving the use of phosphorus in animal feed.

Nitrogen excretions per animal are declining in both pigs and cattle. The feed track had a positive impact in cattle in 2012, but the nitrogen and phosphorus content of compound feed rose again in subsequent years, primarily due to the greater demand for protein-rich compound feeds on account of the poor quality of roughage in 2013. In addition, expensive soya was replaced by phosphorus-rich rapeseed. Finally, the favourable milk price enabled farmers to opt for more expensive protein-rich feed. The downward trend in broiler chickens over the past few years was brought about by an increase in simple wheat in the ration.

From 2012 to 2015, the total annual quantity of nitrogen excreted by livestock amounted to 480 million kg, representing a reduction of around 31% compared with the amount excreted in 1992-1995 (see Table 3.13). The annual excretion of phosphorus, expressed as phosphate (P_2O_5), was 169 million kg in 2012-2015, 27% lower than in 1992-1995 (see Table 3.14). Two factors play a role here: the continuing decline in annual nitrogen and phosphorus excretions in all animal species (see Tables 3.11 and 3.12) and the smaller cattle and pig populations (see Table 3.10).

Table 3.11 Nitrogen excretion per animal per year (kg N per animal per year)[1]

	1992-1995	2008-2011	2012-2014
Dairy cows	155.0	129.8	124.7
Young female livestock (1-2 years)	95.6	73.1	71.2
Young female livestock (0-1 years)	43.7	35.9	34.8
Meat-type pigs	14.6	12.6	12.1
Sows (with piglets)	31.3	30.4	29.9
broiler chickens	0.62	0.52	0.47
Laying hens	0.85	0.78	0.76

[1] Figures exclude gaseous losses.
Source: CBS StatLine, 2016

Table 3.12: Phosphorus excretion per animal per year (kg P per animal per year)[1]

	1992-1995	2008-2011	2012-2014
Dairy cows	19.1	18.2	17.2
Young female livestock (1-2 years)	10.1	9.7	9.8
Young female livestock (0-1 years)	4.5	4.3	4.1
Meat-type pigs	2.5	2.2	1.8
Sows (with piglets)	7.5	6.5	6.1
broiler chickens	0.10	0.08	0.07
Laying hens	0.21	0.17	0.17

[1] Conversion from phosphorus (P) to phosphate (P_2O_5) with factor 142/62 = 2.29
Source: CBS StatLine, 2016

The downward trend levelled off around 10 years ago. Since the abolition of the MINAS mineral accounting system in 2005 and the introduction of the system of application standards, annual nitrogen excretions have been between 460 and 500 million kg. In the same period, annual phosphate excretions have been between 160 and 179 million kg P_2O_5. The lowest excretion in the past 10 years, for both nitrogen and phosphate, was in 2012. Both nitrogen and phosphate excretions rose in subsequent years. In 2015 the phosphate ceiling of 172.9 million kg P_2O_5 was once again exceeded. The phosphate ceiling is an agreement between the Netherlands and the European Commission entered into in 2005 with the aim of avoiding intensification as a result of applying the requested derogation (EU, 2005). Over the past ten years, this was also the case between 2008 and 2010.

Nitrogen and phosphate excretions increased on dairy farms after 2012 as a result of the expansion of the dairy herd and higher N and P levels in concentrate in anticipation of the abolition of the milk quota on 1 April 2015.

Table 3.13: Nitrogen excretions by Dutch livestock (kg N millions per annum)

	1992-1995	2008-2011	2012-2015*
Cattle excl. veal calves	437	279	280
Veal calves	8	15	18
Pigs	153	107	102
Poultry	70	63	60
Horses and ponies	5	7	6
Other	24	14	14
All livestock[1]	698	486	480

[1] The 2012-2014 figure for the entire livestock population is the equivalent of 474 million kg nitrogen.
* Reporting year 2015 is provisional. Previous years are definitive.
Source: CBS StatLine, 2016

Table 3.14: Phosphorus excretions by Dutch livestock (kg P millions per annum)

	1992-1995	2008-2011	2012-2015*
Cattle excl. veal calves	52	38	38
Veal calves	1	2	3
Pigs	29	20	17
Poultry	15	12	12
Horses and ponies	1	1	1
Other	3	2	3
All livestock[1]			
As phosphorus (P)	100	76	74
As phosphate (P_2O_5)[2]	230	175	169

[1] The 2012-2014 figure for all livestock is the equivalent of 72 million kg phosphorus.

[2] Conversion from phosphorus to phosphate with factor 142/62 = 2.29

* Reporting year 2015 is provisional. Previous years are definitive.

Source: CBS StatLine, 2016

3.3 Nutrient balances

3.3.1 Nitrogen balance of agriculture

Annual inputs of nitrogen in Dutch agriculture amount to 639 million kg, in the form of concentrate, artificial fertiliser and other products, and via atmospheric deposition (Figure 3.2: average of annual figures from 2012 to 2014). Outputs of nitrogen via animal and plant-based agricultural production and disposal of manure outside agriculture amount to 367 million kg. The difference of 272 million kg partly disappears into the ground (185 million kg) and partly into the air (87 million kg).

There are two input flows in livestock farming: (1) the use of roughage and (2) the use of concentrate. These input flows are in balance with three output flows: (1) fixing in animal products, (2) volatilisation (NH_3 + other N) from animal housing, storage and grazing, and (3) excretions from livestock minus volatilisation.

Cultivated land has five input flows: (1) livestock manure, excluding manure disposed of to destinations outside Dutch agriculture, (2) artificial fertiliser, (3) atmospheric deposition outside agriculture, (4) atmospheric deposition from within the agricultural sector and (5) other inputs consisting of, for example, biological nitrogen fixing, compost, and seed and propagating material. These input flows are in balance with three output flows: (1) plant products, (2) volatilisation (NH_3) from fertiliser application, and (3) losses into the soil.

The first item, plant products, can be subdivided into three output flows: (1) disposal of plant products, excluding roughage, (2) harvesting of roughage, and (3) conservation losses into the air, supplemented with N losses from ripening crops and crop residues.

Harvested roughage minus roughage used equals the increase in roughage stocks. The precise magnitude of roughage stocks is also influenced by the international trade in roughage, however, but this falls outside the scope of this diagram.

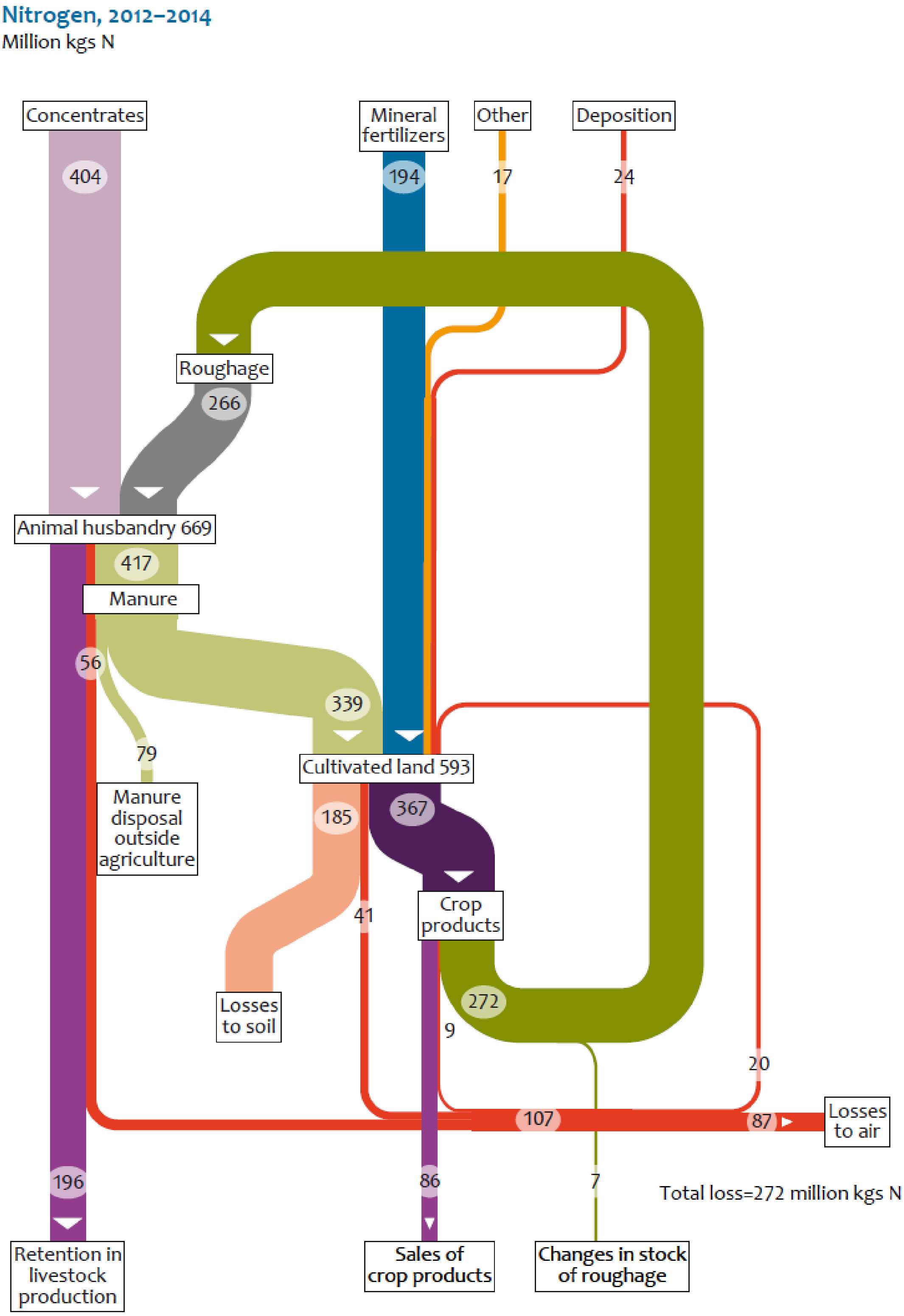


Figure 3.2: Diagram of nitrogen flows within Dutch agriculture in the period 2012-2014
Source: Statistics Netherlands

3.3.2 *Nitrogen and phosphorus soil surface balances*

The loss of nutrients into the soil is declining. Nitrogen losses have dropped from 408 million to 185 million kg (Table 3.15). Phosphorus losses have dropped from 65 million to 5 million kg (Table 3.16). Phosphorus losses into the soil have almost reached the zero mark.

The largest inputs in the soil surface balance are livestock manure and artificial fertiliser. In 1992-2014, nitrogen input from livestock manure decreased by 33% and phosphorus input by 42%. The reduction in input from artificial fertiliser was 47% for nitrogen and 86% for phosphorus. In 1992-2014, output to crops fell by 26% for nitrogen and 9% for phosphorus.

The surplus for both phosphorus and nitrogen from Dutch agriculture has been declining since 1986 (Figure 3.3). The phosphorus surplus is the same as the losses into the soil. The figure for nitrogen includes losses into the air ("Total loss" in Figure 3.2). Excluding volatilisation from animal housing, storage and grazing has virtually no impact on the declining trend. Phosphorus losses are approaching zero.

Table 3.15: Nitrogen balance of cultivated land

	1992-1995	2008-2011	2012-2014
Input[1] via:	*in kg N millions per annum*		
Livestock manure	453	314	301
Artificial fertilisers	361	204	190
Other[2]	19	17	17
Atmospheric deposition	70	48	43
Total input	903	583	551
Total output[3] (crops)	495	371	366
Losses into the soil	408	212	185
	Losses and surplus in kg N per ha		
Losses into the soil	205	112	100
Losses into the air	98	49	47
Surplus	303	161	148

[1] Excluding ammonia emissions from fertiliser application (in 2012-2014: 31 million kg N from livestock manure and 11 million kg N from artificial fertiliser). Also excluding N volatilisation from animal housing, storage and grazing (in 2012-2014: 56 million kg N) and excluding manure disposed of to destinations outside Dutch agriculture (in 2012-2014: 79 million kg N). Artificial fertiliser contains discharge water from air washers (in 2012-2014: 7 million kg N).

[2] Also includes other products such as organic nitrogen fixation, compost, and seed and propagating materials.

[3] Also includes N volatilisation as a result of conservation losses from grass silage, silage maize and hay and from maturing crops and crop residues.

Source: CBS StatLine, 2016

Table 3.16: Phosphorus balance of cultivated land

	1992-1995	2008-2011	2012-2014
Input via:	*in kg P millions per annum*		
Livestock manure	93	61	55
Artificial fertilisers	29	89	4
Atmospheric deposition	-	-	-
Other[1]	5	3	3
Total input	127	73	62
Total output (crops)	63	56	57
Losses into the soil	65	16	5
	Losses in kg P per ha		
Losses into the soil	32	9	3

[1] Also includes items such as compost and seed and propagating material.
Source: CBS StatLine, 2016

Year-on-year fluctuations in surpluses from 1986 onwards relate to the differences in harvests caused by fluctuating weather conditions. These fluctuations are not visible up to 1986 as the surplus was not yet calculated annually at the time.

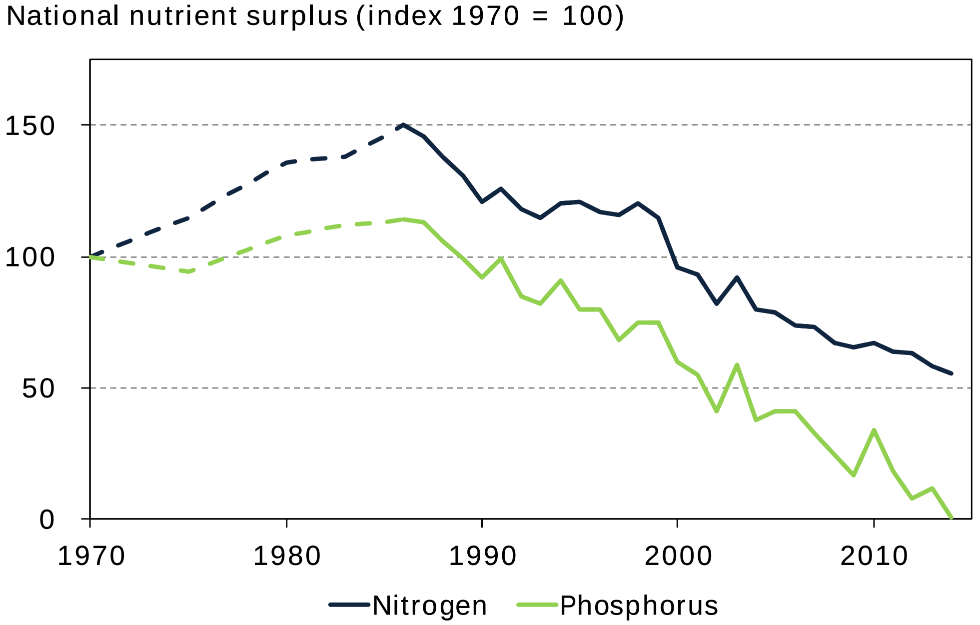


Figure 3.3: Trends in the relative nitrogen and phosphorus surplus in Dutch agriculture, with 1970 values defined as 100; observed annually from 1986
Source: CBS StatLine, 2016

3.4 Developments in agricultural practice

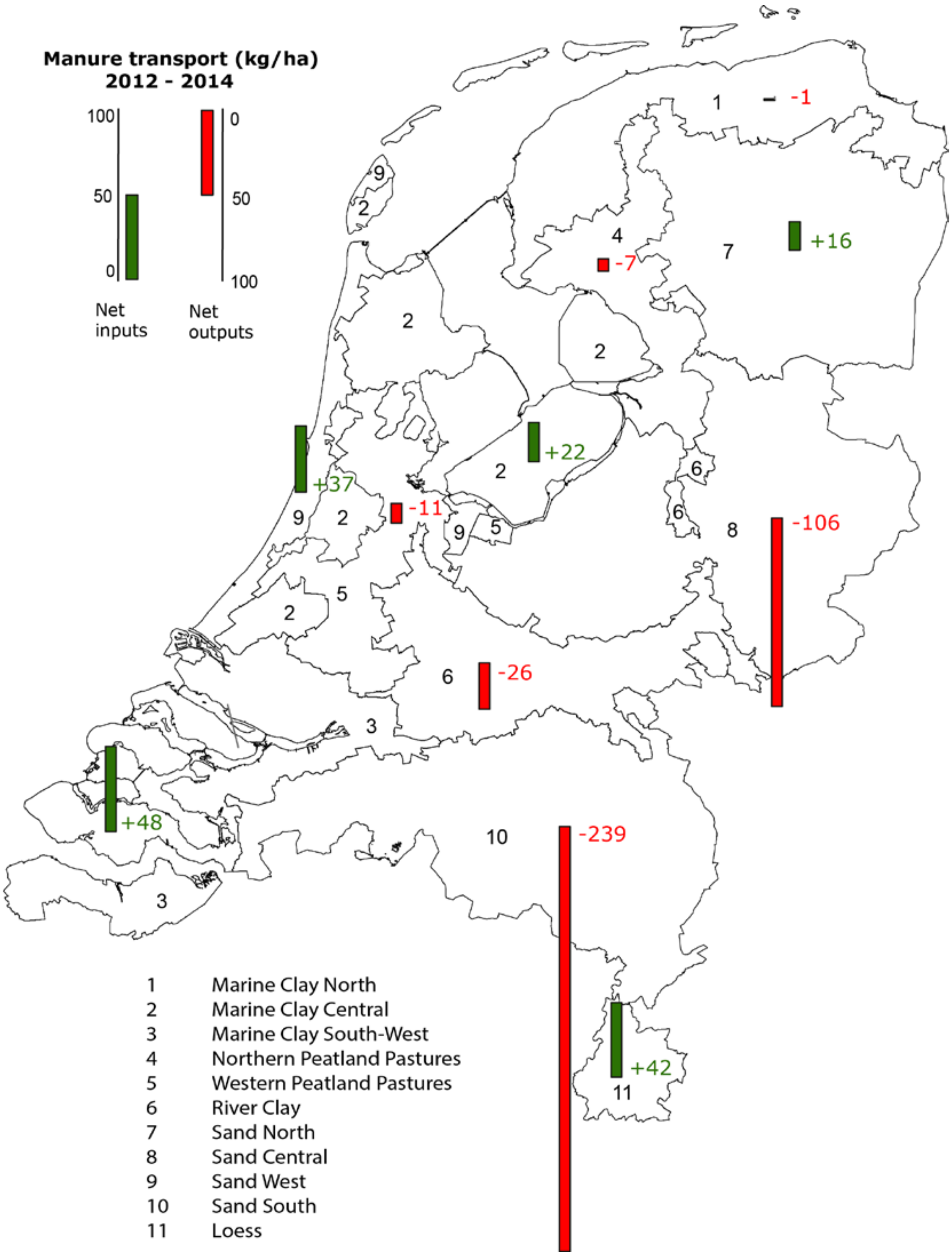
3.4.1 Introduction

This section considers the other aspects of agricultural practice, namely the developments in manure transportation and processing (Section 3.4.2), the developments in manure storage capacity in the Netherlands (Section 3.4.3), fertilisation practices (Section 3.4.4) and compliance with fertiliser legislation (Section 3.4.5).

3.4.2 Transport and processing of manure

Due to the tightening of the application standards for phosphate, increasing quantities of livestock manure have to be transported from farms with a nitrogen and/or phosphate surplus to other farms that have space to accommodate it. To begin with, farmers would transfer as much of their excess manure as possible to nearby farms. However, manure now has to be transported over ever greater distances, mainly from areas with high levels of intensive farming and therefore a regional surplus (Map 3.3). In the period 2012-2014, it can be seen that more manure was removed by farms on balance (expressed as nitrogen) than in preceding periods. This was caused by the drop in deposit capacity as a result of (1) the tightening of the application standards combined with the introduction of phosphate usage standards that depend on the phosphate status of the soil and (2) the reduction in the area of cultivated land. The phosphate status of a large area of land has not been ascertained, and this soil is automatically assigned the phosphate status “high” along with the lowest phosphate usage standard. The deposit capacity could increase slightly over the next few years because the area described as “unknown” is decreasing slightly (LEI, 2016). This is because more and more of the area is being sampled, as a result of which some of the area described as “unknown” (which is rated “high” by law) will switch to “neutral” or “low”. The Sand Central and Sand South areas have the largest net output due to the high number of intensive, non-land-bound pig and poultry farms there. The net output from these two areas showed a downward trend 20 years ago but has been showing an upward trend for more than ten years.

The total output of livestock manure to destinations outside Dutch agriculture, as shown in the flow diagram in Figure 3.2, has been increasing over the past few years and has in fact doubled compared with 20 years ago (see Table 3.17 for nitrogen and Table 3.18 for phosphorus). Roughly half is now exported abroad. In 2014, around 65% of the exported manure went to Germany, with most of the rest going in almost equal shares to France and Belgium (BMA, 2015). The share of “other manure processing” has been increasing since 2008. This currently accounts for a quarter of the total disposal of livestock manure to destinations outside agriculture.



Map 3.3: Transport balance for livestock manure, expressed as kg nitrogen per ha, for the period 2012-2014, from and to farms
Source: Statistics Netherlands (2015)

Table 3.17: Nitrogen manure disposal to destinations outside Dutch agriculture (kg N millions per annum)

	1994-1995	2000-2003	2008-2011	2012-2014
Manure processing - export	25	23	39	40
Other manure processing[1]	3	4	16	21
Non-agricultural use[2]	12	12	17	18
Total output outside agriculture	40	39	72	79

[1] This concerns processing processes in which the end product is no longer used as fertiliser in Dutch agriculture, with the exception of exports.
[2] Use by hobby farms, private individuals and nature areas
Source: Van Bruggen *et al.* (2015)

Table 3.18: Phosphorus manure disposal to destinations outside Dutch agriculture (kg P millions per year)

	1994-1995	2000-2003	2008-2011	2012-2014
Manure processing - export	5	6	10	10
Other manure processing[1]	1	1	3	4
Non-agricultural use[2]	3	2	3	3
Total output outside agriculture	8	9	16	18

[1] This concerns processing processes in which the end product is no longer used as fertiliser in Dutch agriculture, with the exception of exports.
[2] Use by hobby farms, private individuals and nature areas
Source: Van Bruggen *et al.* (2015)

3.4.3 *Manure storage capacity*

Livestock farms must have sufficient storage capacity for livestock manure because of the ban on spreading in the autumn and winter. As mentioned above, this does not apply to farms that can demonstrate that they have disposed of or used the excess in a responsible manner. This applies in particular to pig and veal calf farms. In 2010, 96% of dairy farms, 95% of pig farms and 87% of veal calf farms had storage facilities sufficient for at least six months' storage of manure production. Between 2010 and 2014, the number of farms with storage capacity of at least seven months increased to around 90% of dairy and pig farms and 77% of veal calf farms.

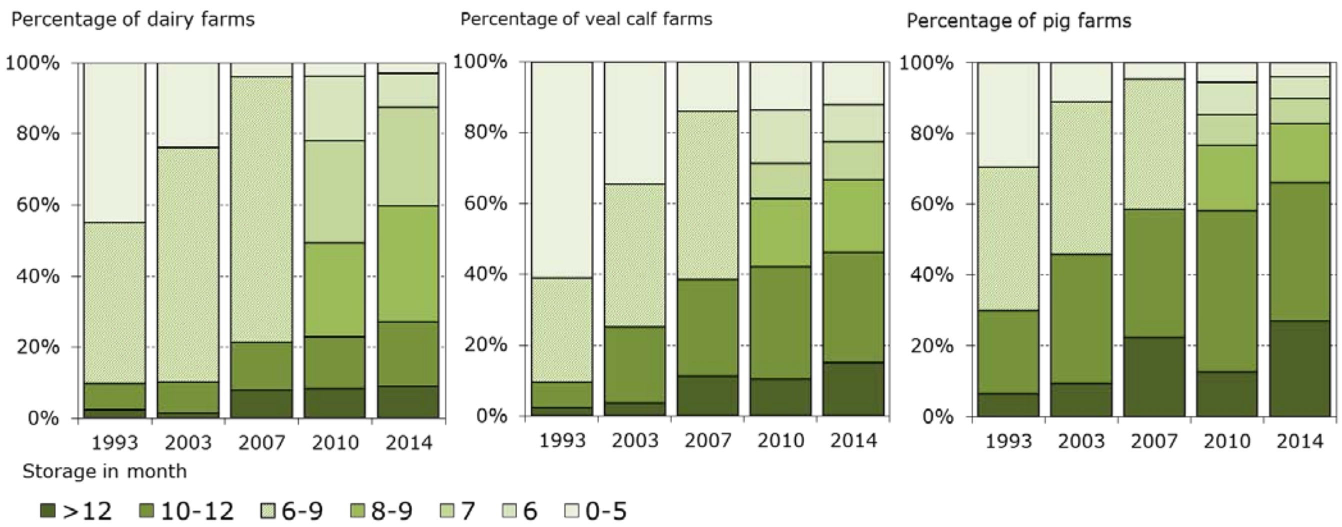


Figure 3.4: Storage capacity for liquid manure by type of farm, based on the number of months the farm is able to store its own liquid manure
Source: Statistics Netherlands, customised

3.4.4 *Fertilisation practices*

3.4.4.1 Timing and method of fertilisation

Since 1992, both the timing and method of fertilisation (Table 3.2) have become subject to an increasing number of limitations, in order to comply with the requirements of the Nitrates Directive (ND) which forbid the application of fertilisers in inappropriate periods (ND, Annex III (1)(1)) and require measures to be taken to limit nutrient losses to water (ND Annex II A (2-6) and Annex III (1) (3)). The rules for the method of application were specifically targeted at limiting the emission of ammonia into the atmosphere (see Section 3.4.4.5), but they also play a role in limiting run-off (see the following section). Since 2012, grassland may only be fertilised between 15 February and 1 September, and arable land between 1 February and 1 August (Table 3.2), using low-emission methods. The rules for low-emission application on arable land were tightened in 2008. Since that year it has no longer been permitted to spread livestock manure on agricultural land and to work it into the soil in two passes. Instead, this either has to be done in one pass or using approved low-emission technology (LNV, 2005a). Since 2014 it has been forbidden to use inorganic phosphate fertiliser on farms that have applied for derogation (EZ, 2014; EU, 2014).

In addition to the requirements for the timing of fertilisation as described above, the application of fertiliser to soil partially or completely covered with snow has been prohibited in the Netherlands since 1994 (LNV, 1995) (as per ND Annex II A (3)). This ban was extended in 1998 to include the application of fertiliser on completely or partially frozen soil (LNV, 1997b) (as per ND Annex II A (3)), although this rarely occurred in practice due to the requirement to work manure into the soil, which is difficult if it is frozen.

It has also been prohibited since 1999 to use livestock manure or inorganic nitrogen fertiliser if the top layer of the soil is saturated (LNV,

1999) (as per ND Annex II A (3)). In practice, this already rarely occurred because the equipment needed for spreading fertiliser is heavy and therefore causes considerable damage to the grass and soil structure in wet conditions. Since 2002 it has been forbidden to apply fertilisers to steeply sloping ground affected by erosion (LNV, 2001c) (as per ND Annex II A (2)).

Since 2006 farms with a derogation have been required to keep a fertilising plan describing the crop rotation of the farmland and the planned application of livestock manure and nitrogen and phosphate fertilisers (EU, 2005). These farms are also required to carry out periodic nitrogen and phosphate analyses of the soil at least once every four years for each area of the farm with homogeneous crop rotation and soil characteristics, and an analysis of the quantity of mineral nitrogen and parameters to assess the nitrogen contribution from organic matter mineralisation after ploughing grassland (EU, 2005). In addition, livestock manure may not be spread in the autumn before grass cultivation (EU, 2005).

In the past few years there have been developments in the sector that have further improved fertilisation practices on a voluntary basis. These include precision fertilisation, fertilisation in rows, and the use of processed manure products such as mineral concentrate. The provincial authorities and water authorities are attempting to encourage this, as was the case recently when the province of Noord Brabant set aside a project budget of €4 million for precision fertiliser application in 2015 (Noord Brabant, 2016). These developments have been difficult to quantify up to now. They have attracted attention in the press and improved practices are being incorporated in model projects (see Section 3.4.5.1).

3.4.4.2 Fertilisation close to waterways

The requirement to spread manure by a low-emission method not only limits ammonia emissions and the associated nitrogen deposition, but also improves the quality of surface water. With the aid of techniques that limit ammonia emissions, manure is spread more evenly and absorbed more effectively in or under the sods (as per ND, Annex II A (6)), thus preventing the manure running off and directly entering watercourses.

In addition, the ban on fertilisation during the winter months prevents the spreading of manure during the wettest period of the year (as per ND, Annex II A (1)). As a result, the chance of nitrogen entering watercourses due to leaching and run-off is small.

Since 2000, surface water has also been protected against pollution by the Discharge Open Cultivation and Livestock Farming Decree (VenW, 2000), which includes rules concerning the method (distance) of fertiliser application near watercourses (as per ND, Annex II A (4)).
A strip of land next to a watercourse, known as a buffer strip, must not be fertilised. The width of this buffer strip varies from 0.25 to 6 metres (in special cases, as much as 14 metres wide) and corresponds to the width of the strip that must not be sprayed with pesticides. When spreading artificial fertiliser alongside watercourses and/or buffer strips,

it is obligatory to use a boundary spreading device to prevent the fertiliser from entering the watercourse or buffer strip. Since 2006 it has been compulsory to allow a buffer zone at least 5 m wide along natural watercourses, as described in the Fertilisers Implementing Decree (see Map 3.1) (LNV, 2005a). The rules concerned were incorporated in the Activities (Environmental Management) Decree in 2013 (IenM, 2012).

Research carried out shortly after the introduction of the Discharge Decree in 2000 revealed that these rules are generally complied with: on about 91% of farms, the buffer strip has the required width (Vroomen and Van Veen, 2004). The Inspectorate concluded in 2006 that verifying compliance with the LOTV, especially concerning surprise checks, was substandard (Transport and Water Management Inspectorate, 2006). Research by Alterra (Noij *et al.*, 2012) revealed that while unfertilised 5 metre buffer zones with mown grass have no effect on plots with tile drainage, they may be relevant on plots that only have shallow drainage and phosphate leeching soils, but that the effects of buffer strips are limited on other types of plots.

3.4.4.3 Crop cover in winter months

Around half the total acreage in the Netherlands is under grass and is therefore covered in winter. Cultivating winter cereals on arable land is a suitable method for limiting nitrate leaching. Winter cereals are sown in the autumn and not fertilised until the following spring. The proportion of winter crops in the total area of cultivated land is stable at around 60% (Table 3.19).

Table 3.19: Area with crop cover as the main winter crop[1]

Crop	Acreages (x 1,000 ha)			Proportion of total cultivated area (%)		
	1992-1995	2008-2011	2012-2015*	1992-1995	2008-2011	2012-2015*
Grassland[2]	1068	1005	993	53.7	53.0	53.8
Winter wheat	110	129	128	5.5	6.8	6.9
Winter barley	4	5	5	0.2	0.2	0.3
Green manure	14	2	2	0.7	0.1	0.1
Total	1196	1141	1128	60.2	60.2	61.2

[1] Based on registration as main crop in the Agricultural Census (reference date 15 May)
[2] Permanent as well as temporary grassland (see Table 3.8)
* Reporting year 2015 is provisional. Previous years are definitive.
Source: CBS StatLine, 2016

Since 2006, it has furthermore been compulsory to sow a catch crop after cultivating silage maize on sandy and loess soils (LNV, 2005a). This meets the requirements of the option offered in the Nitrates Directive to provide a minimum quantity of vegetation cover during rainy periods (ND, Annex II B (8)). Research by Hilhorst and Verloop (2009) demonstrated that nitrogen fixing by catch crops can vary significantly depending on the catch crops used and the extent of fertilisation of the main crop. In 2015 there were 224,000 ha of silage maize. The approximately 140,000 ha of catch crops after silage maize, registered as follow-on crops in the Agricultural Census, consist of 90,000 ha of green manure, 30,000 ha of grassland and 20,000 ha of winter cereals.

Catch crops are also grown with other crops besides silage maize. In 2015 the total area of catch crops was equal to approximately 340,000 ha: 210,000 ha of green manure, 90,000 ha of grassland and 40,000 ha of winter cereals. The area of green manure, based on follow-on crops, is now much larger than the area registered as main crop in the Agricultural Census (see Table 3.19). Bearing this in mind, it is more likely that roughly three-quarters of the total area of cultivated land has crop cover in winter than the previous figure of 60% based simply on main crops.

3.4.5 Other developments

3.4.5.1 Information and demonstration projects

A few years ago, LTO Nederland launched an initiative designed to help resolve water issues and at the same time boost the agricultural and horticultural sectors. This initiative, known as *Deltaplan Agrarisch Waterbeheer* (DAW, Delta Plan for Agricultural Water Management), will be implemented in collaboration with the water authorities and with the involvement of the Ministry of Infrastructure and Environment, the Ministry of Economic Affairs, the provinces and the drinking water sector (LTO, 2013). The aim of the project is to have resolved the water quality problems and to have implemented a sustainable agricultural water supply by 2027. The initiative is being implemented on four levels ranging from national to farm-scale level. At the end of 2015 around 40 new and existing projects were brought under the DAW umbrella (see the DAW website for a list of projects; DAW, 2016a). An example of an existing project is *Koeien en Kansen* (Cows and Opportunities), in which a group of 16 dairy farmers from various parts of the Netherlands have been working with research institutes testing, evaluating and improving the effectiveness and practicability of existing and planned fertiliser and environmental legislation since 1998. An example of a new project is *Vruchtbare Kringloop Achterhoek en de Liemers* (VKA; Fertile Cycle) which started in 2013. In this project, around 250 dairy farmers are working to improve the fertility of their soil and are being encouraged and helped to use the minerals present on their farms more efficiently (VKA, 2016). In addition to the projects, the DAW website has a facility which displays a list of possible measures by sector, soil type and subject area, along with the advantages and disadvantages and a rough indication of the costs (DAW, 2016b).
Besides these, some provinces and drinking water companies are also working on initiatives. For example, since 2012 the province of Overijssel has been working with the drinking water company Vitens, agricultural advisers and farmers on the *Boeren voor Drinkwater* project (Farming for Drinking Water) aimed at reducing the nitrate load in five vulnerable extraction areas. Since 1997, the drinking water company WML has been working on the *Duurzaam Schoon Grondwater* project (Sustainable Clean Groundwater) with farmers who own land in drinking water protection areas. The aim of this project is to reduce nitrogen and pesticide leaching.

The strategy described above fits into a long tradition of research in collaboration with the agricultural sector. Examples are the *Management Duurzame Melkveebedrijven* project (Management Sustainable Dairy farms) carried out in 1991-1995 with 16 farms across all parts of the Netherlands (Beldman, 1993), the *Bioveem* project, carried out in two phases, 1997-2000 and 2001-2005, in which 10 and 17 organic dairy farmers took part respectively (Iepema *et al.*, 2006; Spruijt-Verkerke, 2004), and the various projects in the professional network *Telen met toekomst* (Farming with a Future), which were carried out in two phases between 2000 and 2010. The setup and the number of participants in *Telen met toekomst* varied between the two phases. The first phase (2000-2003) involved 34 operational farms in the arable, open-air vegetable, flower and bulb sectors (De Ruijter and Smit, 2003). The second phase (2004-2010) involved participants from all plant crop sectors in the Netherlands, with a total of around 400 participants working in 35 groups (Van Geel and Brinks, 2011; Drent, 2010).

3.4.5.2 Irrigation by sprinkling

Irrigation by sprinkling is carried out at least once a year over a small acreage in the Netherlands, usually between 4 and 8% (fig. 3.5). This can increase to 15% of the acreage in years with both a dry spring and a dry summer.

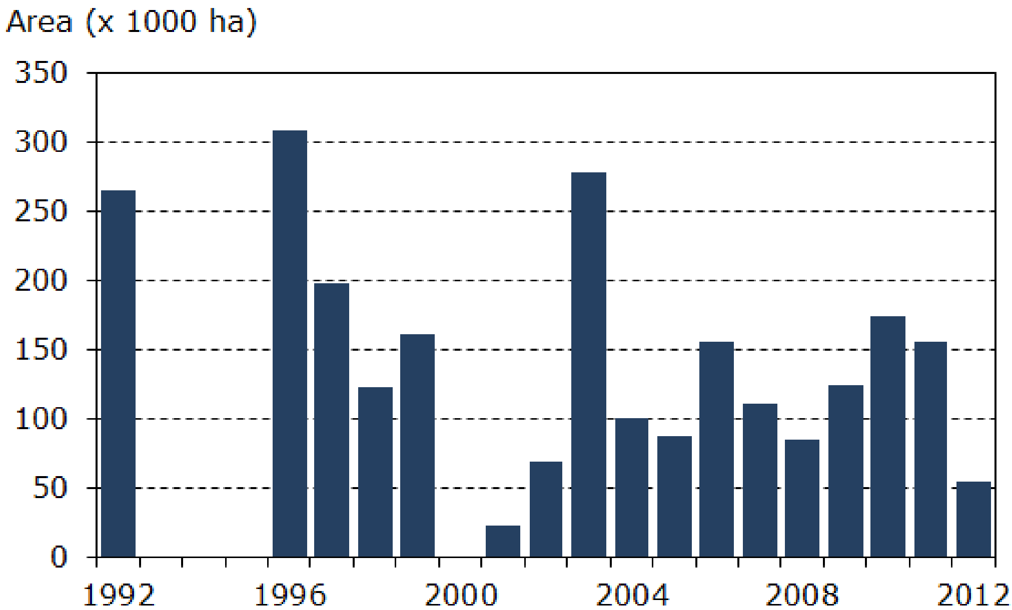


Figure 3.5: Cultivated land area (x 1,000 ha) in the Netherlands irrigated at least once a year by sprinkling between 1992 and 2012
Sources: 1992-1999: Hoogeveen *et al.* (2003) and Meeusen *et al.* (2000); 2001-2003: LEI Binternet (2011); 2004-2012: Van der Meer (2013 and 2014)

3.4.5.3 Ammonia, emission-reducing measures

Agriculture is the main source of ammonia emissions in the Netherlands. Most of these emissions eventually end up in the soil, the vegetation, and water via deposition from the atmosphere. Emission-reducing measures have resulted in a decrease in the volatilisation of ammonia.

In the period 1992- 2014, ammonia emissions from livestock manure and artificial fertiliser declined by 58% (Table 3.20), the main causes being the reduction in the amount of nitrogen excretion by livestock, the increased use of low-emission animal housing and the obligation to apply fertiliser using low-emission methods. The obligation to apply fertiliser using low-emission methods brought about a steep decline in emissions in the early 1990s. This decline in ammonia emission has slowed down somewhat over the past 10 years. Since 2008 it has no longer been permitted to spread liquid manure on agricultural land and work it into the soil in two passes. As a result of this measure, soil injection has increased significantly. In addition, the increased use of low-emission animal housing has brought about an annual reduction in emissions (Van Bruggen *et al.*, 2015).

Table 3.20: Ammonia emissions from livestock manure and artificial fertilisers (in kg NH_3 millions)

	1992-1995	2008-2011	2012-2014
Livestock manure	242	106	94
Housing and storage[1]	101	65	55
Application	124	39	37
Grazing	17	2	1
Artificial fertilisers	13	10	14
Total emissions[2]	255	116	107

[1] Nitrogen losses from housing and storage in Figure 3.2 include both NH_3 losses and other N volatilisation.

[2] This only concerns ammonia emissions from Dutch agriculture; emissions by hobby farms, private persons and nature area are not included.

Source: Emissions Registration, 2015

A number of changes have been made to the time series for ammonia emissions compiled for Emissions Registration since the previous Nitrates Directive report (Van Bruggen *et al.*, 2015):

- New, higher emission factors for ammonia from cattle and pig housing
- New emission factors for other nitrogen compounds from produced manure
- New, higher emission factors for some fertiliser application techniques on arable land
- Some new, minor emission sources have been added, such as maturing crops, crop residues and the use of sewage sludge and compost

National emissions and the concentration of ammonia in the Netherlands do not show similar trends in the period 1993-2014. In addition, the trends in national emissions and average concentrations have diverged in recent years. Based on this difference in trends, a quick scan of the causes was performed in mid-2014 and recommendations for further research were made by the Scientific Committee for the Fertiliser Act (CDM). In June 2015, an international scientific review of the entire ammonia emission, modelling and measurement chain was performed. This review stated that the assumed ammonia emissions in the early 1990s were most likely overestimated (Sutton *et al.*, 2015).

3.4.6 Compliance with fertiliser legislation

The new approach, which involves focusing more on the results and the impact of the surveys (see Section 2.2.2) is beginning to bear fruit. The number of farms fined for exceeding the application standards or for failing to account for their manure rose in 2012 by 14% by comparison with the control year 2010 (6%).

Random checks on application standards and accountability
Out of the 375 completed administrative checks of farms within a random sample, violations were discovered on one farm, which was fined (Table 3.21). The violation concerned the application standards for phosphate and livestock manure (Table 3.24). The observed compliance levels are well above the desired expected levels. The number of fines in 2012 was lower than in the previous three years (Table 3.22), although it must be borne in mind that there are still nine cases pending (Table 3.21).

Table 3.21: Overview of farm-level compliance in the administrative sample in 2012 (reference date 7 June 2014)

	Farms surveyed			Fines		Collected
Target group	Total	Completed	Pending	Number	Percentage	
Grazing livestock	212	212	-	1	0.5%	0
Arable	57	57	-	0	0%	-
Factory	40	33	7	0	0%	-
Horticulture	36	36	-	0	0%	-
Mixed	27	25	2	0	0%	-
Intermediary	1	1	-	0	0%	-
Other	11	11	-	0	0%	-
Total	384	375	-	1	0.3%	0

Source: RVO.nl, customised

Table 3.22: Overview of compliance at target group level over the past four inspection years among farms from which fines were collected (reference date 7 June 2014)

Target group	2009	2010	2011	2012*
Grazing livestock	7	2	5	1
Arable	2	2	3	-
Factory	3	-	-	-
Horticulture	-	1	2	-
Mixed	-	-	-	-
Intermediary	-	-	-	-
Total	12	5	10	1

* Nine cases were still pending on the reference date. The above data may change.
Source: RVO.nl, customised

Selected administrative checks
In addition to the randomly selected checks, 755 farms that met the risk criteria were surveyed (see Section 2.2.2), resulting in 149 of the 755 farms being fined on the reference date (7 June 2014) (Table 3.23).
A total of 241 violations were discovered (Table 3.24), often involving multiple violations of standards on individual farms. There were a further 174 files in various stages of processing. An intention to issue a penalty was sent to 60 farms. Over the control year 2012, seven of the farms surveyed in respect of application standards and duty of accountability were passed on to the Netherlands Food and Consumer Product Safety Authority (NVWA) for further physical inspection.

Of the 149 farms fined, 49 had registered for derogation. In the event of a violation of the application standards, the amount of extra space allowed drops from 250 to 170 kg nitrogen/ha. In practice, this results in high administrative fines.

Table 3.23: Number of find farms following administrative checks in the control year 2012 (reference date 7 June 2014)

Target group	Number of farms surveyed	Fines		Objections [1]	
		Number of farms	% of farms	Number	%
Grazing livestock	312	63	20%	30	48%
Arable	134	35	26%	17	49%
Factory	152	7	5%	3	43%
Horticulture	31	13	42%	7	54%
Mixed	92	7	8%	4	57%
Intermediary	20	16	80%	14	88%
Other	14	8	57%	4	50%
Total	755	149	20%	79	53%

[1] A total of 79 objections had been submitted by the reference date, 17 of which were declared fully or partially valid; 37 objections are still pending.

Source: RVO.nl, customised

Table 3.24: Overview of compliance at standard level, based on random and selected administrative checks; control year 2012 (reference date 7 June 2014)

Standard	Randomly selected checks		Selected checks	
	Surveyed	Violations[1]	Surveyed	Violations[1]
Nitrogen application standard	375	0	755	22
Phosphate application standard	375	1	755	117
Livestock manure application standard	375	1	755	85
Duty of accountability	375	0	755	17

[1] There were often violations of multiple standards on individual farms.

Source: RVO.nl, customised

3.5 Cost effectiveness

The cost of measures for reducing leaching and run-off of nitrogen and phosphorus into surface water and the reductions in leaching and run-off achieved show great variations (Tables 3.25-3.27). The potential reduction also depends on the legislation applicable at the time. Most studies refer to the fertiliser policy applicable in 2009 or 2006. Recent developments in the manure market, manure processing and suboptimal fertilisation are not included in these studies. These are factors that have a significant impact on cost effectiveness, for example due to higher manure disposal costs (Willems *et al.*, 2012; De Koeijer *et al.*, 2011). To determine the cost effectiveness of measures, a regional approach is required: not only does land use differ significantly between regions, but the effectiveness of measures also depends to a large extent on local (geohydrological) circumstances (Clevering *et al.*, 2007; DAW, 2016). Compared with the fertiliser policy in 2009, it was found that there was still scope in arable and outdoor vegetable farming to further reduce the nitrogen load on surface water down to approximately 20% with “cheaper” source-based measures, most of the costs incurred being due to the need to use alternative organic sources (Clevering *et al.*, 2007). In cattle farming, there were no other "cheaper" solutions for further reducing the load on surface water using source-oriented measures, mainly due to the high cost of manure disposal (Clevering *et al.*, 2007, 2006). These costs will mount up even further for the livestock sector if arable farms start using less livestock manure.

Table 3.25: Effect of additional source-oriented farm-level measures for reducing nitrogen leaching and run-off into surface water[2]

Measure	N reduction (kg/ha)	Cost (€/ha)
Arable		
Removal of crop residues	0.5-4.2	102-269
Catch crops	0-0.8	0-9
Additional nitrogen fertiliser system (NBS)[2]	0-0.9	0-1
Suboptimal fertilisation (-10%)	0.1-1.3	9-38
Suboptimal fertilisation (-20%)	1.7-3.1	40-378
No livestock manure	1.4-3	56-66
Use of solid fraction in autumn	1.1-2	-5-15
Dairy farming		
Use of 15% natural grass	<0	19
less intensive/ organic / organic concentrate / 15% natural grass	5-7.7	-133-413[3]
Less young livestock	0	98
Less young livestock plus full-time housing	6.2-8.6	300
Year-round housing	2.4-2.7	216
Less N on grassland	2.4-2.7	37

[1] Reference is fertiliser policy 2009.
[2] NBS is an additional nitrogen fertiliser system based on N mineral measurement in soil.
[3] Switching to organic farming is less complicated for livestock farmers (-€133/ha). However, the cost-effectiveness of this measure will decrease if more farmers decide to switch to organic farming. Making a farm less intensive is much more expensive (€370/ha).

Source: Clevering *et al.* (2006 and 2007)

Table 3.26: Effect of additional source-oriented farm-level measures for reducing phosphorus leaching and run off to surface water[1]

Measure	P reduction (kg/ha)	Cost (€/ha)
Arable		
P input = half output	0.2-2.3	-4 - 1125
P input = half output; no livestock manure	0.3-4.2	31-1153
P input = 0	0.4-4.4	28-1344
Dairy farming		
Less young livestock plus full-time housing	0.2	216
Artificial fertiliser plus P input = half output	0.4	46

[1] Reference is fertiliser policy 2009.

Source: Clevering *et al.* (2006 and 2007)

Marshy buffer strips and helophyte filters have been found to be more cost effective than far-reaching source-oriented measures, despite the space they take up (Clevering *et al.*, 2007, 2006). The cost effectiveness, expressed in euros per treated quantity of nitrogen or phosphorus, improves as the scale increases (De Haan *et al.*, 2011). De Haan *et al.* (2011) conclude that creating water treatment marshes can deliver an effective reduction and is a cost-effective measure for removing nitrogen and phosphate in drained areas and areas with a lot of surface water. These authors put the cost effectiveness at around €5-€40 per kilogram of removed nitrogen, depending on the variant chosen. The cost effectiveness of phosphate is €115 per kg phosphorus.

Table 3.27: Impact of effect-oriented farm-level and regional measures for reducing nitrogen and phosphorus leaching and run off into surface water

	N reduction (kg/ha)	Cost (€/ha)	P reduction (kg/ha)	Cost (€/ha)
Dredging	-	-	0.1	29-50
Grass buffer strips[1]	0.1-0.7	2-52	0.1	1-92
Marsh buffer strip 2.5%[1]	3.1-4	92-163	0.1-2	19-231
Helophyte filter 2.5%[1]	4.5-8.1	114-185	0.3-2	114-185
Helophyte filter 5%[1]	6-11.2	228-369	0.6-2.4	142-505
Water treatment marshes[2]	3.5-29.3	19-684	0.21	24

[1] Reference is fertiliser policy 2009; % is percentage of land taken up by a strip or filter.

[2] Savings expressed in load removed via filter. For P, the value is only available for one of the seven variants, with the lowest N savings and the lowest cost per ha. The variants vary in plot size, level of measures and type of water. The cost decreases as the size of the plot increases.

Source: [1] Clevering *et al.* (2006 and 2007); [2] De Haan *et al.* (2011)

According to a recent study, the regional situation determines which measure is the most effective for reducing the phosphate load (Van der Salm *et al.*, 2015).

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4 Effects of Action Programme on agricultural practice and nitrate leaching

4.1 Introduction

This chapter presents the results of the farm measurements for the four main soil type regions in the Netherlands: the Sand, Clay, Peat and Loess Regions, and the three main sand areas in the Sand Region (see Figure 2.1). Approximately 47% of the area of the Netherlands under cultivation is in the Sand Region, 1.5% in the Loess Region, 41.5% in the Clay Region and 10% in the Peat Region.

Arable and dairy farming account for the largest share of land use in the Netherlands. (Together, they represent over 60% of the acreage in each region, as shown in Table 4.1.) Dairy farming accounts for the largest shares in the Peat and Sand Regions. In the Clay and Loess Regions, arable and dairy farming both account for significant shares of land use. LMM covers between 76% and 85% of the agricultural area in the different regions.

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

	Arable	Dairy	Factory	Other[1]	Non-LMM[2]
Sand Region	16%	46%	8%	14%	16%
Loess Region	33%	28%	-	22%	17%
Clay Region	39%	35%	-	11%	15%
Peat Region	-	77%	-	-	23%

[1] The category “Other” relates to other livestock farms (see Section 2.3.2).

[2] “Non-LMM” includes farm types that are not covered by LMM, as well as farms that do not satisfy the LMM criteria for acreage and/or economic size. This report does not include these farms.

In the next Section (4.2), the data on agricultural practice are presented for the farm types represented in LMM. Section 4.3 describes the nitrate concentrations in water on LMM farms. As in the chapters on groundwater and surface water quality, the nitrate concentrations are compared with the EU standard of 50 mg/l. Strictly speaking, this standard does not apply to soil moisture, i.e. the water in unsaturated soil. Almost all measurements of leaching from the root zone in the Loess Region and a limited number of measurements in the Sand Region concern nitrate concentrations in soil moisture. This is because the groundwater (the saturated zone) in these locations is at great depth - often tens of metres below surface level – and is therefore not representative of leaching out of the root zone.

In this chapter there is a difference of one year between the reporting periods for the agricultural practices on the one hand and the nitrate concentration in the water that leaches from the root zone on the other. Specifically, the farm data from 1991 to 1994 are compared with the on-farm water quality between 1992 and 1995 (see also Section 2.3.2). It is assumed that the main factor affecting on-farm water quality in year x is farm practice in year x-1. The relationship between changes in agricultural practice and nitrate concentrations in on-farm water is discussed in Section 4.4.

4.2 Agricultural practice

This section describes the general characteristics of agricultural practice followed by farms that fall within the LMM sample population in the FADN (Section 2.2.3) (Table 4.2 arable farms, Table 4.3 dairy farms, and Table 4.4 other livestock farms). The purpose of presenting this data here is to provide background information for identifying trends in the quality of water at these farms (Section 4.3). Developments in agricultural practice for the Netherlands as a whole are described in Chapter 3.

The general tendency is for farms to become larger, with livestock density (calculated on the basis of phosphate excretion) increasing slightly in recent years, and the use of nitrogen from both livestock manure and artificial fertilisers decreasing, although very little if at all in the past few years.

Arable

Arable LMM farms in the Sand and Clay Regions are approximately the same size on average (about 60 ha between 2011 and 2014) (Table 4.2). Arable farms in the Loess Region have a much smaller surface area (46 ha). Arable farms in the Sand and Clay Regions have grown in size by around 30% since the initial period (1991-1994 for the Sand Region and 1995-1998 for the Clay Region), but the average surface area has been stable in all regions since the 2007-2010 period. The proportion of potatoes and sugar beet in crop rotation plans has dropped and that of cereals has risen.

In general, the use of nitrogen via livestock manure on arable farms is fairly stable. The use of inorganic nitrogen fertiliser has fallen since the initial period, but there has been little change since 2007-2010. The use of nitrogen from other organic fertilisers shows an increase, although this is for the most part smaller than the decrease in artificial fertiliser. The nitrogen surplus in the soil surface balance fell between 2007 and 2014, except in the Clay Region. Besides a reduction in the quantity of fertiliser applied, factors influencing the drop in the nitrogen surpluses in the soil surface balance on arable farms may include higher crop yields, and therefore more outputs.

Table 4.2: Arable farms in the Netherlands that are part of the LMM sample population; leading characteristics of agricultural practice for farms in the Sand, Clay and Loess Regions[1] for various reporting periods

Arable farms	Sand Region 1991-1994	Sand Region 2007-2010	Sand Region 2011-2014	Clay Region 1995-1998	Clay Region 2007-2010	Clay Region 2011-2014	Loess Region 2007-2010	Loess Region 2011-2014
Area (hectares)	46	60	58	44	60	61	44	43
% potatoes	44	35	36	25	24	24	15	16
% sugar beet	19	13	13	17	12	12	18	17
% cereals	17	28	24	33	36	36	48	47
% other crops	20	24	27	25	28	28	19	20
N from livestock manure (kg/ha)	124	132	112	101	77	73	121	111
N artificial fertiliser (kg/ha)	114	81	75	172	138	141	109	88
N other organic fertilisers (kg/ha)	0	10	17	2	12	19	1	4
N surplus in soil surface balance (kg/ha)	158	129	100	164	104	108	118	84

[1] Arable farming is rare in the Peat Region; the Clay and Peat Regions have been part of LMM since 1996, and the Loess Region since 2002.

Table 4.3: Dairy farms in the Netherlands that are part of the LMM sample population; leading characteristics of agricultural practice for farms in the Sand, Clay, Peat and Loess Regions[1] for different reporting periods

Dairy farms	Sand Region 1991-1994	Sand Region 2007-2010	Sand Region 2011-2014	Clay Region 1995-1998	Clay Region 2007-2010	Clay Region 2011-2014	Peat Region 1995-1998	Peat Region 2007-2010	Peat Region 2011-2014	Loess Region 2007-2010	Loess Region 2011-2014
Area (hectares)	28	43	45	35	53	55	34	49	51	45	49
Grassland (%)	77	76	77	90	84	86	96	91	92	66	65
% maize	20	21	20	8	12	11	4	8	7	21	21
% other crops	3	3	3	2	4	3	0	1	1	13	13
Livestock (phosphate LSU/ha)[2]	2.8	2.2	2.4	2.2	2.0	2.1	2.1	1.9	2.1	1.9	2.1
% manure storage[2]	94	145	146	108	152	168	102	150	158	150	144
N from livestock manure (kg/ha)	362	235	229	301	231	231	293	229	230	221	219
N artificial fertiliser (kg/ha)	245	113	108	279	135	140	252	101	108	97	106
N other organic fertilisers (kg/ha)	0	2	1	0	1	1	0	0	0	0	2
N surplus in soil surface balance (kg/ha)	331	152	145	328	171	161	415	230	220	130	126

[1] The Clay and Peat Regions have been part of LMM since 1996, and the Loess Region since 2002.
[2] Phosphate LSU is the number of livestock units calculated on the basis of phosphate excretion: 41 kg phosphate per year is the equivalent of 1 dairy cow.
[3] Percentage of total manure production that can be stored on a farm for six months

Dairy farming

Dairy farms in LMM cover a smaller area than arable farms but are still growing in area, including in the years 2011-2014 by comparison with the years 2007-2010 (Table 4.3). Crop rotation has remained fairly stable. Stock density fell up to the fifth period (2007-2010) but started to rise again after that as the milk quota was extended by 1-2% almost every year from 2008 onwards. The manure storage capacity has since increased to 8-9 months.

Compared with the initial period, the use of nitrogen from both livestock manure and artificial fertiliser fell up to the fifth period. However, there was virtually no difference in dairy farms in all regions between the fifth and sixth period. Nitrogen surpluses in the soil surface balance did fall slightly between the fifth and sixth periods, partly due to lower nitrogen levels in feed.

Other livestock farms

The LMM group of other livestock farms can only be presented for the Sand and Clay Regions: there were found to be too few farms per year available in the Loess Region. In terms of acreage trends, this group of farms is similar to arable farms (stable in the last two periods) (Table 4.4). With regard to the other results, developments in the "other livestock farms" group bear more resemblance to those in dairy farms.

Table 4.4: Other livestock farms in the Netherlands that fall within the LMM sample population; leading characteristics of agricultural practice for farms in the Sand and Clay Regions[1] for each reporting period

Other livestock farms	Sand Region			Clay Region		
	1991-1994	2007-2010	2011-2014	1995-1998	2007-2010	2011-2014
Area (hectares)	23	36	35	30	41	41
% grassland	49	63	64	75	70	71
% maize	25	17	18	10	8	8
% potatoes, sugar beet, cereals	19	16	14	12	17	16
% other crops	7	4	3	3	6	6
Livestock (phosphate LSU/ha)[2]	4.3	1.8	1.7	1.4	1.3	1.2
% manure storage [3]	105	214	226	63	135	190
Nitrogen from livestock manure (kg/ha)	306	207	195	194	144	154
Artificial fertiliser nitrogen (kg/ha)	159	69	87	148	109	117
Nitrogen from other organic fertilisers (kg/ha)	0	1	7	0	14	6
N surplus in soil surface balance (kg/ha)	281	133	167	185	112	161

[1] The Clay Region has been part of LMM since 1996. Other livestock farms are rare in the Peat and Loess Regions in the LMM sample population.

[2] Phosphate LSU is the number of livestock units calculated on the basis of phosphate excretion: 41 kg phosphate per year is the equivalent of 1 dairy cow.

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

The large drop in stock density in the "other livestock farms" group in the Sand Region is striking. Many of these mixed farms stopped keeping pigs, so the group now has a higher number of other grassland farms and combinations of arable and dairy than in the initial period.

The “other livestock farms” group started using slightly more nitrogen from artificial fertiliser in the sixth period (2011-2014) compared with the preceding period. Partly as a result of this, the nitrogen surpluses in the soil surface balance have also risen.

The surplus figures in this chapter are based on the LMM sample and are shown by farm type (arable and dairy farms) and by region (Sand, Clay, Peat and Loess Regions). The nutrient surplus in kg N per ha, as shown in Table 3.15, corresponds both in terms of magnitude and trend with the N surplus in the soil surface balance on arable and dairy farms forming part of the LMM sample population (see Tables 4.2 and 4.3). The Statistics Netherlands surplus figures in the previous chapter relate to N losses both into air and soil for the whole of the Dutch agricultural and horticultural sector.

4.3 Nitrate concentrations

4.3.1 Overview at national level

Nitrate is the main component of nitrogen in the water leaching out of the root zone into the groundwater and ditch water (leaching water) and also in the ditch water on farms in the Sand, Loess and Clay Regions (about 85%, over 95% and about 80% respectively, see Figure 4.1). It is a smaller component of the nitrogen in leaching water and ditch water in the Peat Region (under 30%). In the Peat Region, ammonium is the main form of nitrogen in leaching water (30-60%) and organic nitrogen is the main form in ditch water (25-50%). The ammonium concentration in the groundwater of the Peat Region increases with the depth at which the water is located (Van der Grift, 2003), the cause being attributed to the mineralisation of organic material (Meinardi, 2005).

The average nitrate concentration in leaching water varies from region to region. It is lowest in the Peat Region, higher in the Clay Region, and highest in the Sand and Loess Regions (see Figure 4.1).

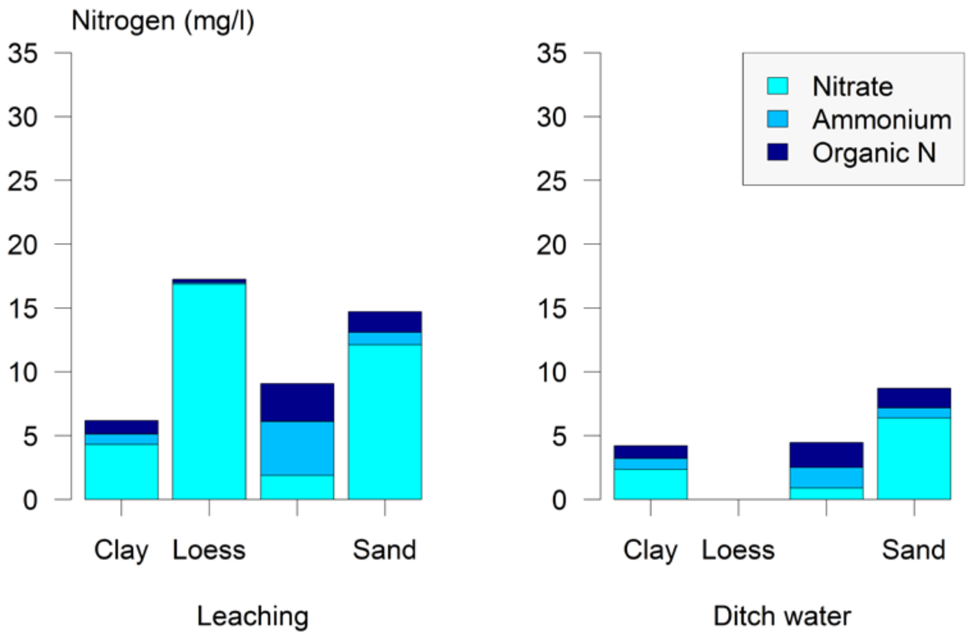

Figure 4.1: Dissolved nitrogen concentrations (in mg N/l) in water leaching from the root zone (left section of table) and in ditch water (right section) on farms in the Sand Region, Loess Region (no ditches), Clay Region and Peat Region in the Netherlands; average concentration in 2012-2014

From 1992 to 2003, the nitrate concentrations measured in the leaching water on farms in the Sand Region showed a clear decrease, followed by a period of stabilisation (see Figure 4.2 and Table 4.5). After 2008, nitrate levels dropped further to averages just above 50 mg/l. Following stable, high nitrate concentrations in the initial period, the Loess Region showed a decline and stabilisation in the years after 2008. For the entire period, nitrate concentrations in the Clay Region exhibited a downward trend, apart from a few years in the period 2004-2007. The explanation for the high concentration might be the relatively dry 2003. No discernible trend can be seen in the leaching water on farms in the Peat Region. The higher concentrations in some years such as 2004 and 2007 are attributable to the greater proportion of farms that exceeded the EU standard of 50 mg/l (Figure 4.3).

Nitrate concentrations in the Sand, Clay and Peat Regions rose in the period 2012-2015 (Figure 4.2). However, average nitrate concentrations in this period were lower than or almost equal to those in the preceding period (2008-2011) (Table 4.5a). The average nitrate concentration in the Sand Region dropped from 63 mg/l in 2008-2011 to 54 mg/l in 2012-2015. Regarding nitrate concentrations in the Loess and Peat Regions, there has been no change between the previous and the latest reporting periods.

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

Table 4.5a: Nitrate concentrations (mg/l as NO_3) in water that leaches from a root zone. Averages per period[1], measured (M) and standardised (S)

Region	Result[2]	1992-1995	1996-1999	2000-2003	2004-2007	2008-2011	2012-2015
Sand	M	149	114	68	76	63	54
	S	149	117	90	76	63	55
Clay	M		46	33	41	25	19
	S		60	44	35	29	22
Loess	M			86	90	78	75
Peat	M		9	3	13	7	8

[1] Average of farm averages per period
[2] M = Measured, S = Standardised

Table 4.5b: Percentage of farms with nitrate concentrations higher than 50 mg/l (as NO_3) in water that leaches from a root zone. Averages per period[1], measured (M) and standardised (S)

Region	Result[2]	1992-1995	1996-1999	2000-2003	2004-2007	2008-2011	2012-2015
Sand	M	95	82	59	64	51	46
	S	90	81	70	61	51	43
Clay	M		36	23	32	12	7
	S		55	37	26	17	9
Loess	M			90	89	65	64
Peat	M		0	0	9	0	0

[1] Average of farm averages per period
[2] M = Measured, S = Standardised

There was a marked reduction in this standardised nitrate concentration in the leaching water on farms in the Sand Region from about 150 mg/l in the period 1992-1995 to 55 mg/l in the period 2012-2015 (Figure 4.4, Table 4.5). The standardised nitrate concentration also fell in the Clay Region, from 60 mg/l at the end of the 1990s to just over 20 mg/l in 2012-2015.

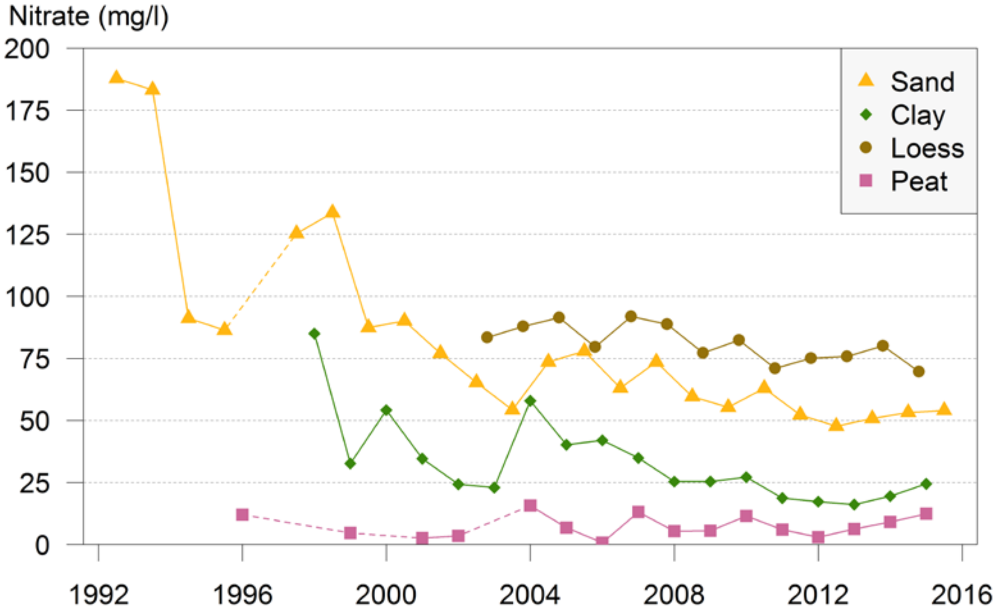

Figure 4.2: Nitrate concentrations (as NO_3 in mg/l) in water leaching from root zones on farms by region in the period 1992-2014; annual average of measured concentrations

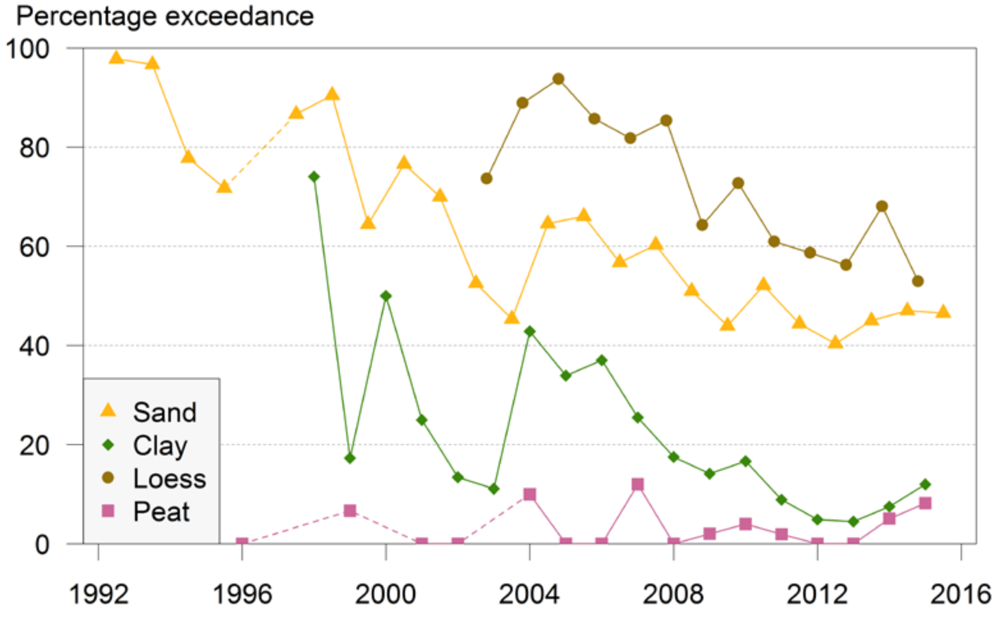

Figure 4.3: Percentage of exceedances of the EU standard of 50 mg/l nitrate in water leaching from root zones on farms by region in the period 1992-2014; exceedance based on measured concentrations

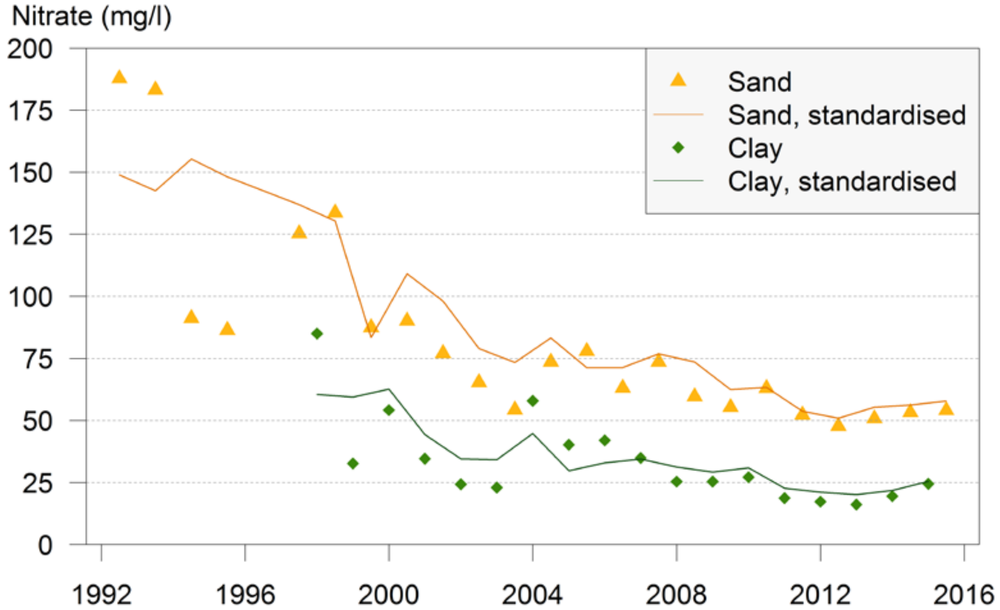

Figure 4.4: Nitrate concentrations (as NO_3 in mg/l) in water leaching from root zones on farms in the Sand and Clay Regions in the period 1992-2014; average annual measured and standardised concentrations

The percentage of farms with a nitrate concentration above the EU standard of 50 mg/l (see Figure 4.3) shows a falling trend similar to that in the nitrate concentration (Figure 4.2). The level of 50 mg/l was most often exceeded in the Loess Region. In the Sand Region, there were more exceedances of the standard than in the Clay and Peat Regions. In the Peat Region, the concentration is rarely above 50 mg/l. The fall in the average nitrate concentration in the Loess Region (from almost 90 mg/l to 75 mg/l) coincides with a drop in the exceedance percentage of more than 30 percentage points since measurements began. Variation from year to year is attributable to confounding factors. Even if allowance is made for them, the percentage of exceedances of the EU standard still shows a decline in the Clay and Sand Regions (Figure 4.5). The standardised exceedance in the Sand Region fell from about 90% in the period 1992-1995 to less than 45% in the period 2012-2015 (Table 4.5b). The number of exceedances in the Clay Region fell to less than 10% in the period 2012-2015 from about 55% in the period 1996-1999.

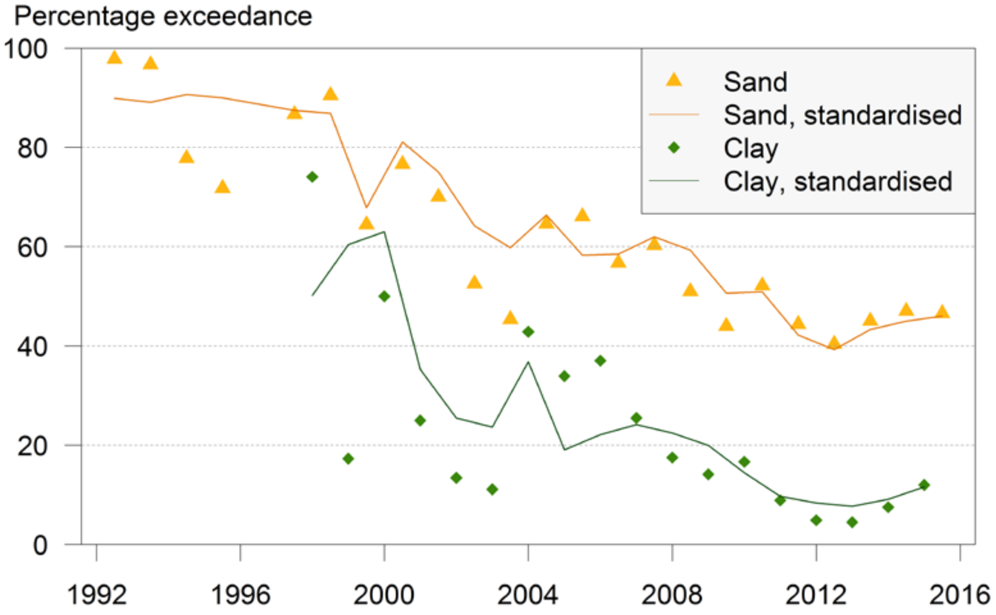

Figure 4.5: Percentage of exceedances of the EU standard of 50 mg/l nitrate in water leaching from root zones on farms in the Sand and Clay Regions in the period 1992-2014; exceedance based on measured and standardised concentrations

The average winter nitrate concentration in ditch water varies from region to region, as is the case with leaching. It is lowest in the Peat Region, higher in the Clay Region, and highest in the Sand Region (see Figure 4.6 and Table 4.6). There are virtually no ditches on farms in the Loess Region. The trend in both the Sand and Clay Region in the period 2004-2015 was downward, although concentrations started to rise again slightly from 2014. The average nitrate concentration in every region has been below 40 mg/l over the past four years. Exceedances of the 50 mg/l standard in the Clay and Peat Regions have all but ceased (Figure 4.7). The percentage of farms in the Sand Region on which the average winter concentration exceeds 50 mg/l dropped from around 40% in the mid-2000s to around 20% over the past four years.

Table 4.6: Nitrate concentrations (mg/l as NO_3) and, in brackets, percentage of farms with a concentration higher than 50 mg/l in ditch water. Averages per period[1]

Region	Result[2]	1996-1999	2000-2003	2004-2007	2008-2011	2012-2015
Sand	M			43 (32%)	37 (27%)	28 (19%)
Clay	M			23 (14%)	13 (2%)	10 (1%)
Peat	M	4 (0%)	3 (0%)	5 (0%)	4 (0%)	4 (0%)

[1] Average of farm averages per period
[2] M = Measured, S = Standardised

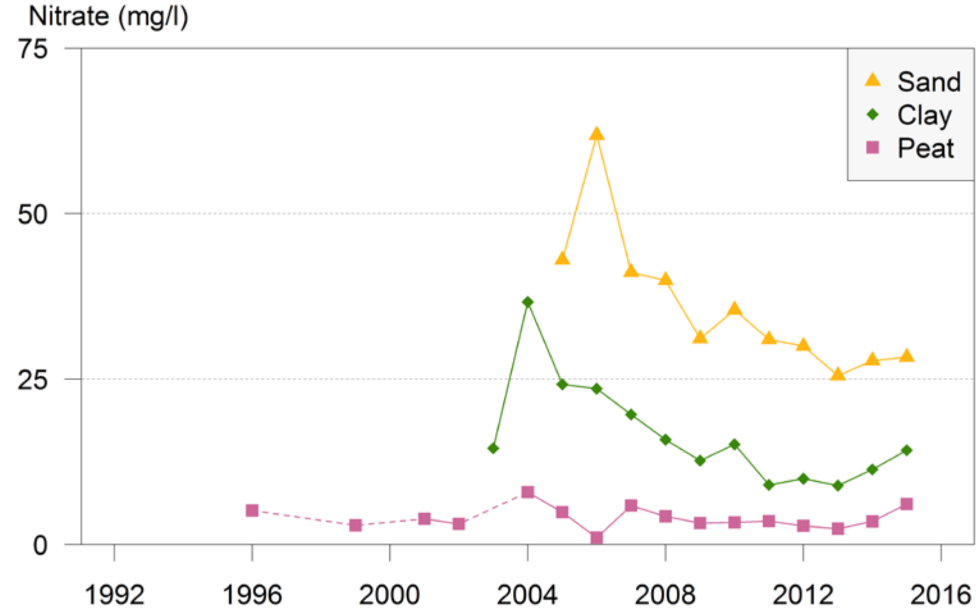

Figure 4.6: Nitrate concentrations (winter average, as NO_3 in mg/l) in ditch water on farms by region in the period 1992-2014

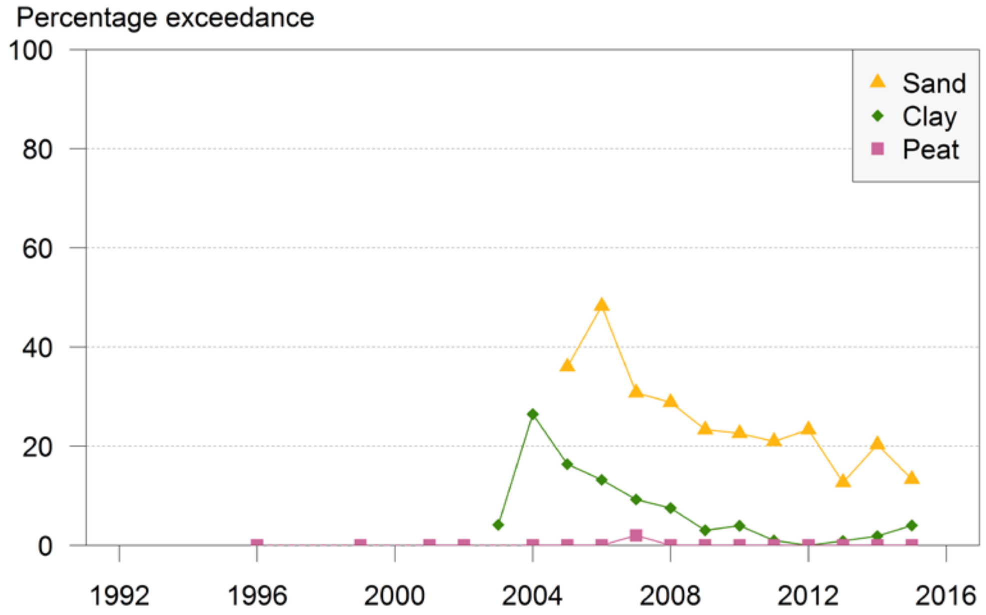

Figure 4.7: Percentage of exceedances of the EU standard of 50 mg/l nitrate in ditch water on farms by region in the period 1992-2014; exceedance based on measured concentrations in winter

The following sections contain information by region, in the form of cumulative frequency diagrams and other representations. With the aid of Figure 4.8, this section explains how such a diagram has to be interpreted. It can be determined from the diagram that in the period 2012-2015 some 25% of the monitored arable farms had an average nitrate concentration below the EU standard of 50 mg/l, while 30% of these farms had a concentration above 100 mg/l. Follow the horizontal 50 mg/l line (EU standard, red line) from the y-axis until it intersects the cumulative frequency curve for the period 2012-2015 (diamonds). Then trace a vertical line downwards from the point of intersection of the 50 mg/l line to the x axis. Where it meets the x-axis is the percentage of farms that had a measured nitrate concentration below 50 mg/l. It is also possible to see from the curve that in this period some 70% of arable farms had an average concentration lower than 100 mg/l, and hence that 30% had a higher concentration. Trace a (vertical) line from the 70% point on the x axis until it intersects the cumulative frequency curve for the period 2012-2015 (diamonds). Then from the point of intersection, trace a horizontal line to the y-axis. Where it meets the y-axis is where the concentration is not exceeded, 100 mg/l in this example.

4.3.2 *Sand and Loess Regions*

Between the first and last two monitoring periods, there was a reduction in the nitrate concentrations in the upper groundwater on arable farms in the Sand Region (see Figure 4.8). Some differences can be seen between the latest and the preceding periods. Nitrate concentrations fluctuate around the same level, but the number of exceedances of the EU standard fell in the latest period. However, this is not expressed either in the median or average nitrate concentrations; both of these are slightly higher in the period 2012-2015.

On dairy farms, nitrate concentrations diminished gradually after the first period. A minimal drop can be seen between the two most recent periods (Figure 4.9), but the largest drop was in the period before 2008. The percentage of dairy farms with a concentration below the EU standard grew from approximately 5% in the period 1992-1995 to almost 80% in the period 2012-2015.

On other livestock farms in the Sand Region, nitrate concentrations also decreased after the first period (Figure 4.10). The lowest concentrations were measured in the period 2012-2015. The percentage of other livestock farms with a period average concentration below the EU standard rose from about 5% in the period 1997-1999 to more than 40% in the period 2012-2015.

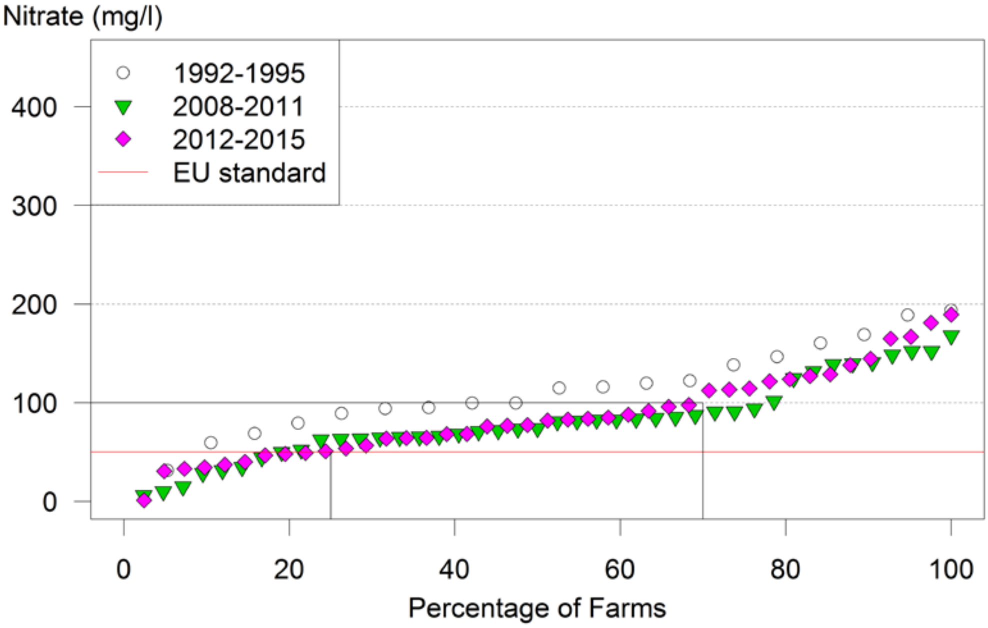

Figure 4.8: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on arable farms in the Sand Region, shown as a cumulative frequency diagram of the farm average per period

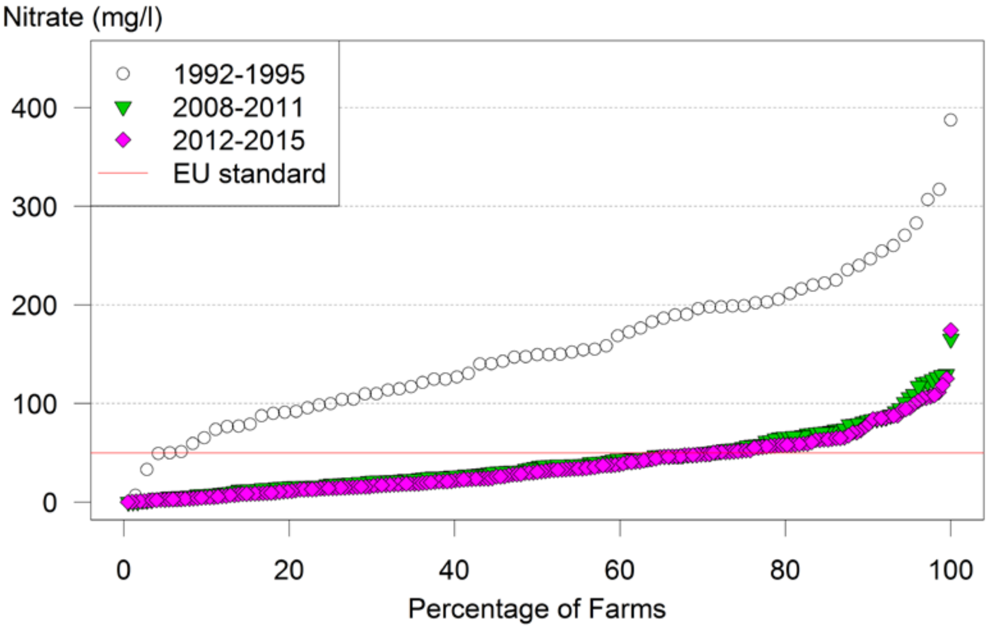

Figure 4.9: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on dairy farms in the Sand Region, shown as a cumulative frequency diagram of the farm average per period

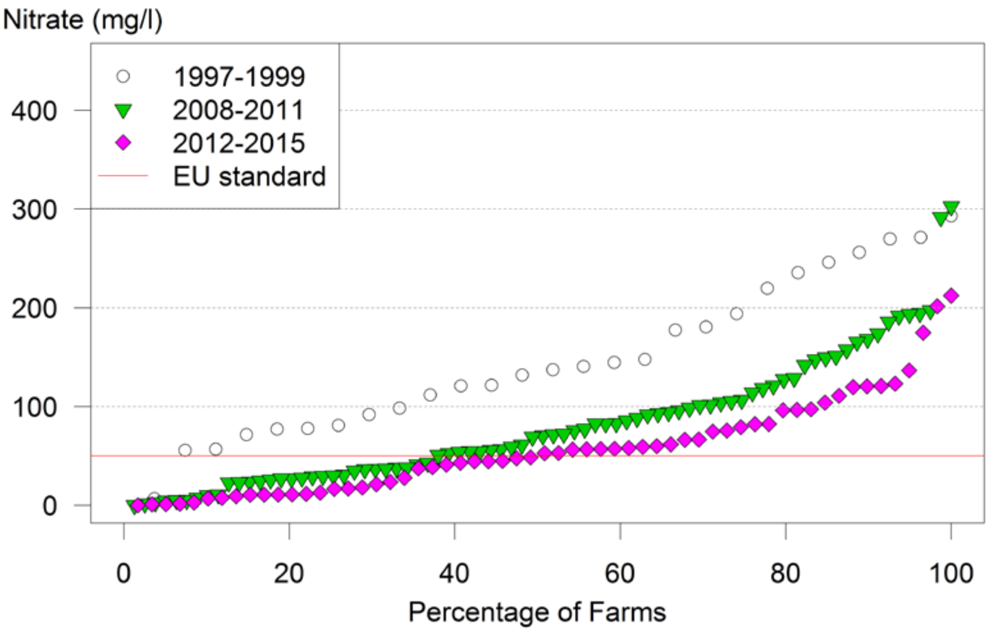

Figure 4.10: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on other livestock farms in the Sand Region, shown as a cumulative frequency diagram of the farm average per period

Nitrate concentrations differ between the three main sand areas in the Sand Region: they are higher in Sand South than in Sand Central and Sand North (Figure 4.11). After 1992, the nitrate concentrations fell in all three sand areas. The concentration in Sand North and Sand Central fell by almost 70% between 1992-1995 and 2012-2015. The average nitrate concentration in Sand South fell by almost 60% in the same period. Compared with the period 2008-2011, there was a greater drop in concentrations in Sand Central and Sand South (12-13%) than in Sand North (10%).

The differences in nitrate concentrations as seen in Figure 4.11 are partly the result of differences in the sample, such as differences in the proportions of farm numbers in each farm type per area. A study conducted in 2012 concluded that the differences in nitrate concentrations observed between the sand areas can largely be explained by the N surplus and land use (which differ depending on the farm type), the distribution of groundwater traps and soil types that occur and the precipitation surplus (Schoumans *et al.*, 2012).

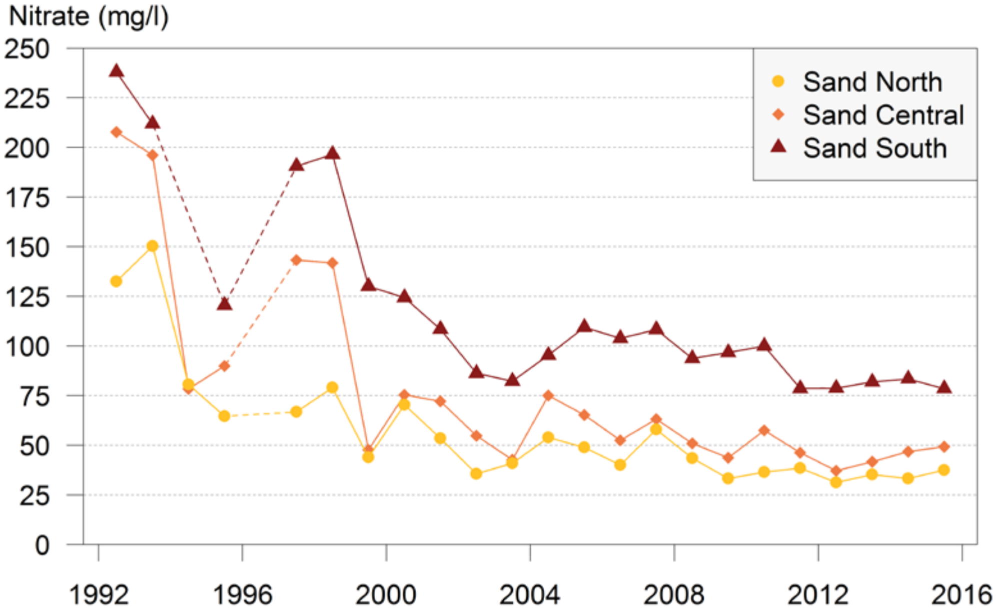

Figure 4.11: Nitrate concentrations (annual average of measured concentrations in mg/l as NO_3) in water leaching from root zones on farms in the Sand North, Sand Central and Sand South areas in the period 1992-2014

The trend in nitrate concentrations in the Loess Region, measured as part of the Soil Moisture Monitoring Network (BVM) of the province of Limburg, is comparable to that shown by the LMM farms in the Sand Region (see Figure 4.12). The concentrations on LMM farms in the Loess Region are higher than those measured in the BVM, however. The discrepancy between the results of the BVM and the LMM is caused by the difference in the area represented by each monitoring network: the province of Limburg's soil moisture monitoring network for the loess plateaux and the LMM for the whole of South-Limburg (Ros, 2014).

The percentage of agricultural plots in the provincial BVM with a nitrate concentration below 50 mg/l increased from less than 10% in the period 1996-1999 to about 50% in 2008 and 2010 together (see Figure 4.13). The percentage of LMM farms with a concentration below 50 mg/l was in the range of 10-20% in the 2002-2003 period (Figure 4.14). During the last two periods, the percentage climbed to approximately 40%.

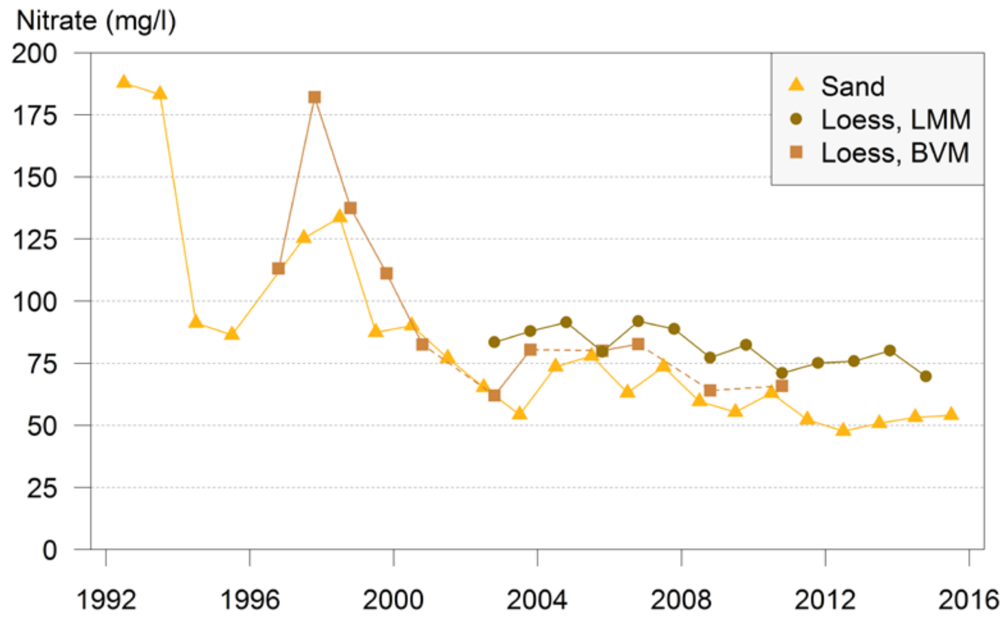

Figure 4.12: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones in the Sand Region (LMM) and in the Loess Region (BVM plots and LMM farms) in the period 1992- 2014
Source: RIVM (Sand/LMM Loess); Province of Limburg (BVM Loess)

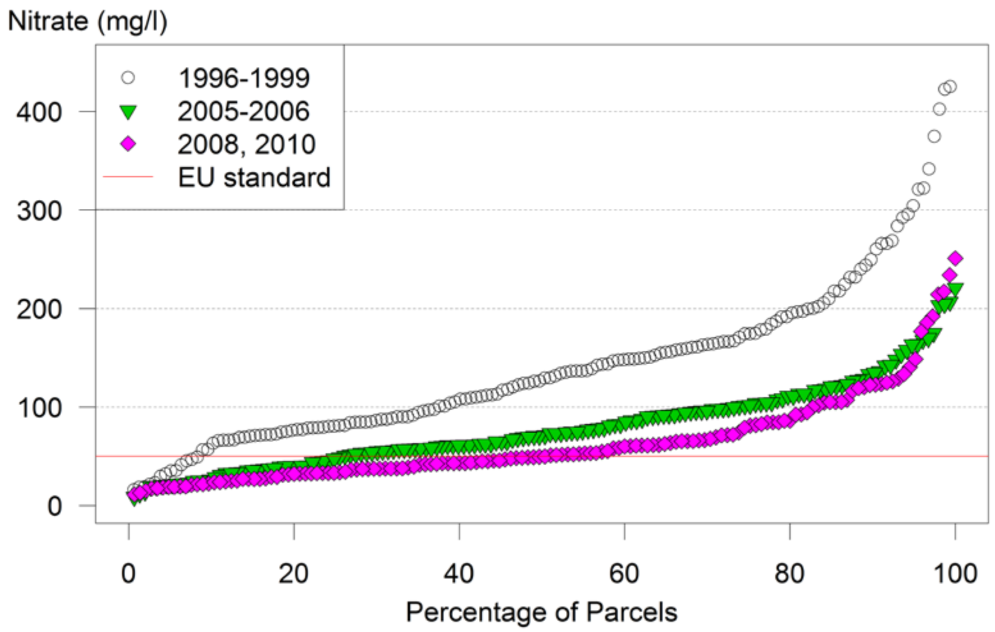

Figure 4.13: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on BVM plots used for farming in the Loess Region, shown as a cumulative frequency diagram of the plot average per period
Source: Province of Limburg

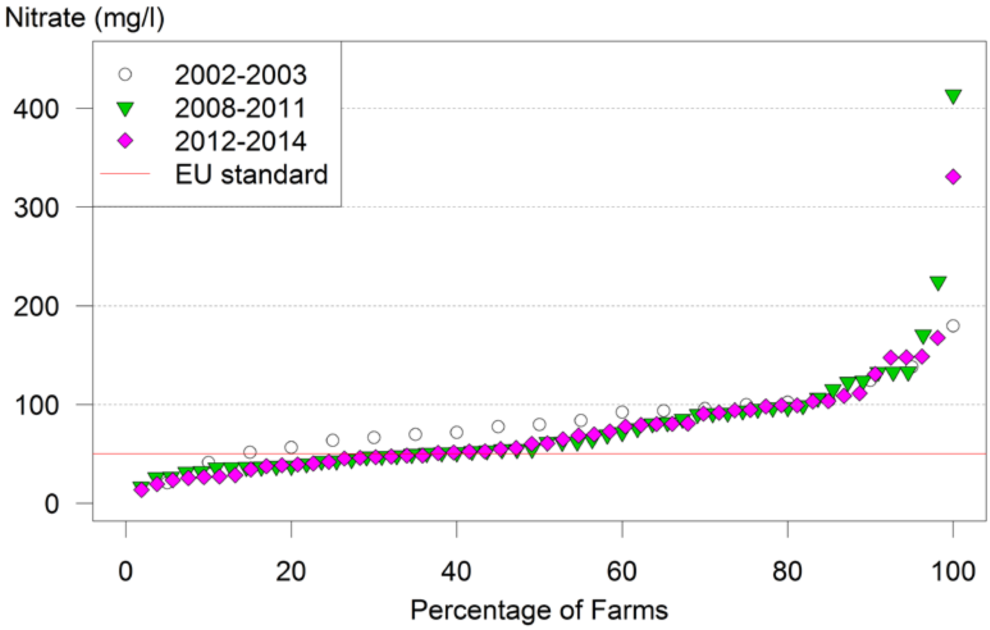

Figure 4.14: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on LMM farms in the Loess Region, shown as a cumulative frequency diagram of the farm average per period
Source: RIVM

4.3.3 *Clay Region*

The nitrate concentration in water leaching from root zones on arable farms in the Clay Region has fallen since 1997-1999 (Figure 4.15). The percentage of arable farms with a nitrate concentration below the EU standard was 60% in 1997-1999, rising to almost 90% in the period 2012-2015 (Figure 4.15). Nitrate concentrations on dairy farms also fell in the period 1997-2015. The percentage of dairy farms that did not exceed the EU standard rose from 70% in 1997-1999 to more than 95% in 2012-2015 (see Figure 4.16).

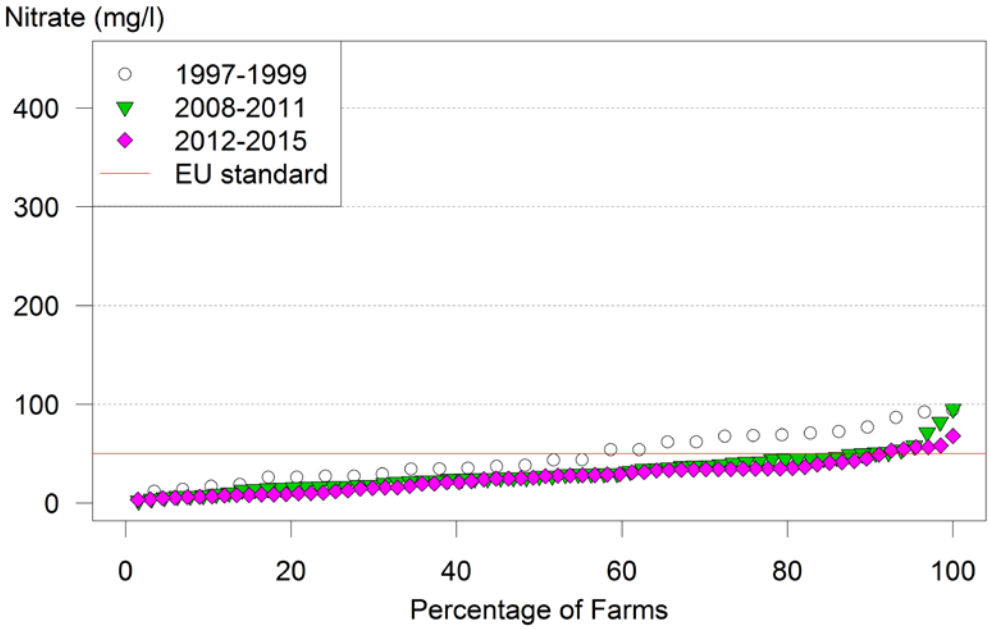

Figure 4.15: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on arable farms in the Clay Region, shown as a cumulative frequency diagram of the farm average per period

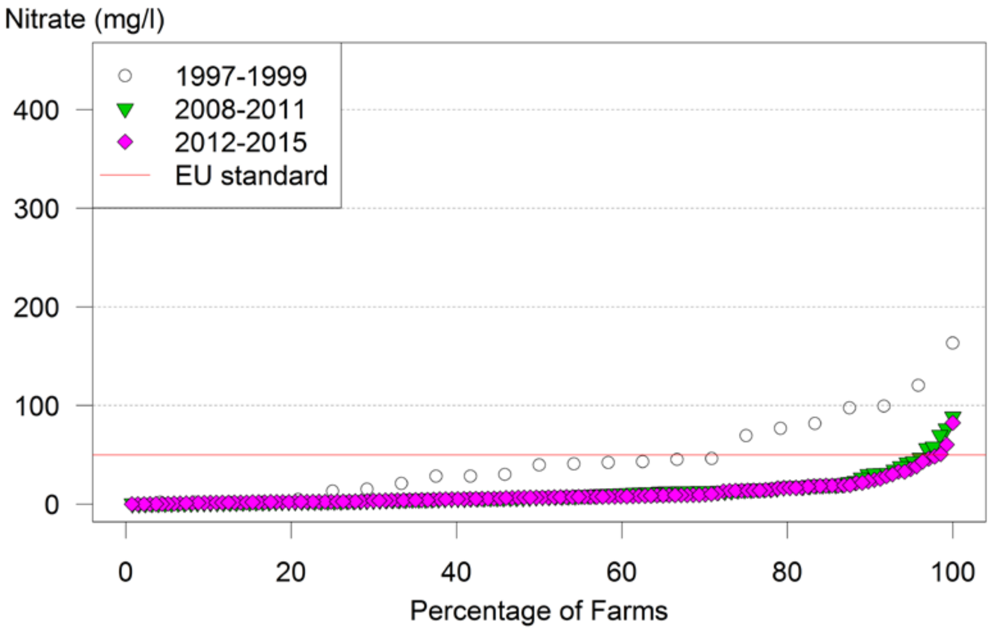

Figure 4.16: Nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on specialist dairy farms in the Clay Region, shown as a cumulative frequency diagram of the farm average per period

4.3.4 *Peat Region*

The average nitrate concentrations in water that leached from root zones were usually below 25 mg/l for dairy farms in the Peat Region (Figure 4.17). There were only isolated cases of the EU standard of 50 mg/l being exceeded, with almost all farms meeting the standard.

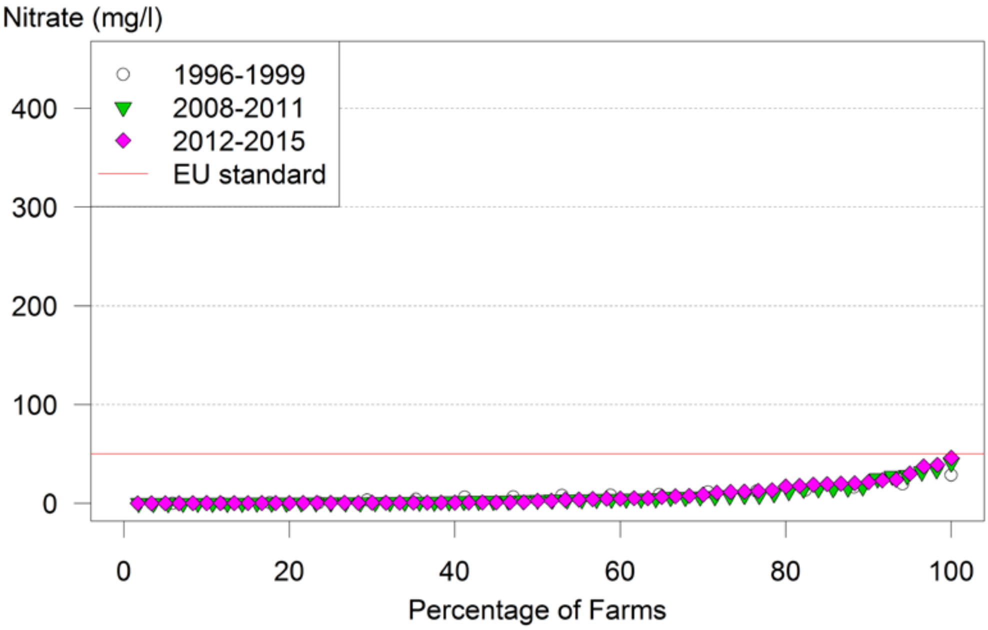

Figure 4.17: Nitrate concentration (as NO3 in mg/l) in water leaching from root zones on dairy farms in the Peat Region, shown as a cumulative frequency diagram of the farm average per period

4.4 Trends in agricultural practice and nitrate leaching in the root zone

The nitrogen surplus and nitrate concentrations in leaching water fell most rapidly on dairy farms in the period 1991/1992-2014/2015 (Figure 4.19), but the nitrogen surpluses and nitrate concentrations also fell on arable farms (Figure 14.18) and other livestock farms (Figure 4.20) during this period. In the Sand Region, for example, nitrogen surpluses on dairy farms dropped by 56% in 1991-2014 and nitrate concentrations by 73% in 1992- 2015, while the respective reductions on arable farms in the same periods were 30% and 24%, and 32% and 63% on other livestock farms.

Developments in the latest periods (from 2007/2008 to 2014/2015) differ depending on the type of farm and the region.

In the Clay Region, nitrate concentrations in the period 2012-2015 on all types of farms were lower than in the period 2008-2011 (-12% to -61%), whereas nitrogen surpluses were the same or only very slightly lower (-6 to +43%). The precise cause of this is unclear, but there is no reason to assume that the drop in the concentration is caused by precipitation or sampling effects since this trend is also visible in the standardised concentration which takes account of these effects (Figure 4.4).

The picture in the Sand Region is varied. On dairy and other livestock farms, nitrate concentrations are still falling (-10% to -25%), but this is no longer the case on arable farms (+7%) despite the fact that the nitrogen surplus on arable farms fell again in the latest period (-22%) to 1999-2002 levels. The surplus on other livestock farms actually rose in the latest period (+25%). It is possible that the impact of the change may only be noticeable in the leaching water in the following period. Both nitrogen surpluses and nitrate concentrations on dairy farms are falling, with reductions of 10% and 5% respectively.

In the Peat Region (dairy farms only), the impact of the drop in the nitrogen surplus on nitrate concentrations is unclear since nitrate concentrations in this area are low due to the soil type (peat) and the hydrological features of the soil (high groundwater levels and poor drainage) which result in relatively high levels of denitrification.

Data on developments in nitrogen surpluses in the Loess Region are as yet sparse. Surpluses and nitrate concentrations on arable farms both declined in the last periods, by 22% and 9% respectively. On dairy farms the reduction in previous periods seems to have stabilised in the last two.

The effects of the Fifth Action Programme (2014-2017) are as yet barely visible in the numbers, both for nitrogen surpluses and nitrate concentrations in leaching water. This is because 2014, the first year of the Fifth Action Programme, was the last year to be included in this report. In addition, the effects of measures taken in any one year are rarely fully evident in the leaching water the following year.

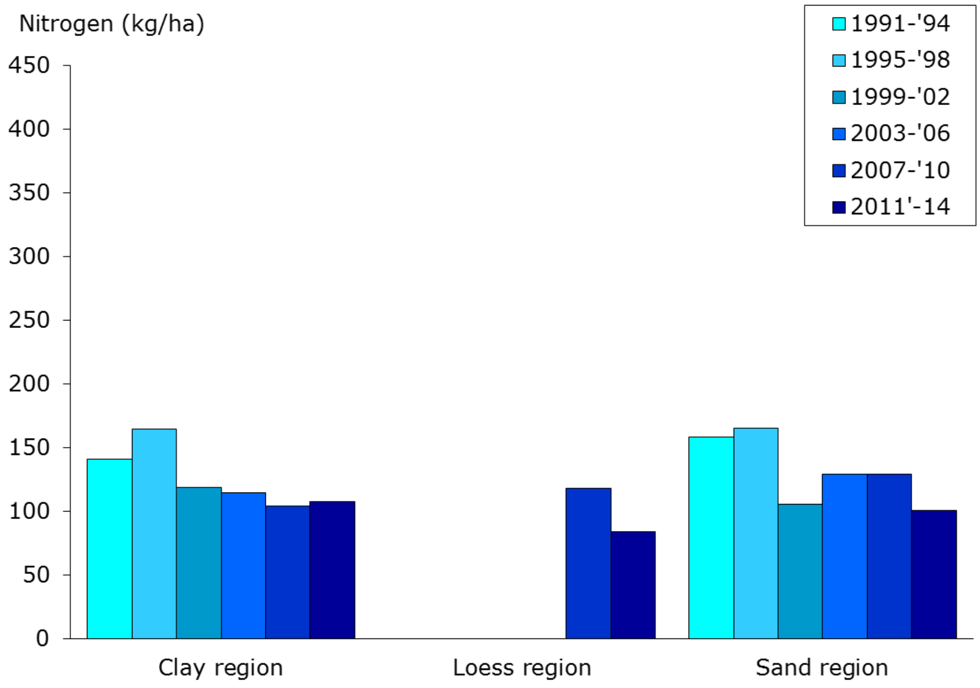

Figure 4.18a: Average nitrogen surplus on the soil surface balance of arable farms by region and period (calculated according to the LEI method, see Section 2.3.3)

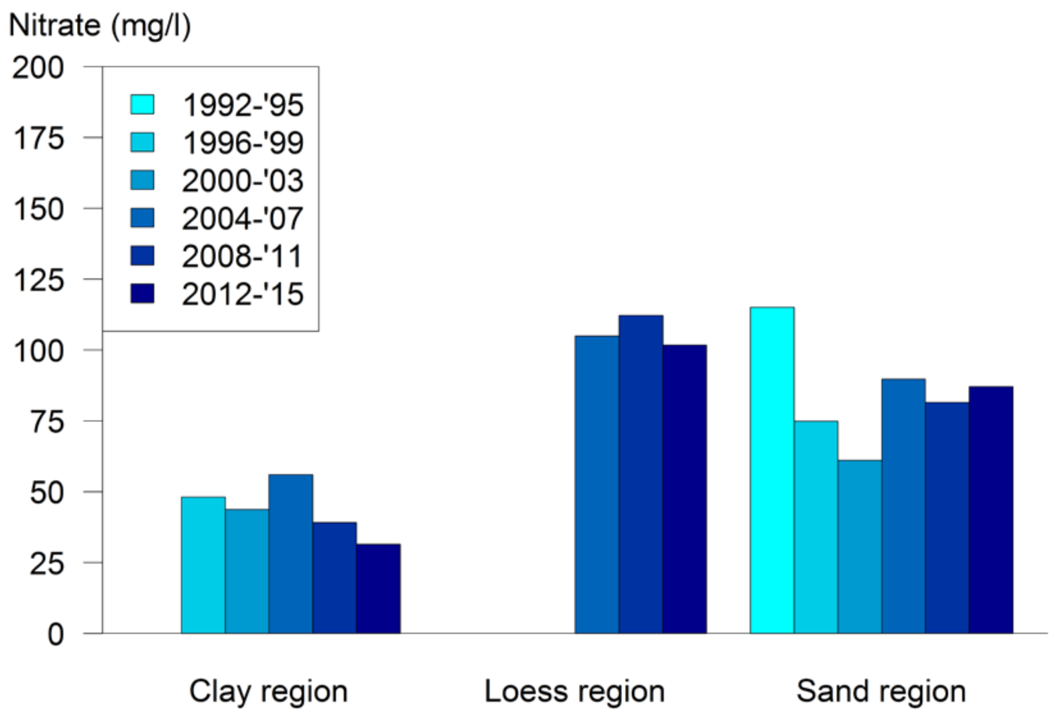

Figure 4.18b: Average nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on arable farms by region and period

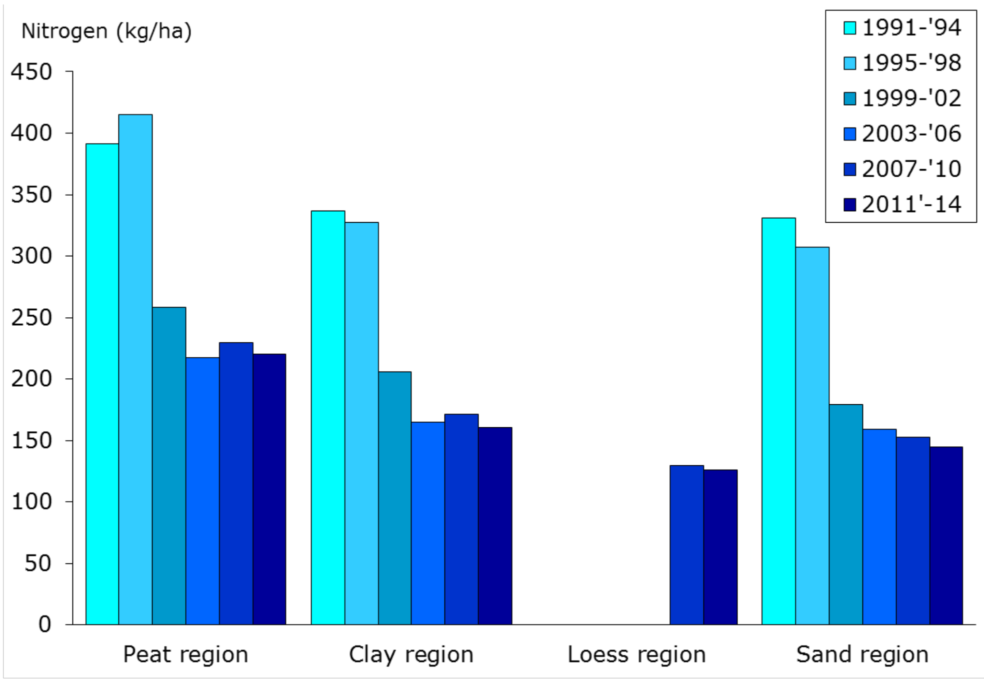

Figure 4.19a: Average nitrogen surplus on the soil surface balance of dairy farms by region and period (calculated according to the LEI method, see Section 2.3.3)

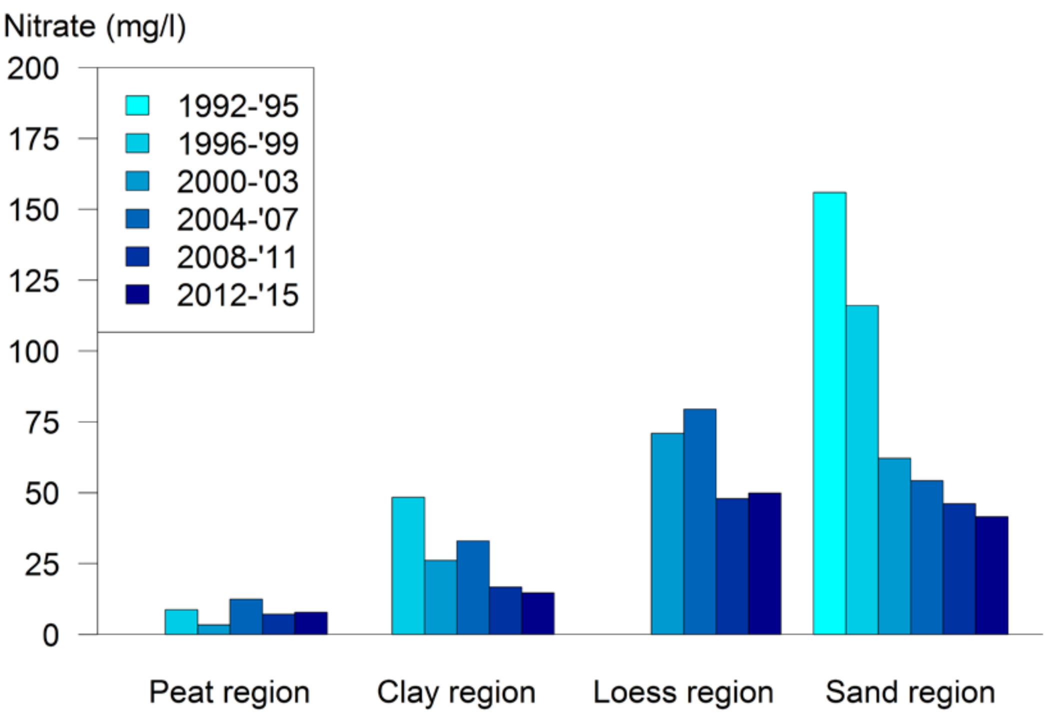

Figure 4.19b: Average nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on dairy farms by region and period

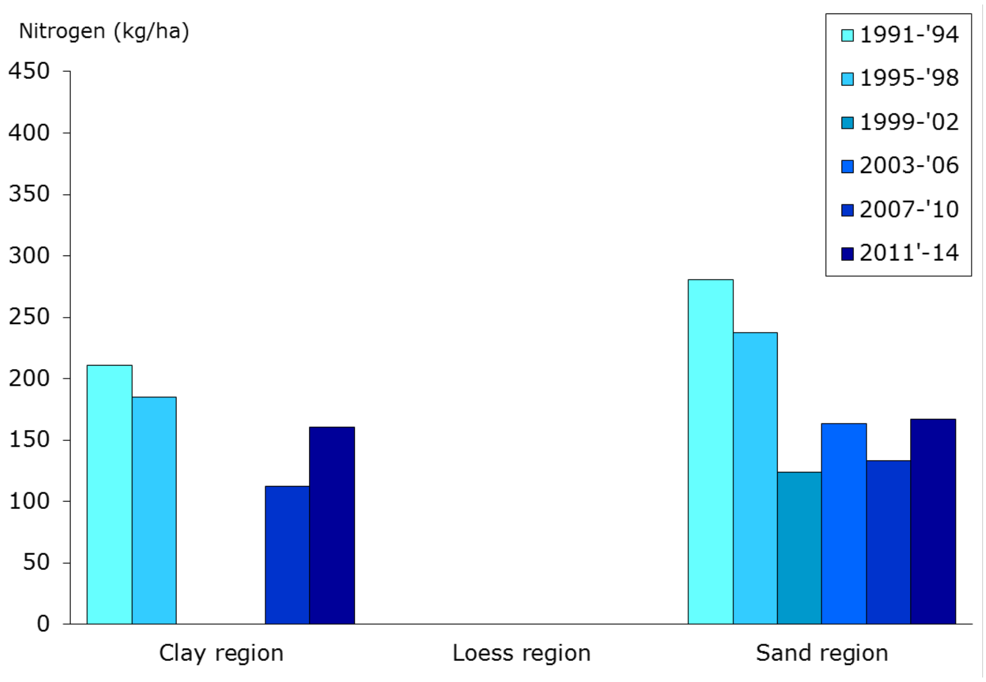

Figure 4.20a: Average nitrogen surplus on the soil surface balance of other livestock farms by region and period (calculated according to the LEI method, see Section 2.3.3)

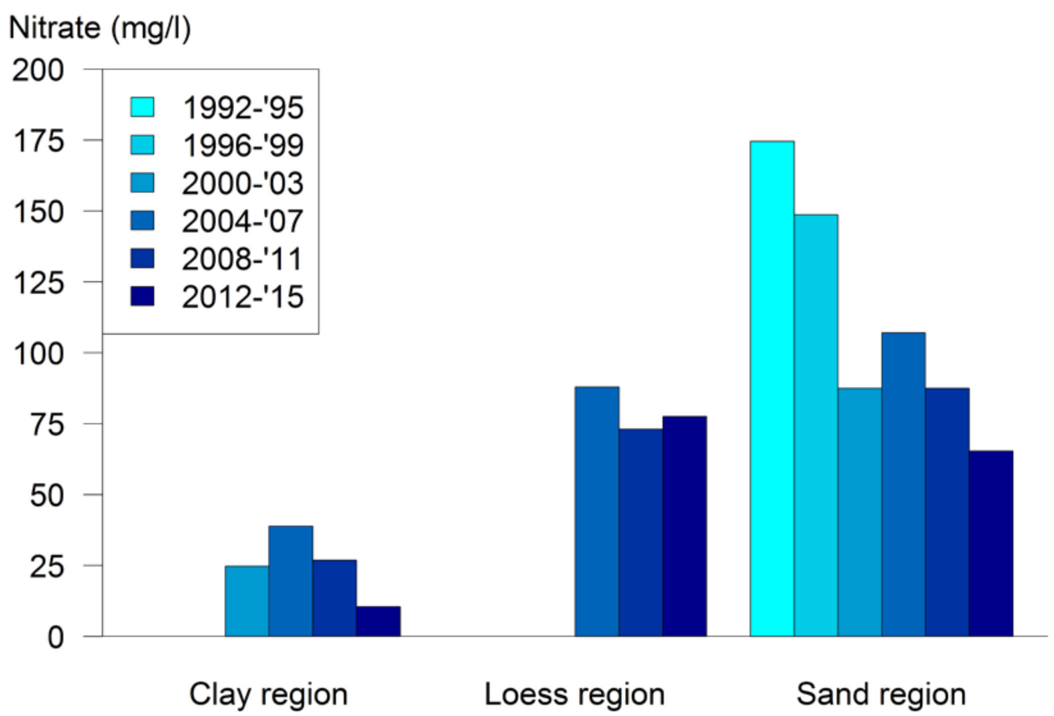

Figure 4.20b: Average nitrate concentration (as NO_3 in mg/l) in water leaching from root zones on other livestock farms by region and period

4.5 References

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5 Groundwater quality

5.1 Introduction

The nitrate concentration in groundwater in the Netherlands shows a wide variation, both between different locations and in terms of depth. The variation between locations is only partly accounted for by the variation in land use and differences in nitrogen emissions. Other causes are the variations in net precipitation, soil type, and the geohydrological characteristics of aquifers (see also Chapter 4).

In general, the nitrate concentration in groundwater is low under peat soil, relatively high under sand soil, and average under clay soil (Van Vliet *et al.*, 2010, Reijnders *et al.*, 2004). Agriculture is a significant source of nitrogen in groundwater; nitrate concentrations below farmland are therefore higher than below land used for other purposes. The nitrate concentration usually decreases as the sampling depth of the groundwater increases. This is caused by the reduction in nitrate concentration during transport (denitrification), the mixing of waters of different ages, and the lateral transport due to the presence of poorly draining layers that partially or completely inhibit downward movement.

This chapter comprises three parts, each dealing with one of the three depths at which groundwater is monitored in the Netherlands: 5-15 metres, 15-30 metres and more than 30 metres. For the first two depth levels, we look at both the groundwater as a whole, as per the Water Framework Directive, and also, specifically, the groundwater under farmland. It is not possible to do this for the deepest groundwater (> 30 m) because this would involve information on drinking water extraction sites where the land use is mixed.

5.2 Nitrate in groundwater at a depth of 5-15 metres

In the period 1984-1996, the nitrate concentration in groundwater at a depth of 5-15 metres below the surface for Dutch farm soil was on average 24-28 mg/l in 1996 (Figure 5.1), about 10 years after the peak in nitrogen surplus in the national nitrogen balance (Figure 3.3). After 1996, the nitrate concentration fell and the average concentration in 2014 was the lowest in the series, at 19 mg/l. In 2008, there was a strikingly low average nitrate concentration for farm soil. This is attributable to two wells that had high nitrate concentrations (around 150 mg/l) for almost the entire monitoring period, but where precisely in 2008 virtually no nitrate was detected. An inspection of the data indicates no question of extreme values (a low value had been measured before), and there is no evidence of a measuring mistake.

Nature areas follow the same pattern as agricultural areas but at a lower level. The nitrate concentration rose to 14 mg/l at the turn of the century, followed by a drop to 9 mg/l in 2014. The reduction coincides with the almost 60% reduction in ammonia emissions from livestock manure and artificial fertiliser since the early 1990s (see Section 3.4.5.3).

In areas used for other purposes (including orchards and urban areas), the nitrate concentration was comparable with that in nature areas, if following an erratic pattern. The rise in nitrate concentrations between 2001 and 2014 is almost entirely due to one monitoring site where, between 2013 and 2014, the nitrate concentration rose from less than 30 mg/l to more than 800.

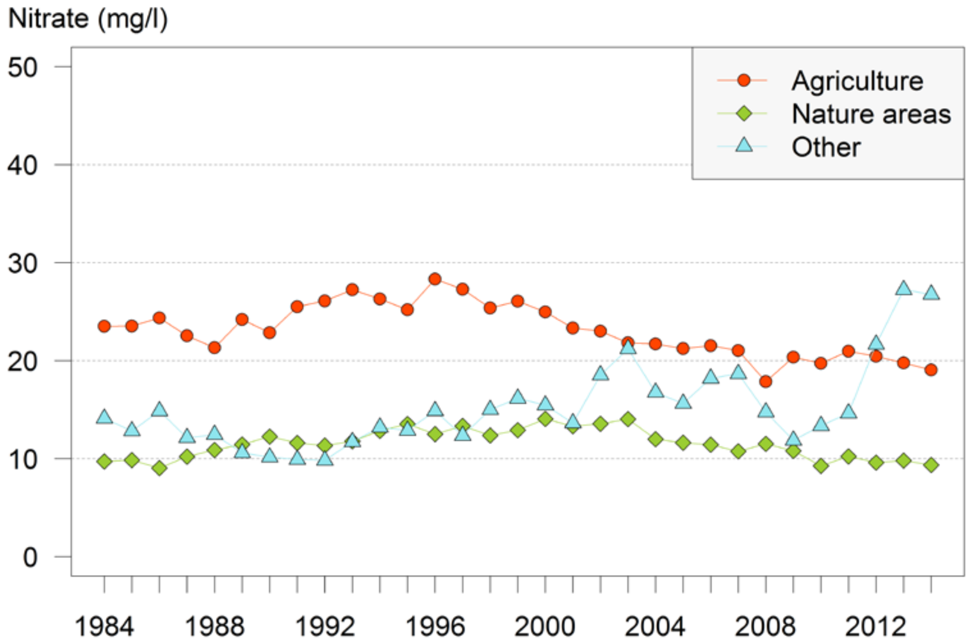


Figure 5.1: Average annual nitrate concentration (mg/l) in groundwater at a depth of 5-15 metres below the surface in the Netherlands by land use type

The nitrate concentration in groundwater originating from farming in the Sand Region (30 to 45 mg/l) was higher than in the Clay and Peat Regions (< 10 mg/l and < 5 mg/l respectively; see Figure 5.2). Prior to 1992, concentrations in agricultural areas were mostly below 40 mg/l, whereas in the period 1992-2000, concentrations hovered between 42 and 47 mg/l. After 2001, the average nitrate concentration remained below 40 mg/l, gradually falling to 32 mg/l in 2014.

Between 2012 and 2014, the EU standard of 50 mg/l for nitrate was exceeded at 12% of the groundwater monitoring wells at a depth of 5 to 15 metres (Table 5.1). For agricultural areas, the figure was 13%; for nature areas, about 6%; and for other areas about 12% (Table 5.1). There were slight variations from year to year (Figure 5.3). The striking feature is the slight increase in exceedances of the EU standard of 50 mg/l in agricultural areas on sand (Figure 5.4) between 2009 and 2014, whereas the average concentration was falling (Figure 5.2). The drop in nitrate concentrations is primarily due to a drop in a small number of wells with extremely high nitrate concentrations. As a result, the trend in average nitrate concentrations and the trend in the number of exceedances appear to be independent of one another.

The EU standard was exceeded at 19% of the monitoring sites in farming areas in the Sand Region; one monitoring site did not meet the standard in the Clay Region (2%); and there were no more exceedances in the Peat Region (Figure 5.4).

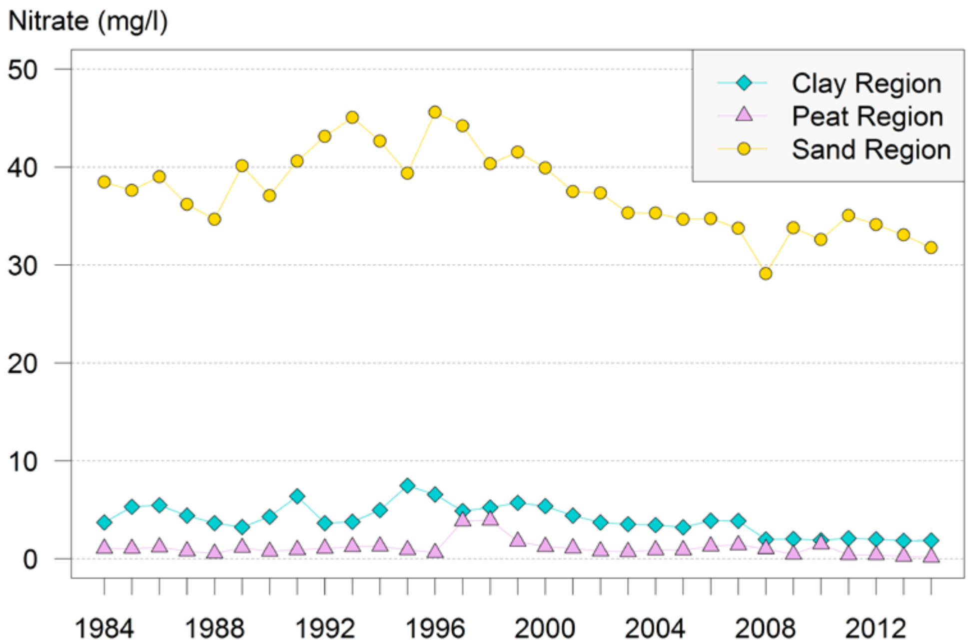


Figure 5.2: Average annual nitrate concentration (mg/l) in groundwater at a depth of 5-15 metres below the surface in agricultural areas by region

Table 5.1: Percentage of monitoring sites in groundwater at a depth of 5-15 metres per nitrate concentration class in the various reporting periods[1]

Nitrate class (NO_3 mg/l)	All monitoring sites			Monitoring sites in agricultural areas		
	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
0 - 15 mg/l	79	82	81	80	82	84
15-25 mg/l	4	3	3	2	3	0
25 - 40 mg/l	2	4	3	1	2	2
40 - 50 mg/l	3	0	1	2	1	1
> 50 mg/l	13	11	12	15	12	13
Number of monitoring sites	348	348	348	219	219	219

[1] The total percentage could be higher or lower than 100 because of rounding.

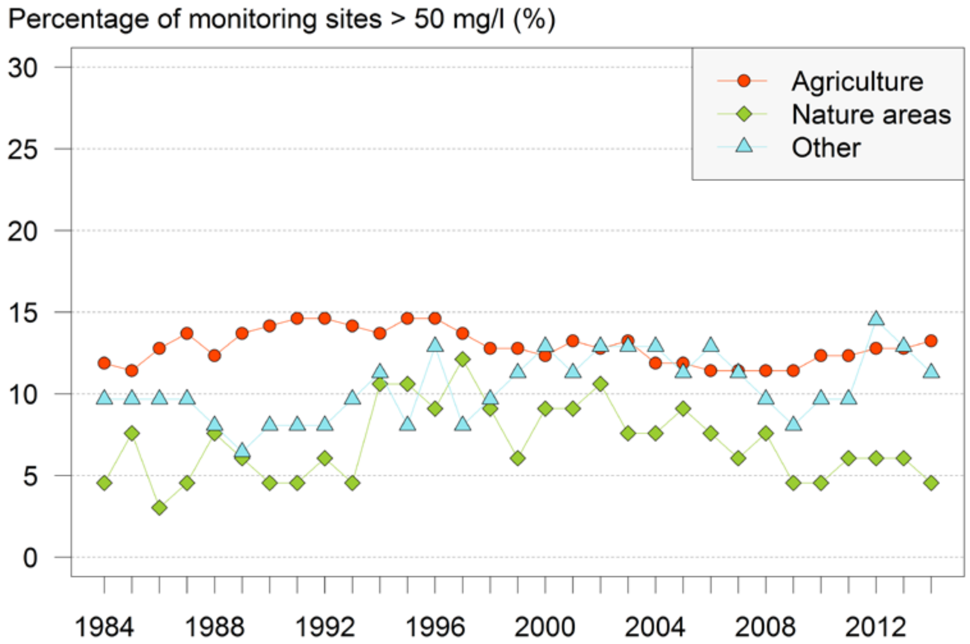


Figure 5.3: Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at a depth of 5-15 metres below the surface by land use type

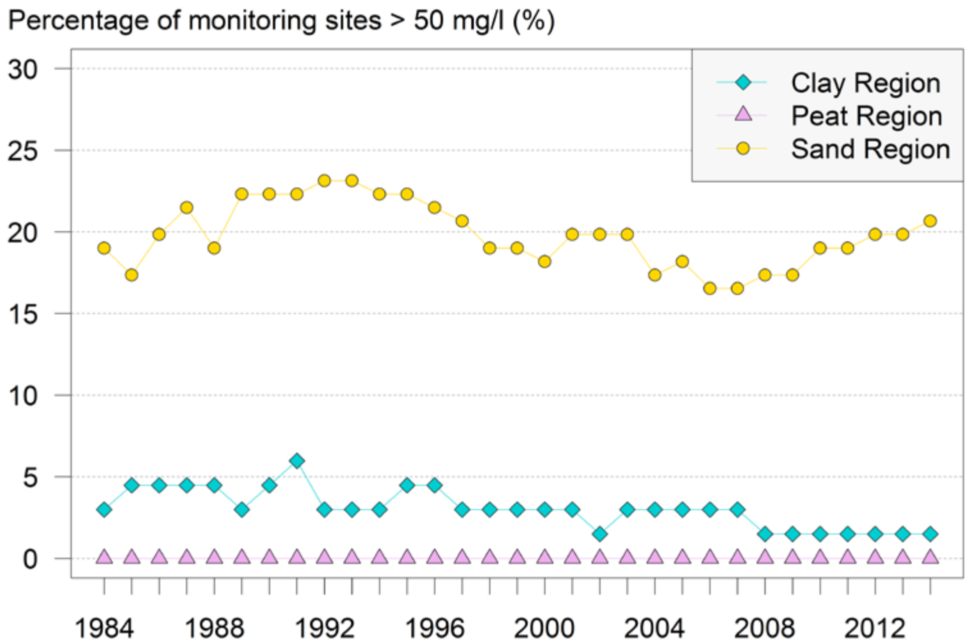


Figure 5.4: Exceedance of the EU standard of 50 mg/l for nitrate in groundwater in agricultural areas at a depth of 5-15 metres below the surface by region

Most monitoring sites (about 73%) showed no change in nitrate concentration between the last two reporting periods (2008-2011 and 2012-2014; Table 5.2). The percentage of sites with a decrease in the concentration was higher than the percentage showing an increase between the last two periods.

Table 5.2: Percentage of monitoring sites in groundwater at a depth of 5-15 metres with increasing or decreasing nitrate concentrations between various reporting periods[1]

Change (NO_3)	All monitoring sites		Monitoring sites in agricultural areas	
	'92-'95/ '08-'11	'08-'11/ '12-'14	'92-'95/ '08-'11	'08-'11/ '12-'14
Large increase (% > 5 mg/l)	7	8	5	9
Small increase (% 1-5 mg/l)	4	4	3	2
Stable (% ± 1 mg/l)	67	73	73	76
Small decrease (% > 1-5 mg/l)	4	6	3	5
Large decrease (% > 5 mg/l)	18	9	16	9
Number of monitoring sites	348	348	219	219

[1] The total percentage could be higher or lower than 100 because of rounding.

Of the three sand areas, North, Central and South, the nitrate concentration is clearly the highest in Sand South (around 75 mg/l) (Figure 5.5). The concentration is lower in Sand Central (about 17 mg/l) and lowest in Sand North (around 12 mg/l). Very low levels of nitrate were found at most of the monitoring sites in Sand North and Sand Central (Table 5.3). The concentration in these areas is determined by a small number of sites with elevated nitrate concentrations. In Sand South, there were roughly the same number of monitoring sites with low concentrations as there were monitoring sites with nitrate concentrations exceeding 10 mg/l. Other soil types also occur in the sand areas. If only the monitoring sites on sandy soil are considered, the nitrate concentrations are slightly higher. Moreover, Sand South has the most wells where the EU standard is exceeded (Figure 5.6).

Table 5.3: Number of wells per nitrate concentration class in agriculture per sand area in the Sand Region at a depth of 5-15 metres for the period 2012-2014

Nitrate class (NO_3 in mg/l)	Sand North	Sand Central	Sand South
<1 mg/l	36	28	17
1 to 10 mg/l	2	3	2
>10 mg/l	8	7	17
Total number of wells	46	38	36

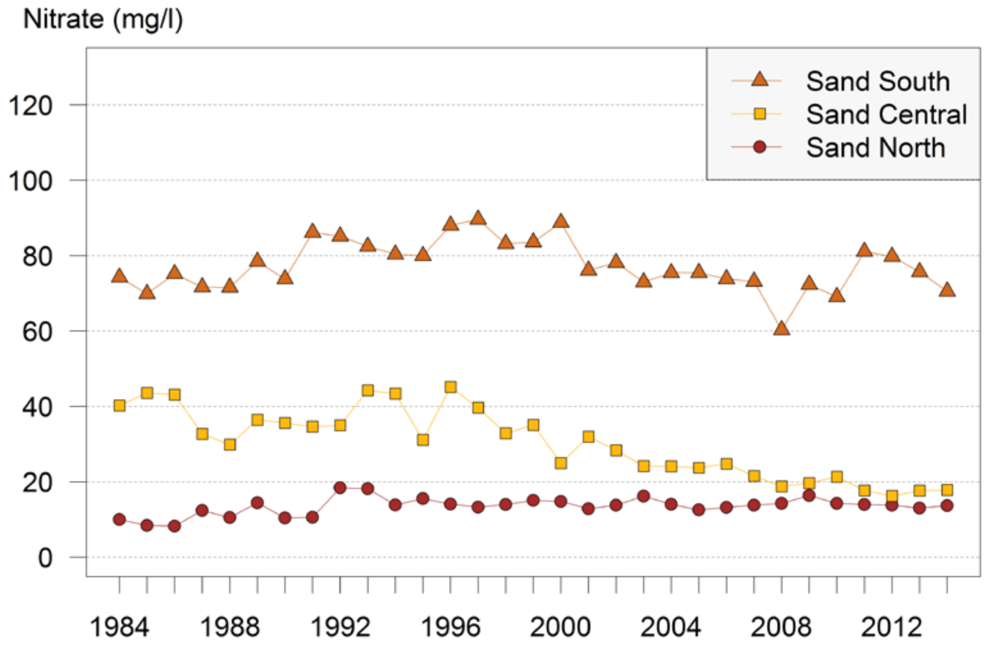


Figure 5.5: Nitrate in groundwater under farming areas at a depth of 15-30 metres below the surface by sand area

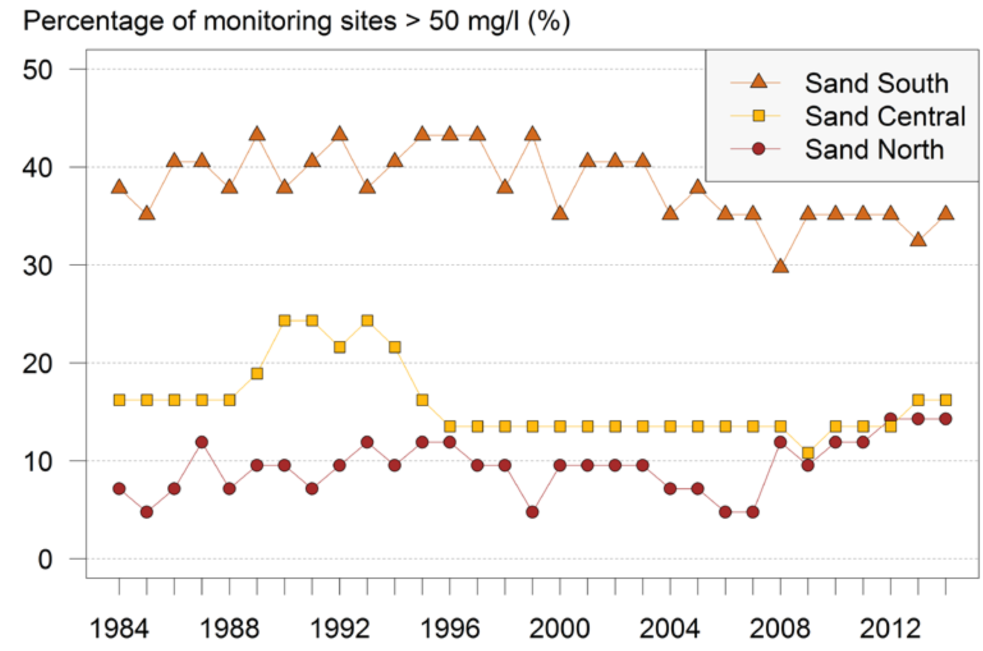


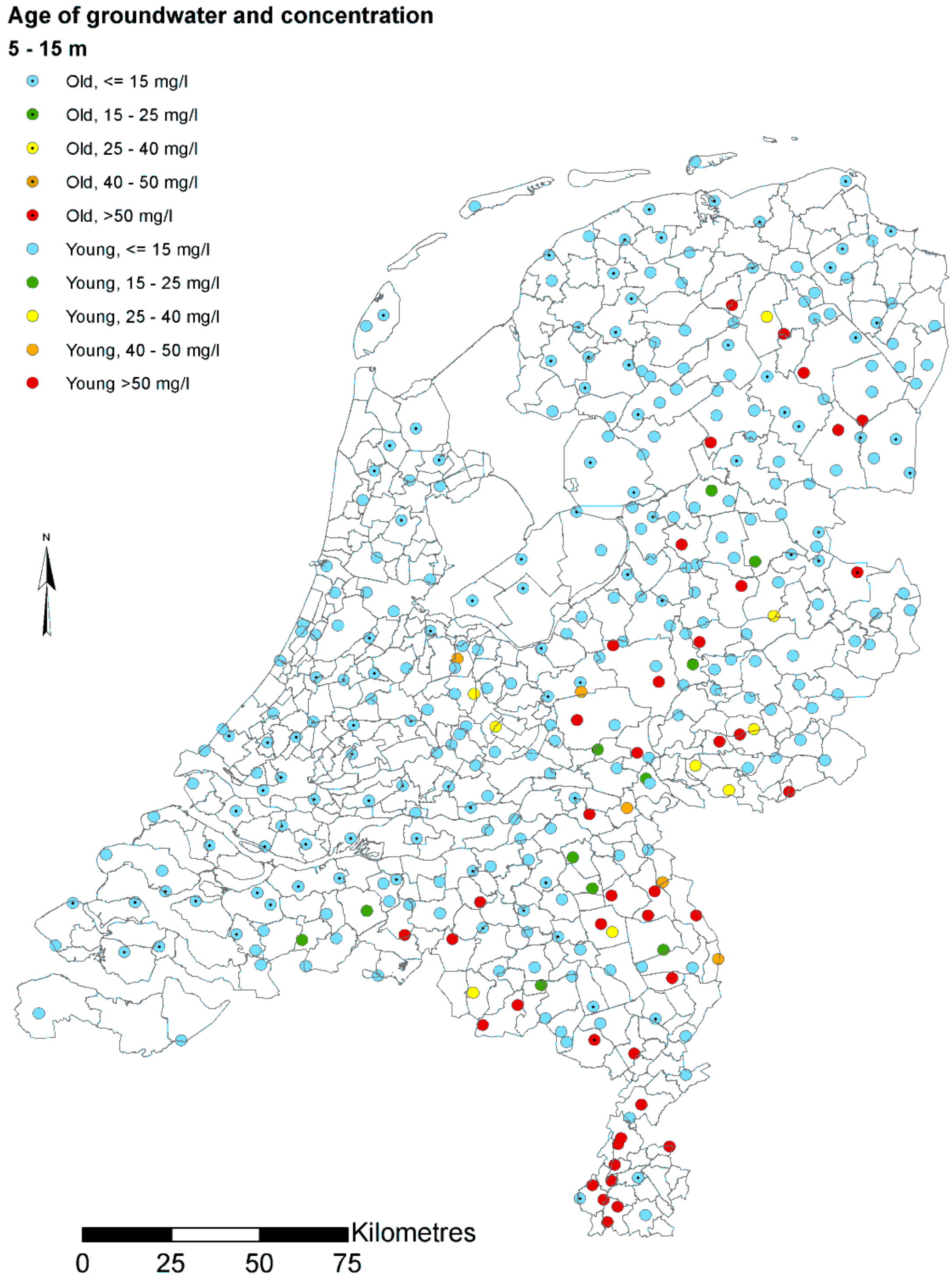
Figure 5.6: Exceedance of the EU standard of 50 mg/l for nitrate in groundwater under farming areas at a depth of 5-15 metres below the surface by sand area

Note to Figure 5.5: The nitrate concentration in Sand Central is lower in Figure 5.5 than in the same figure in Baumann *et al.* (2012). The classification into LMM regions and areas has changed since the previous report (Section 2.3.2). For example, part of the sandy soils that were previously in the Sand North area are now in the Sand Central area, and some sandy soils that were previously in Sand Central are now in Sand West. As a result, the average nitrate concentration in Sand Central is lower than four years ago, and that in Sand North is slightly higher.

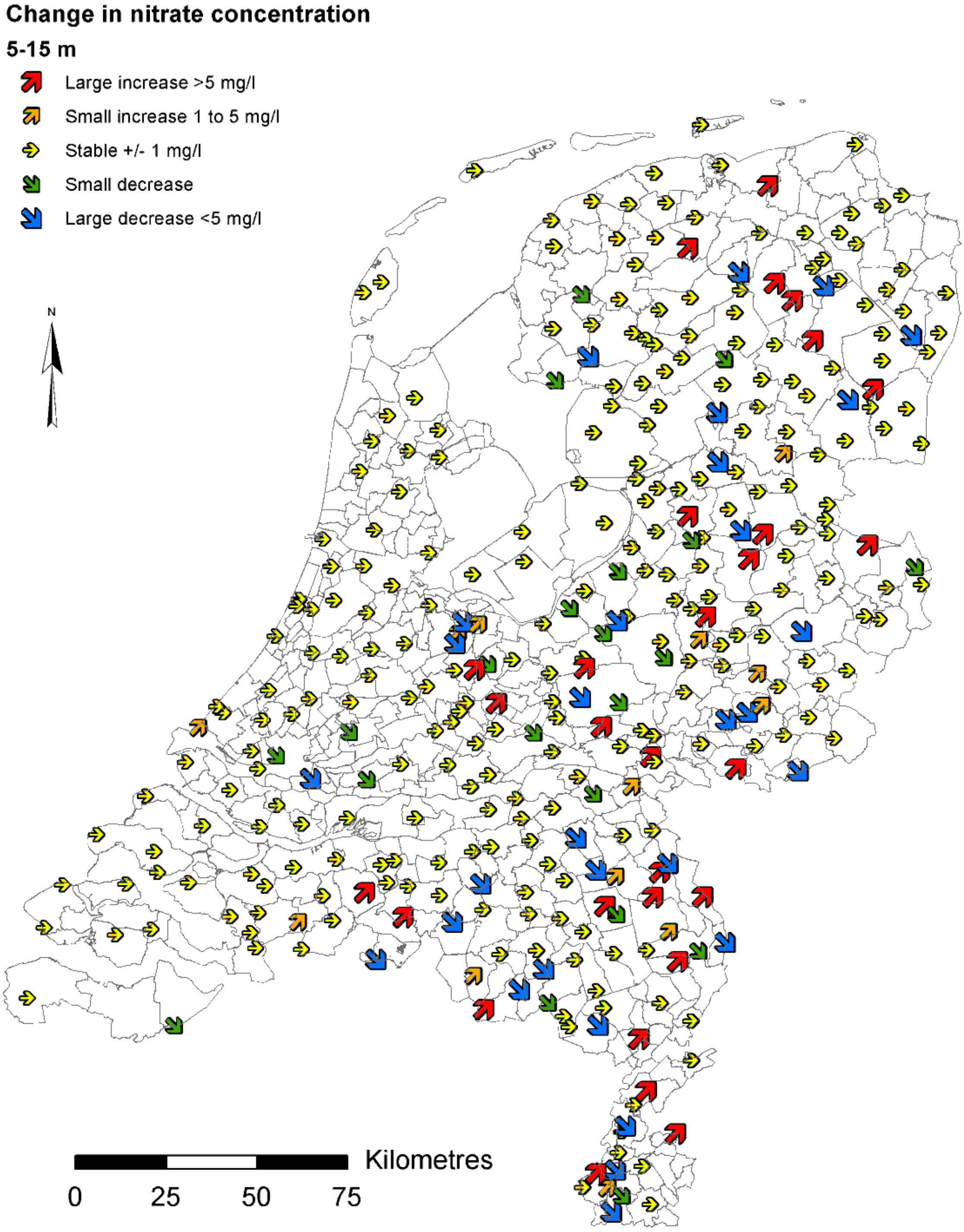
A second consequence of the new classification is that the areas follow the boundaries of the sandy soil more closely. As a result, there is now less clay and peat soil in the sand areas, so the differences between the trend lines for the areas as a whole and solely for the sandy soils in the areas have become smaller.

The monitoring sites can be divided into those with wells containing old groundwater (> 25 years) and young groundwater (< 25 years) (Map 5.1). In the wells containing old groundwater, this water is usually from artesian aquifers in which nitrate concentrations are low (< 15 mg/l), whereas in those containing young groundwater, it is from phreatic aquifers which are influenced by activities on the surface. High nitrate concentrations (> 50 mg/l) are found in young groundwater in the sandy and loess soils (the eastern and southern parts of the Netherlands).

Most changes occur in sandy and loess soils (Map 5.2), with increases as well as decreases in nitrate concentrations being found.



Map 5.1: Average nitrate concentration in groundwater at a depth of 5-15 metres for the period 2012-2014; "young" refers to groundwater younger than 25 years, "old" means older than 25 years



Map 5.2: Change in average nitrate concentration in groundwater at a depth of 5-15 metres for the period 2008-2014; the change shown here is the difference between averages for the 2008-2011 and 2012-2014 periods

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

The nitrate concentration at monitoring sites between 15 and 30 metres below the surface is lower than at shallow sites. Until 1998, nitrate concentration was highest under agricultural land, followed by land used for other purposes and nature areas (Figure 5.7). After 1998, the nitrate concentration in land used for other purposes rose substantially, so that it is now higher there than in agricultural areas. These higher values are caused by the fact that a low nitrate concentration was found at one monitoring site up to 1998 (varying between 0 and 6 mg/l) but 202 mg/l was measured there in 1999. During the monitoring period, this concentration rose to 388 mg/l in 2014. The increase in the nitrate concentration in the “other” group is determined entirely by this one well. If this is left out of the equation, the nitrate concentration remains roughly stable at around 5 mg/l, as in the period preceding 1999.

The average concentration for agricultural areas is about 5 mg/l. The pattern is erratic up to 2002, with the nitrate concentration dropping slightly thereafter. In nature areas, the average nitrate concentration is 3 mg/l and shows no trend.

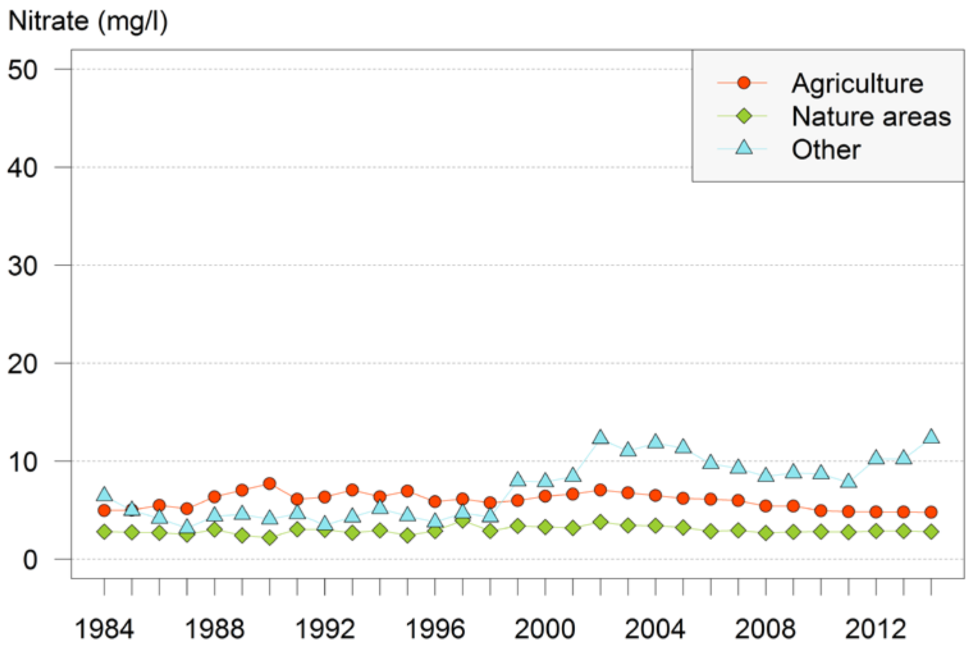


Figure 5.7: Average annual nitrate concentration (mg/l) in groundwater at a depth of 15-30 metres below the surface by land use type

The nitrate concentration in groundwater originating from farming in the Sand Region is higher than in the Clay or Peat Region, where virtually no nitrate is detected at this depth (Figure 5.8). After 2002, the nitrate concentration relating to agriculture in the Sand Region fell from approximately 12 mg/l to approximately 7 mg/l in 2014.

Between 2012 and 2014, the EU standard of 50 mg/l for nitrate was exceeded at 3% of the groundwater monitoring sites at a depth of 15-30 metres. For agricultural areas, the figure was 2%, and for other areas, about 5%; with no exceedances in nature areas (Figure 5.9 and Table 5.4). There were slight variations from year to year.

The percentage of monitoring sites in agricultural areas in the Sand Region where the EU standard for nitrate was exceeded shrank from 7% to 5%, while no exceedances of the EU standard were found in the Clay and Peat Regions (Figure 5.10).

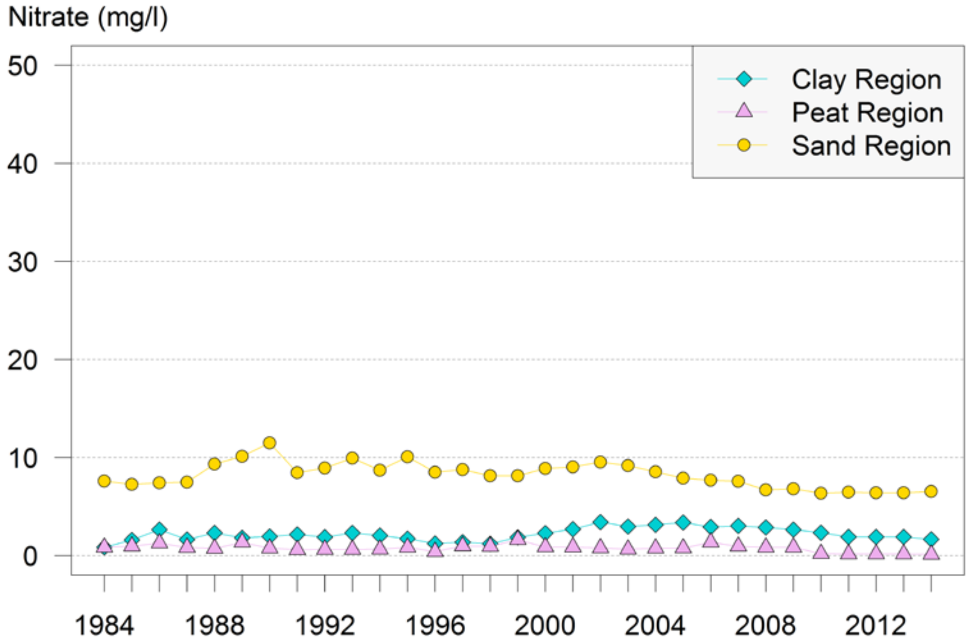


Figure 5.8: Average annual nitrate concentration (mg/l) in groundwater at a depth of 15-30 metres below the surface in agricultural areas by region

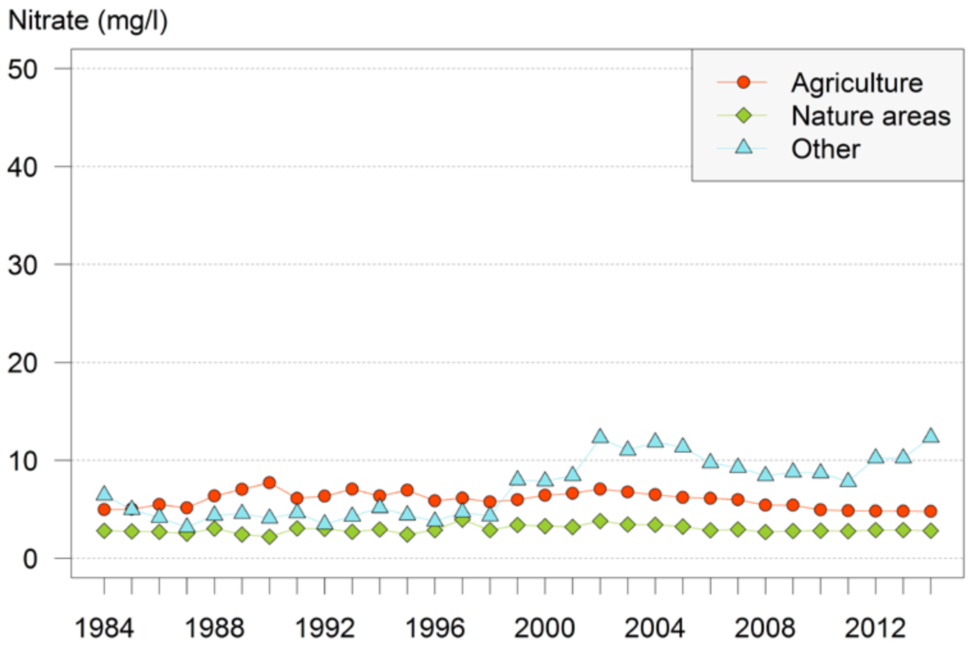


Figure 5.9: Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at a depth of 15-30 metres below the surface by land use type

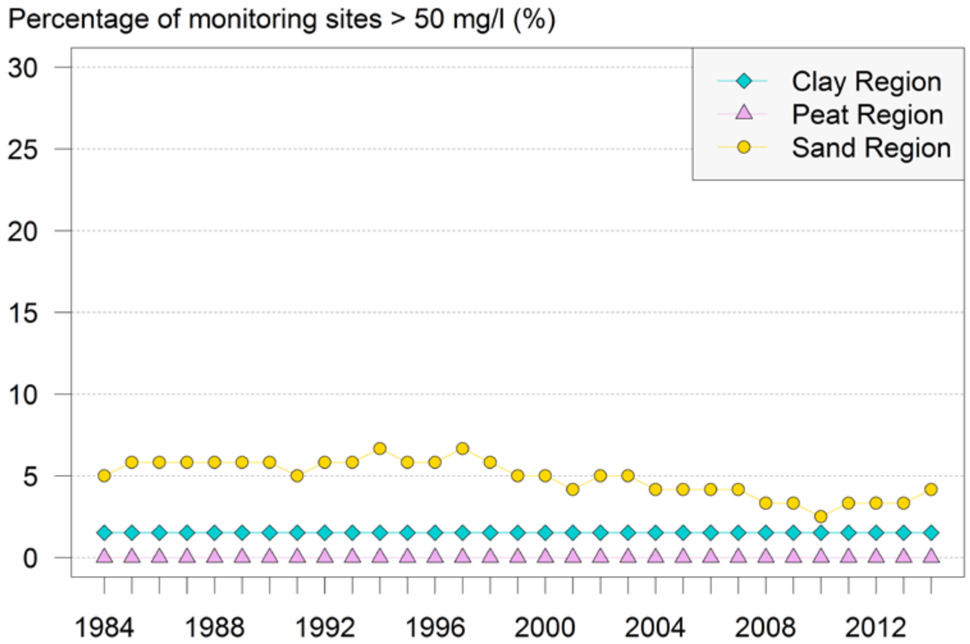


Figure 5.10: Exceedance of the EU standard of 50 mg/l for nitrate in groundwater in agricultural areas at a depth of 15-30 metres below the surface by region

Table 5.4: Percentage of monitoring sites in groundwater at a depth of 15-30 metres per nitrate concentration class in the various reporting periods[1]

Nitrate class (NO_3 mg/l)	All monitoring sites			Monitoring sites in agricultural areas		
	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
0 - 15 mg/l	94	92	93	95	95	95
15-25 mg/l	1	2	1	0	1	1
25 - 40 mg/l	1	1	1	1	1	1
40 - 50 mg/l	1	2	2	1	1	1
> 50 mg/l	3	3	3	4	2	2
Number of monitoring sites	336	336	336	212	212	212

[1] The total percentage could be higher or lower than 100 because of rounding.

Most monitoring sites (almost 90%) showed no change in nitrate concentration between the last two reporting periods (2008-2011 and 2012-2014; Table 5.5). The number of sites with a decrease between the two periods was slightly higher than the number showing an increase. This applies in particular in agricultural areas: 3% of sites show an increase and 7% show a decrease.

Table 5.5: Percentage of monitoring sites in groundwater at a depth of 15-30 metres with increasing or decreasing nitrate concentrations between various reporting periods[1]

Change (NO_3)	All monitoring sites		Monitoring sites in agricultural areas	
	'92-'95/ '08-'11	'08-'11/ '12-'14	'92-'95/ '08-'11	'08-'11/ '12-'14
Large increase (% > 5 mg/l)	7	3	5	2
Small increase (% 1-5 mg/l)	5	2	6	1
Stable (% ± 1 mg/l)	80	89	81	91
Small decrease (% > 1-5 mg/l)	5	3	4	4
Large decrease (% > 5 mg/l)	4	3	4	3
Number of monitoring sites	336	336	212	212

[1] The total percentage could be higher or lower than 100 because of rounding.

In the sand areas, Sand North, Sand Central and Sand South, in contrast to the measuring results for groundwater 5-15 metres below the surface, the nitrate concentration in deeper water is highest in Sand Central (Figure 5.11). The average nitrate concentration at this depth in the sand areas is entirely determined by a limited number of wells with a high nitrate concentration (Table 5.6), meaning that chance (the choice of wells) may be a factor. However, the difference between the deep and shallow wells in Sand South is striking: almost half the shallow wells have a nitrate concentration above 10 mg/l, while this only applies to one well in the deep screens in Sand South. The percentage of wells with a groundwater concentration exceeding the EU standard of 50 mg/l at 15-30 metres is the highest in Sand Central, at approximately 8% (Figure 5.12). However, this percentage is slightly lower than in the groundwater at 5-15 metres (approximately 12%, see Figure 5.6). The situation is different in Sand South, where there are approximately 35% exceedances at 5-15 metres and 0% at 15-30 metres.

Van Vliet *et al.* (2010) had also already observed that the deeper groundwater in Sand South rarely exceeded the EU standard. The Van Loon and Fraters report (2016) also reveals that the problems with over-fertilisation of drinking water sources mainly occurred in Sand Central and not in Sand South. As can be seen in Map 5.7, high maximum nitrate concentrations on sandy soil are mainly recorded in Gelderland and Overijssel, with fewer in Noord Brabant. According to Broers (2002), oxidation of pyrite and a reduction in nitrates are the most likely explanation for low nitrate concentrations in the deeper groundwater in Noord Brabant. Broers (2002) demonstrates that more pyrite occurs in the subsoil in Noord Brabant than in Drenthe. The pyrite content in the subsoil in Sand Central is also likely to be lower than in Sand South.

Table 5.6: Number of wells per nitrate concentration class in agriculture per sand area in the Sand Region at a depth of 15-30 metres for the period 2012-2014

Nitrate class (NO3 in mg/l)	Sand North	Sand Central	Sand South
<1 mg/l	40	30	35
1 to 10 mg/l	2	2	0
>10 mg/l	3	6	1
Total number of wells	45	38	36

Map 5.3 also shows that high nitrate concentrations are recorded at more locations in Sand Central than in Sand North or Sand South. This map depicts all the deep screens of LMG, including those in areas designated as nature areas or for other purposes, and those located in soil types other than sand.

The monitoring sites at a depth of 15-30 metres can be divided into those with wells containing old groundwater (> 25 years) and young groundwater (< 25 years) (Map 5.3). In the wells containing old groundwater, the water is usually from artesian aquifers, whereas in those containing young groundwater, it is from phreatic aquifers. High nitrate concentrations (> 50 mg/l) are found in young groundwater in sand and loess soils (in the eastern and southern parts of the Netherlands). Most changes in nitrate concentration between 2008-2011 and 2012-2014 took place under sandy and loess soil (Map 5.4), with increases as well as decreases in nitrate concentrations being found.

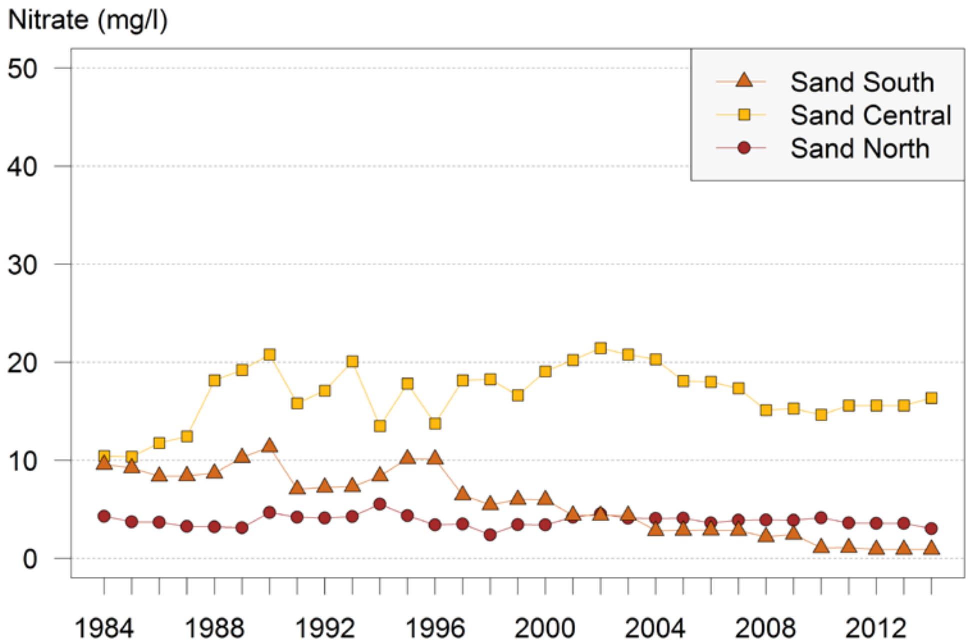


Figure 5.11: Nitrate in groundwater at a depth of 15-30 metres under farming areas by sand area

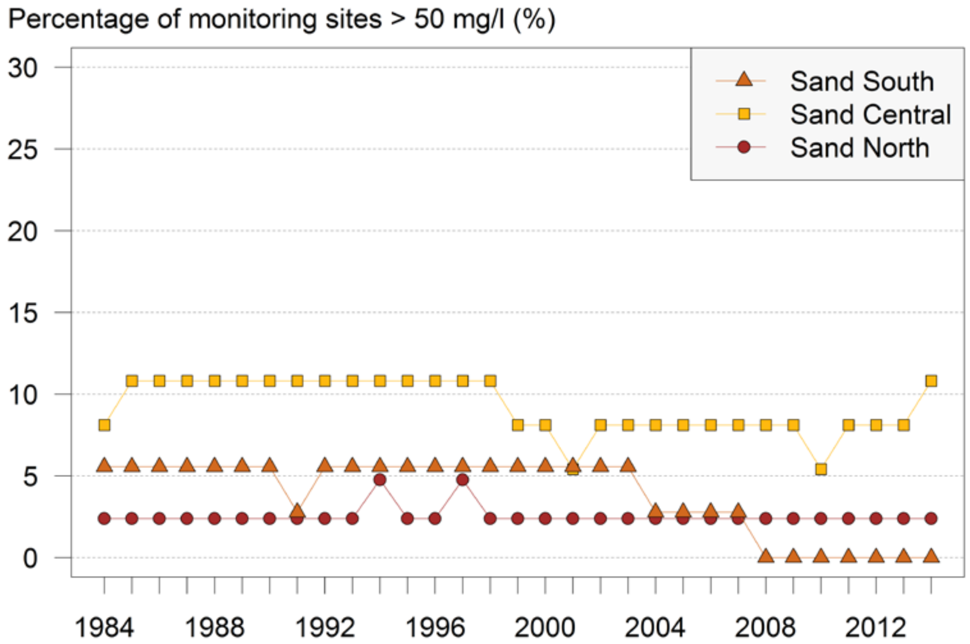
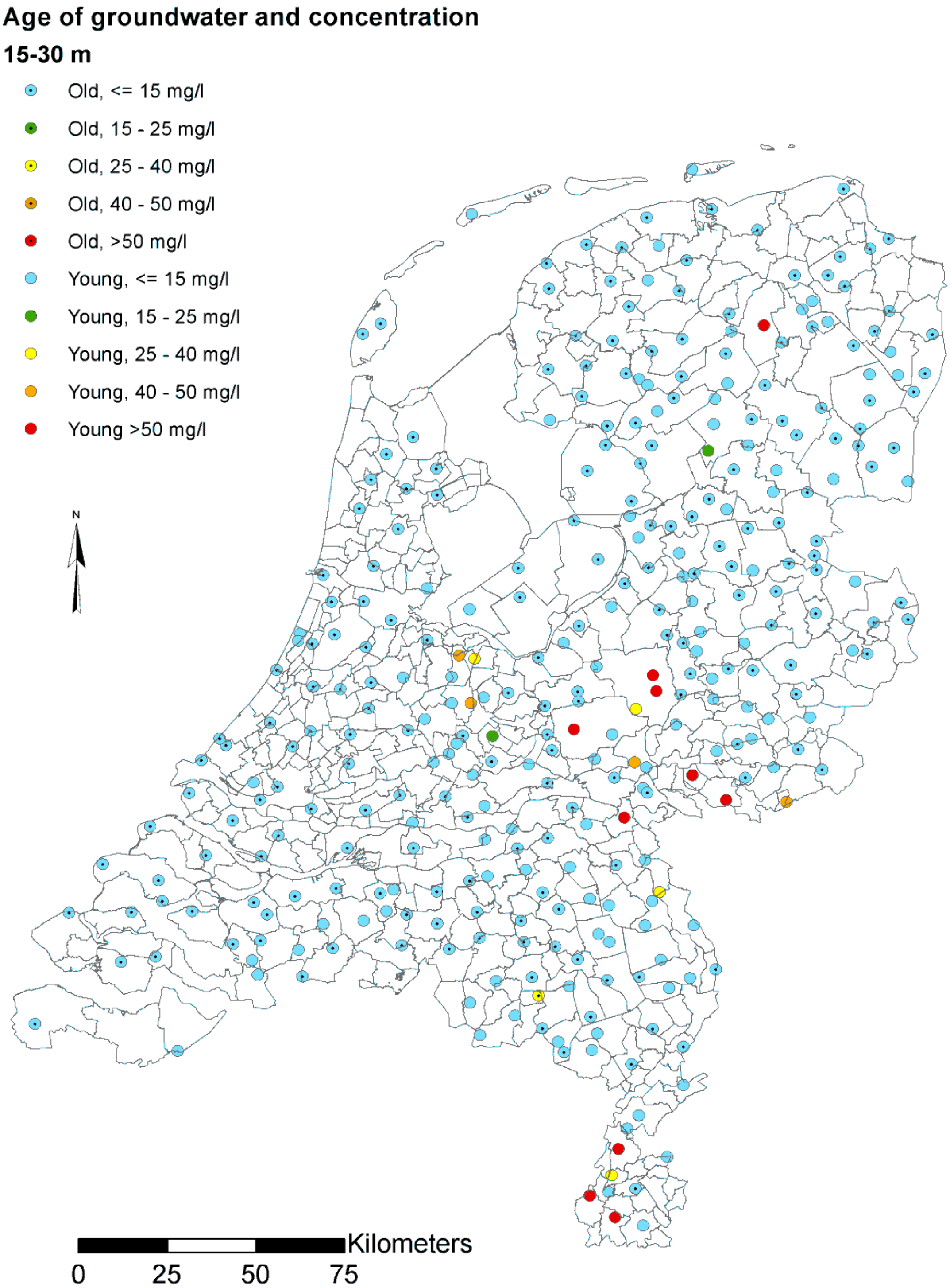
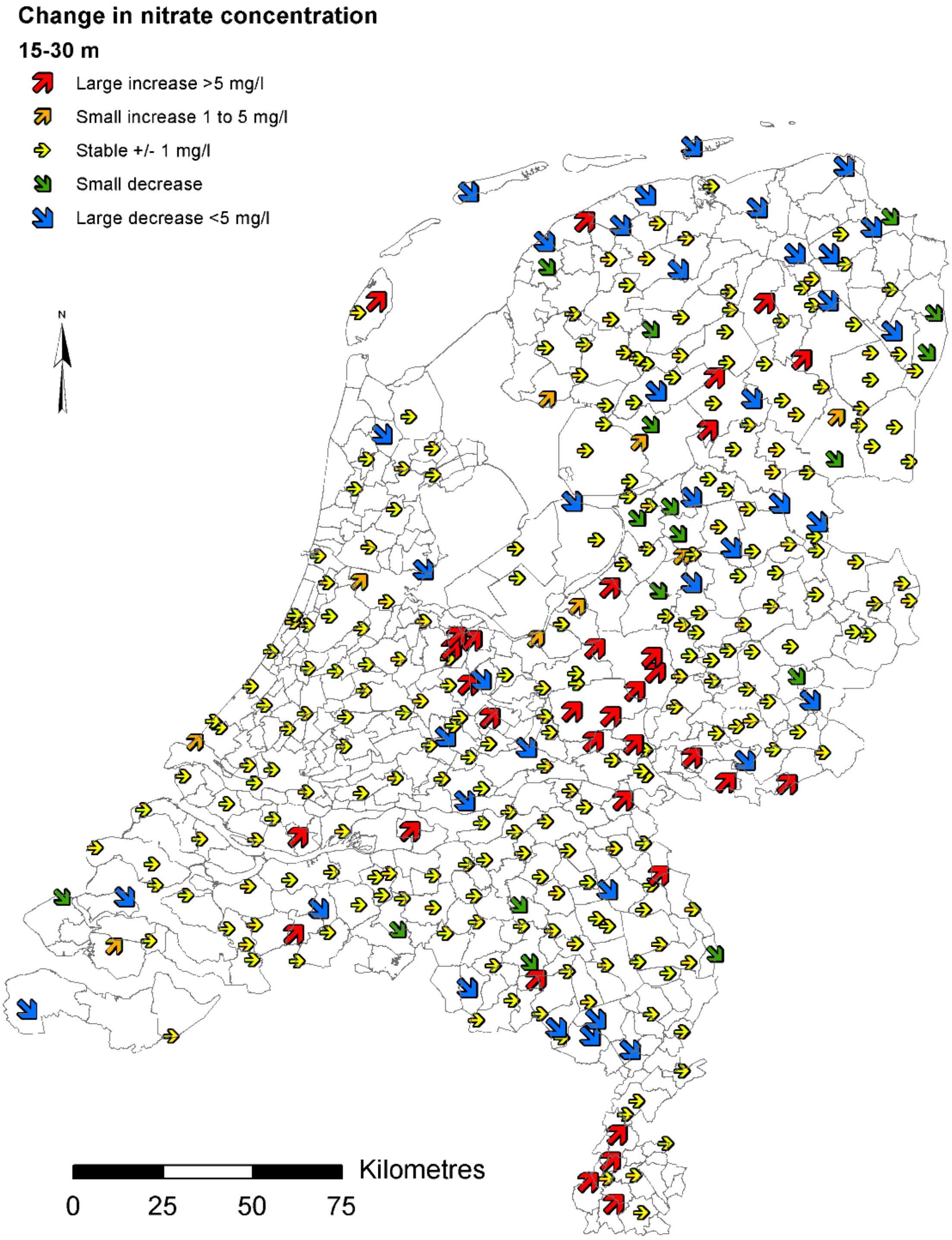


Figure 5.12: Exceedance of the EU standard of 50 mg/l for nitrate in groundwater under farming areas at a depth of 15-30 metres below the surface by sand area



Map 5.3: Average nitrate concentration in groundwater in the Netherlands at a depth of 15-30 metres for the period 2012-2014; "young" refers to groundwater younger than 25 years, "old" means older than 25 years



Map 5.4: Change in average nitrate concentration in groundwater at a depth of 15-30 metres for the period 2008-2014; the change shown here is the difference between averages for 2008-2011 and 2012-2014

5.4 Nitrate in groundwater below 30 metres

In the period 2012-2014, the average nitrate concentration in groundwater used for drinking water production (raw water) was about

6.5 mg/l in phreatic aquifers and less than 1 mg/l in artesian aquifers. The nitrate concentration in raw water from phreatic groundwater increased slightly until 2003 and then decreased until 2006 (Figure 5.13). The nitrate concentration was stable from 2006 onwards. Nitrate concentrations in artesian groundwater increased by 1 mg/l between 2010 and 2011. The cause of this increase is unclear. The increase of approximately 1 mg/l takes place in most sources (drinking water production sites). In 2010, no nitrates were found in 77% of artesian sources, whereas this was only the case in 14% of sources in 2011. The increase per source also takes place in phreatic sources, although it is less pronounced there because the average concentration is higher.

The percentage of sources with an average nitrate concentration in raw water above 50 mg/l was less than 2% (Figure 5.14 and Table 5.7). The 40-50 mg/l class decreased slightly, with some lower classes increasing slightly again as a result.

Between the last two periods, stable nitrate concentrations were found in almost 75% of sources; this applies to 68% of phreatic sources (Table 5.8). Interestingly, the number of sites with an increase was higher than the number showing a decrease. This also has to do with the slight but unexplained increase between 2010 and 2011 described above.

The EU standard of 50 mg/l was not exceeded in distributed drinking water. In 2014, none of the 166 drinking water production sites had a nitrate concentration exceeding 50 mg/l. However, it should be noted that drinking water wells are often closed or mixed to ensure that the concentration drops below 50 mg/l.

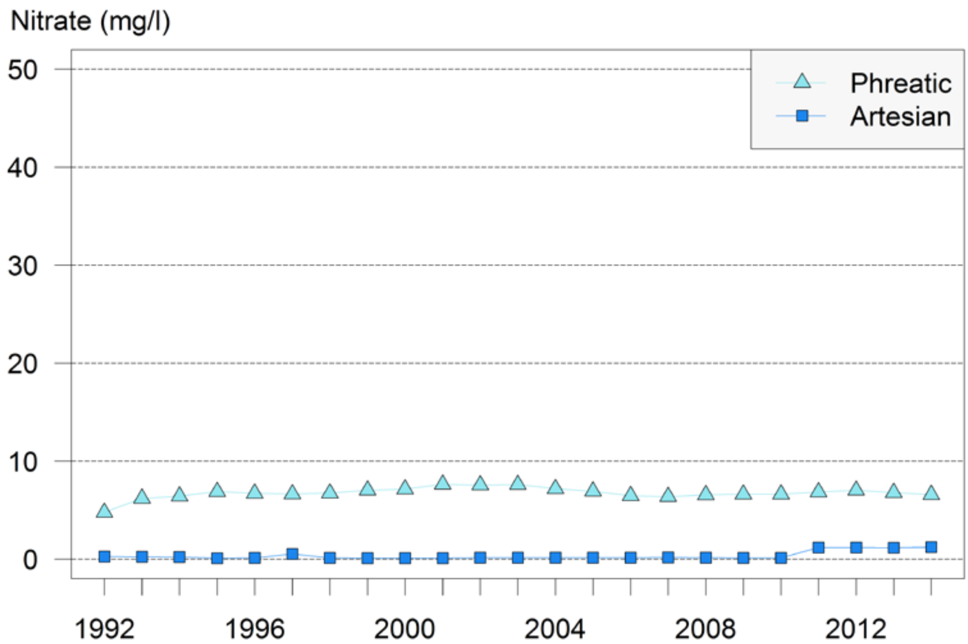


Figure 5.13: Average annual nitrate concentration (mg/l) in groundwater in phreatic and artesian aquifers at drinking water production sites

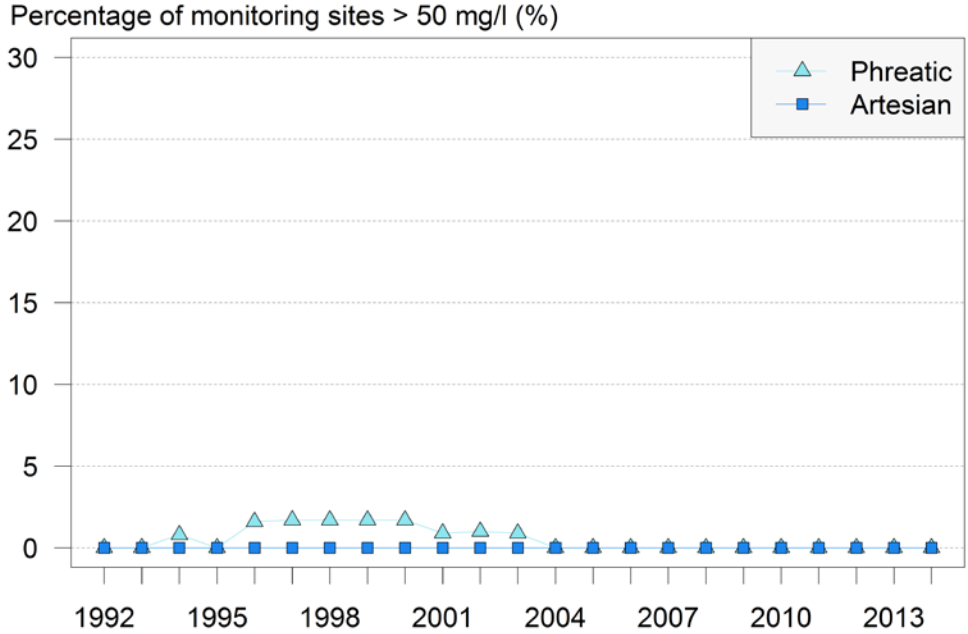


Figure 5.14: Exceedance of the EU standard of 50 mg/l for average nitrate concentration in groundwater at drinking water production sites for phreatic and artesian groundwater; exceedance is expressed as a percentage of all production sites

Table 5.7: Percentage of monitoring sites in groundwater at a depth of over 30 metres per nitrate concentration class in the various reporting periods[1]

Nitrate class (NO_3 mg/l)	All production sites 1992-1995	2008-2011	2012-2014	Phreatic sites 1992-1995	2008-2011	2012-2014
0-15 mg/l	91	91	92	85	84	85
15-25 mg/l	5	5	6	9	9	11
25-40 mg/l	3	2	2	5	4	4
40-50 mg/l	1	2	0	1	3	0
> 50 mg/l	0	0	0	0	0	0
Number of sites	217	178	166	129	101	94

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 5.8: Percentage of monitoring sites in groundwater at a depth of over 30 metres with increasing or decreasing nitrate concentrations between various reporting periods[1]

Change (NO_3)	All production sites '92-'95/ '08-'11	'08-'11/ '12-'14	Phreatic sites '92-'95/ '08-'11	'08-'11/ '12-'14
Large increase (% > 5 mg/l)	3	1	4	2
Small increase (% 1-5 mg/l)	11	18	18	17
Stable (% ± 1 mg/l)	77	74	62	68
Small decrease (% > 1-5 mg/l)	7	6	13	11
Large decrease (% > 5 mg/l)	3	1	4	2
Number of sites	155	155	85	85

[1] The total percentage could be higher or lower than 100 because of rounding.

Maximum concentrations
In the period 2012-2014, the average maximum nitrate concentration in groundwater used for drinking water production was about 9 mg/l for phreatic aquifers and approximately 3 mg/l for artesian aquifers (Figure 5.15). The maximum nitrate concentration in raw water from phreatic aquifers remained constant over the last three years of the period. The number of exceedances of the EU standard has decreased: between 2012 and 2014, no maximum nitrate concentrations exceeded the EU standard (Figure 5.16 and Table 5.9).

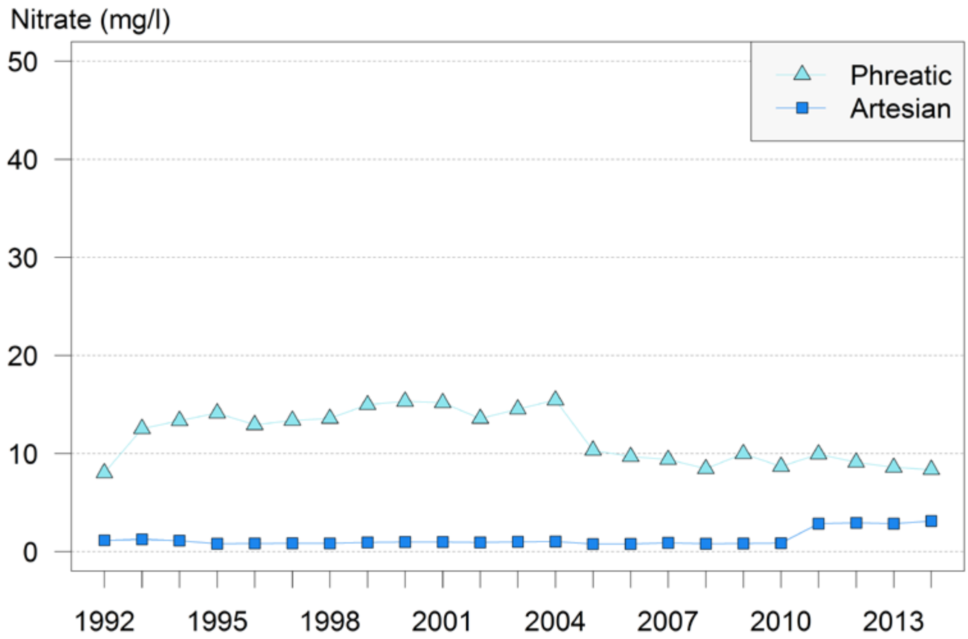


Figure 5.15: Maximum nitrate concentration (mg/l) in groundwater at drinking water production sites for phreatic and artesian groundwater

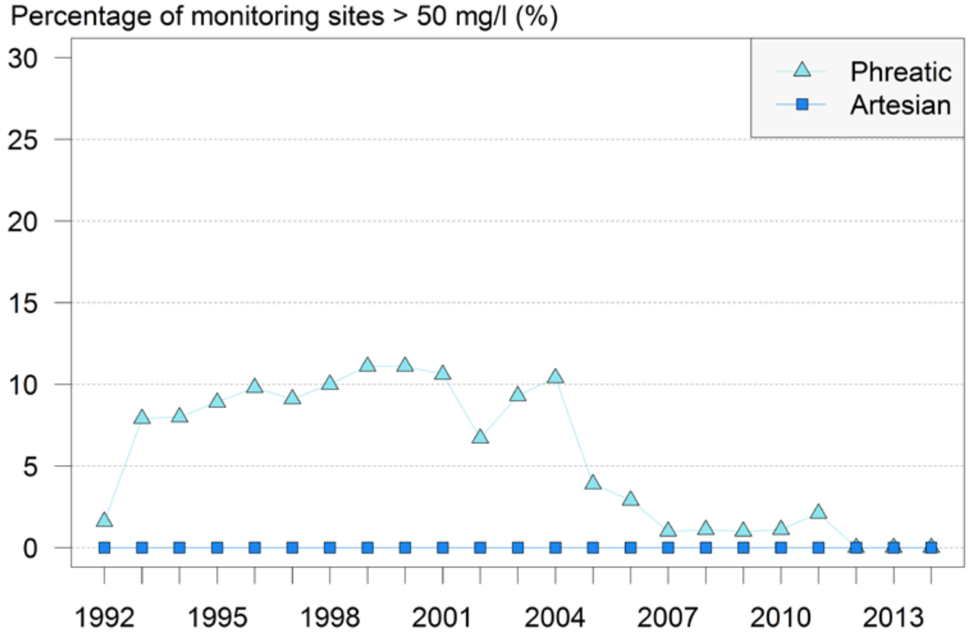


Figure 5.16: Exceedance of the EU standard of 50 mg/l for maximum nitrate concentration in groundwater at drinking water production sites for phreatic and artesian groundwater; exceedance is expressed as a percentage of all production sites

Table 5.9: Percentage of monitoring sites in groundwater at a depth of over 30 m per nitrate concentration class (maxima) in the various reporting periods[1]

Nitrate class (NO_3 mg/l)	All production sites 1992-1995	2008-2011	2012-2014	Phreatic sites 1992-1995	2008-2011	2012-2014
0-15 mg/l	84	85	87	75	74	78
15-25 mg/l	6	5	7	8	9	12
25-40 mg/l	5	5	4	9	9	6
40-50 mg/l	1	4	2	1	7	4
> 50 mg/l	5	1	0	8	1	0
Number of sites	217	178	166	129	101	94

[1] The total percentage could be higher or lower than 100 because of rounding.

Between the last two periods, stable maximum nitrate concentrations were found in 50% of wells (Table 5.10). A total of 36% of sources showed a slight increase: the number of wells with an increase was much higher than the number showing a decrease. The percentage of stable monitoring sites at phreatic sources was 55%.

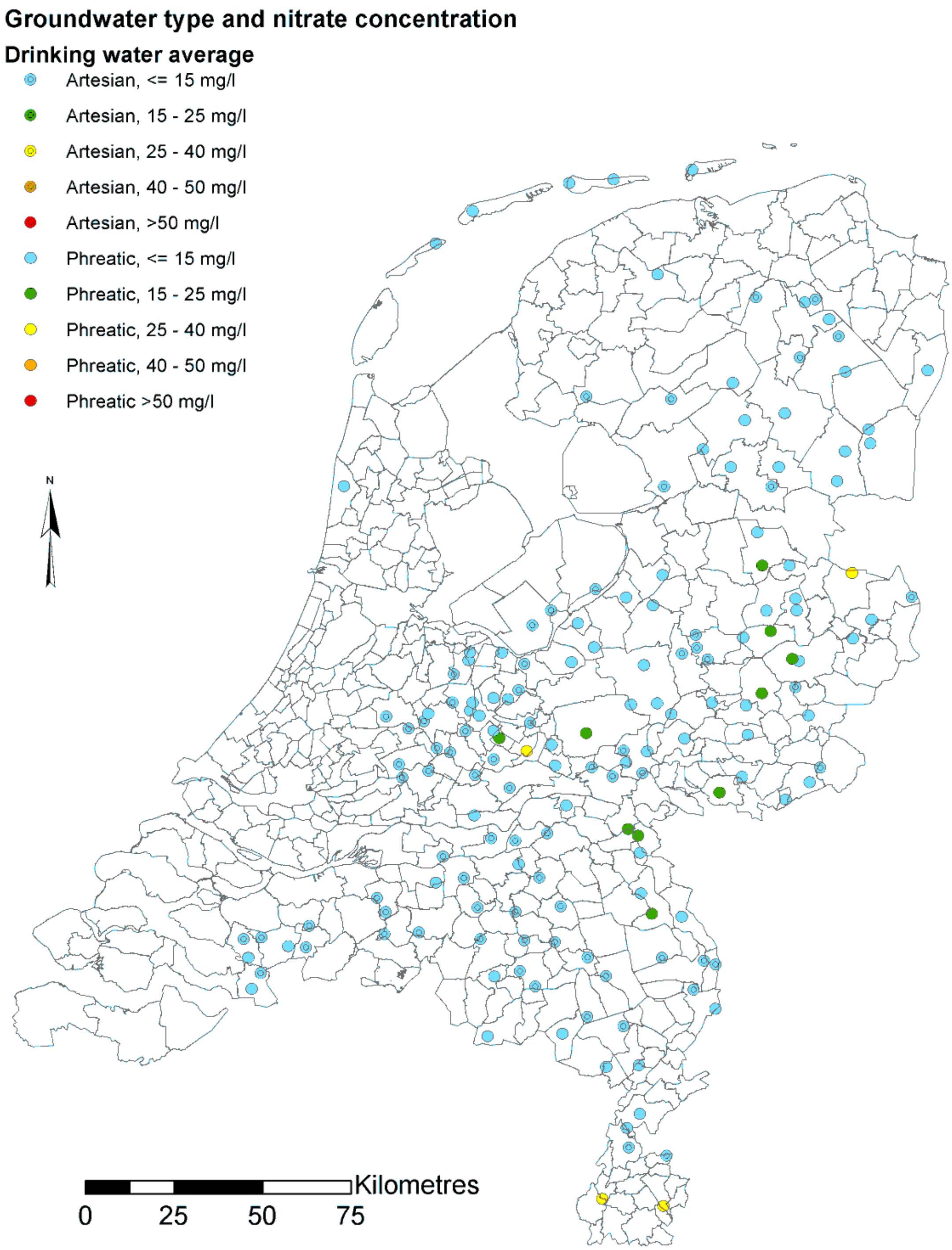
Table 5.10: Percentage of monitoring sites in groundwater at a depth of over 30 metres with increasing or decreasing maximum nitrate concentrations between various reporting periods[1]

Change (NO_3 maximum)	All production sites ‘92-‘95/ ’08-‘11	All production sites ‘08-‘11/ ‘12-‘14	Phreatic sites ‘92-‘95/ ’08-‘11	Phreatic sites ‘08-‘11/ ‘12-‘14
Large increase (% > 5 mg/l)	4	6	7	7
Small increase (% 1-5 mg/l)	19	36	20	22
Stable (% ± 1 mg/l)	59	50	45	55
Small decrease (% > 1-5 mg/l)	9	5	13	8
Large decrease (% > 5 mg/l)	9	4	15	7
Number of sites	155	155	85	85

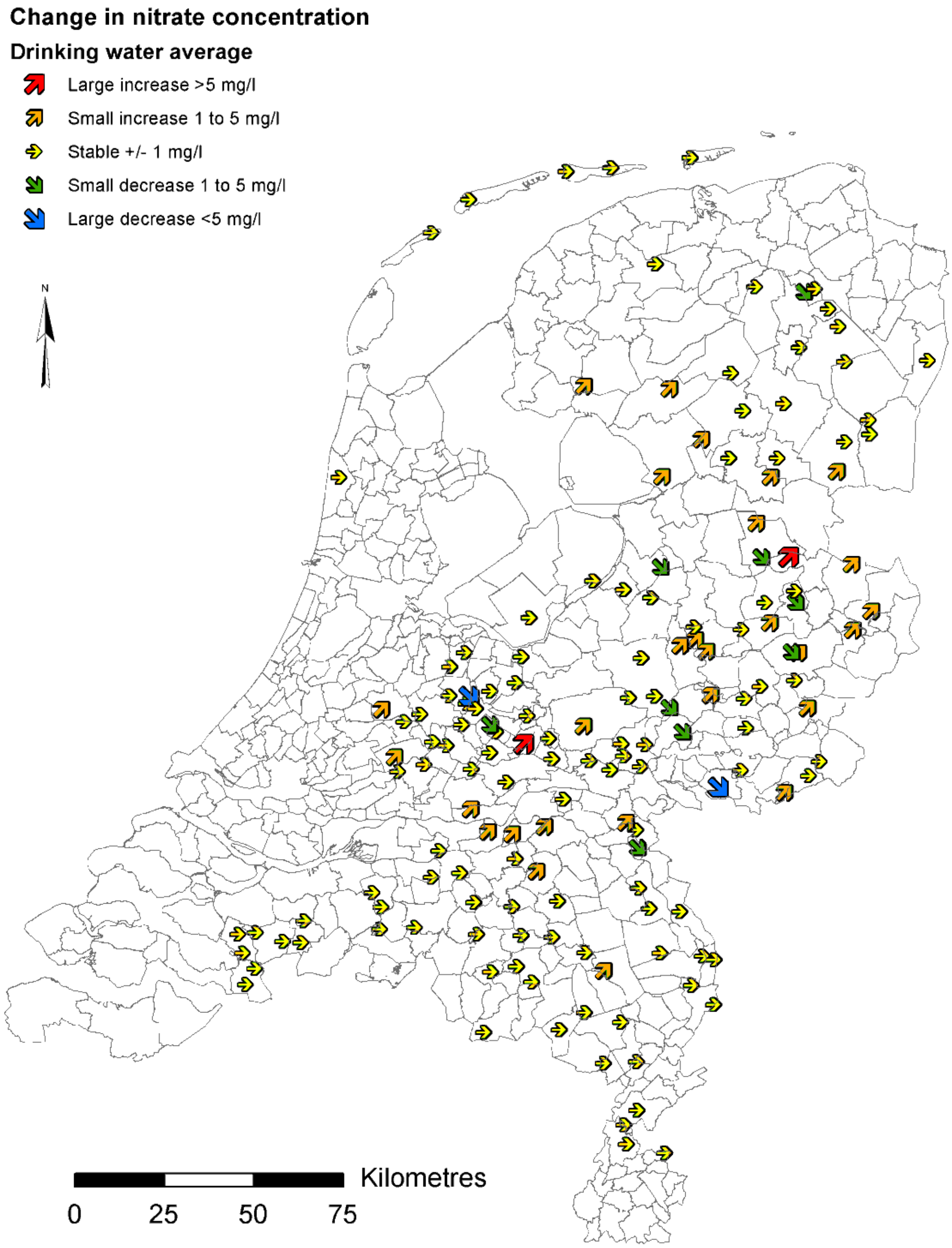
[1] The total percentage could be higher or lower than 100 because of rounding.

The highest nitrate concentrations occur in the southern (mainly in the Loess Region) and eastern parts of the Netherlands near the German border (Sand Region) (Map 5.5). These areas in particular show decreasing trends (Map 5.6).

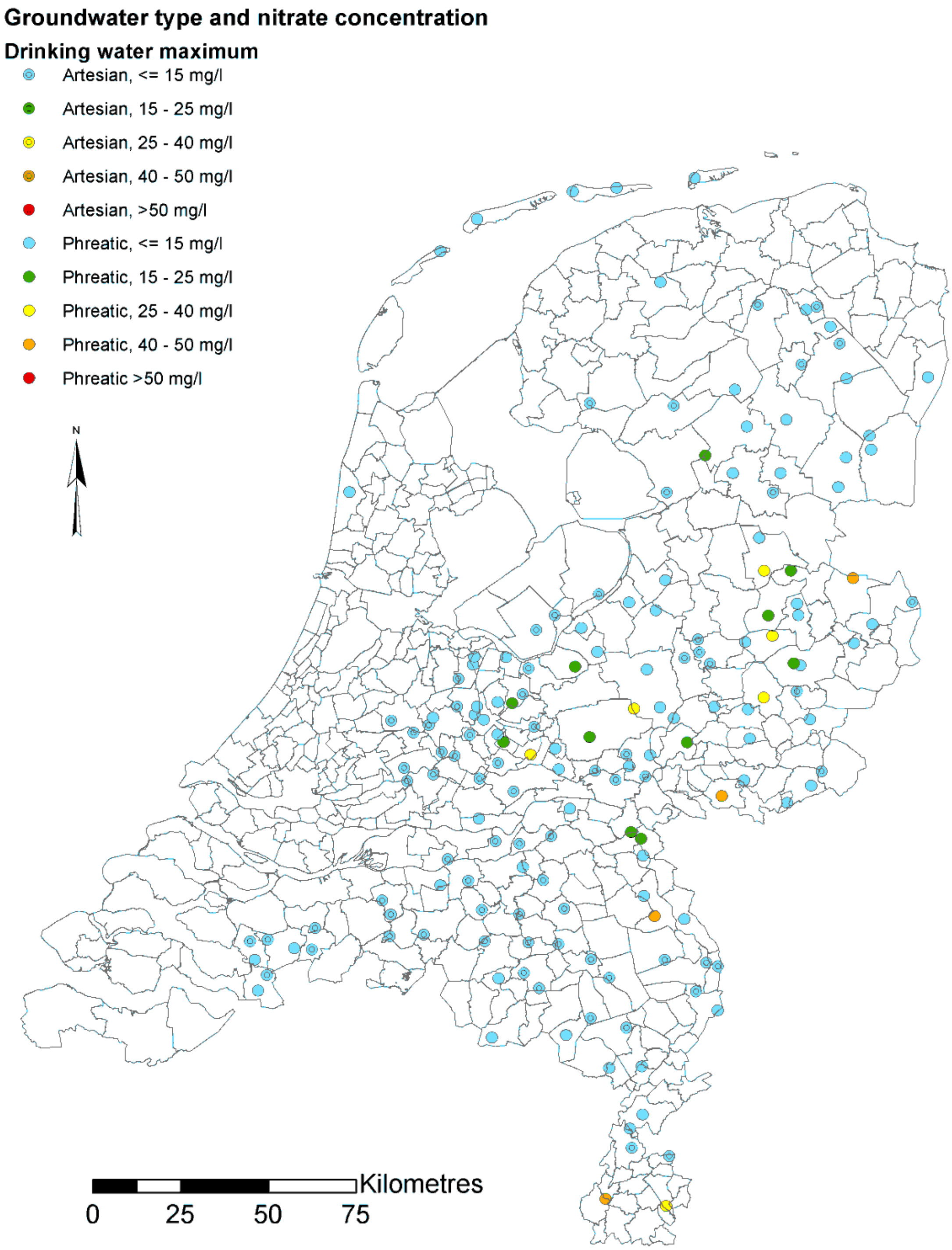
The highest maximum nitrate concentrations also occur in the southern and eastern parts of the Netherlands (Map 5.7). There are many small increases in the nitrate concentration in Sand South (Map 5.8).



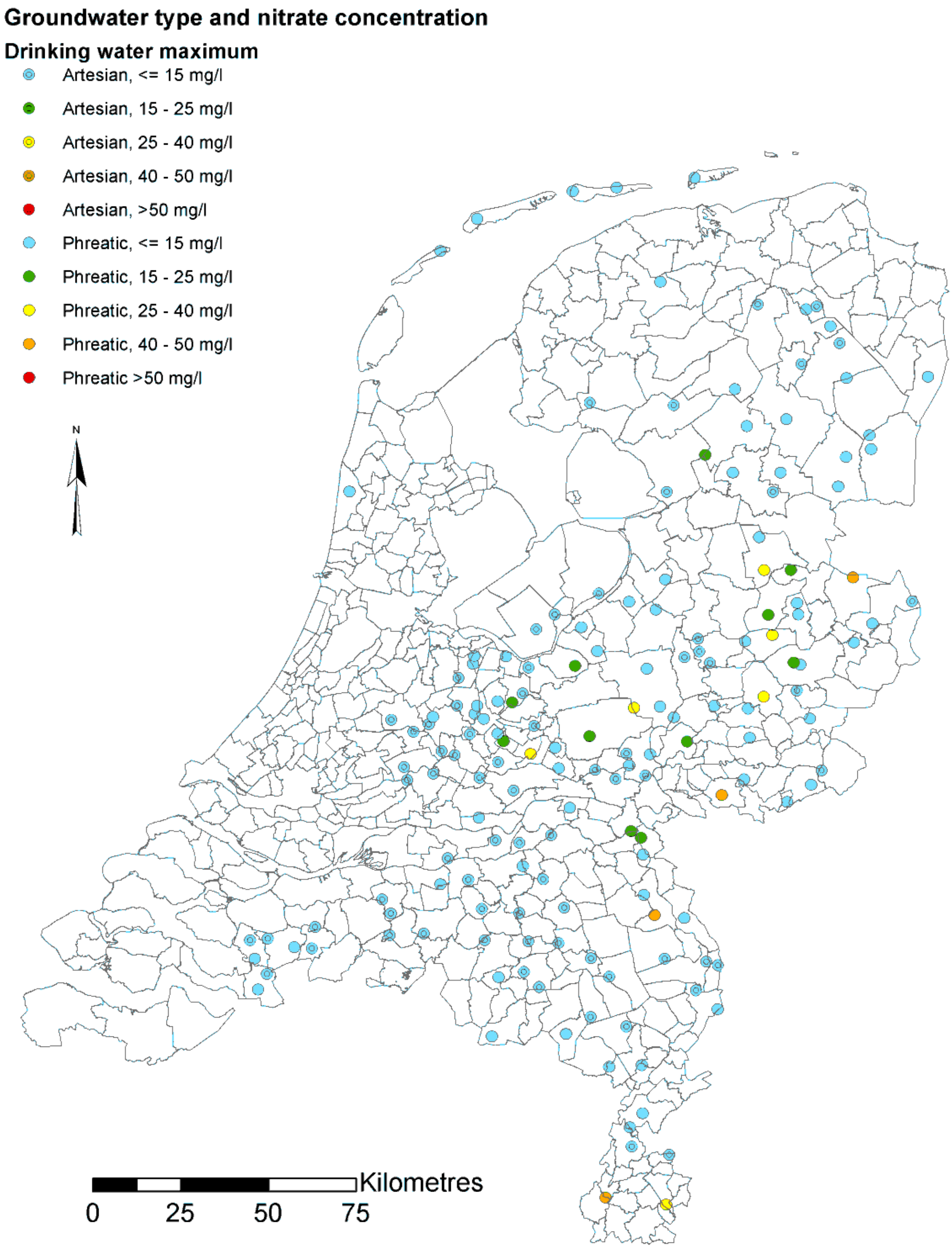
Map 5.5: Average nitrate concentration in groundwater used for drinking water production in the period 2012-2014



Map 5.6: Change in average nitrate concentration in groundwater used for drinking water production in the period 2008-2014; the change shown here is the difference between averages for the 2008-2011 and 2012-2014 periods



Map 5.7: Maximum nitrate concentration in groundwater used for drinking water production in the period 2012-2014



Map 5.8: Change in maximum nitrate concentration in groundwater used for drinking water production in the period 2008-2014. The change shown here is the difference between averages for the 2008-2011 and 2012-2014 periods

5.5 Trends in agricultural practice and nitrate in groundwater

The nitrate concentration in deeper groundwater is a reflection of the concentrations in the upper groundwater. The main source of nitrogen in the upper groundwater is agriculture. Nitrate concentrations monitored under farming areas are therefore higher than under nature areas and other areas. In addition, the nitrate concentration is related to the ability of the soil to break down nitrogen. Nitrate is broken down less readily under sandy soil than under clay and peat. The nitrate concentration under sandy soil is therefore the highest.

The nitrate concentration under farming areas in the Sand Region in the screens 5-15 metres below the surface reached the highest concentration in 1996, approximately 10 years after the peak in the soil surplus (1985, Figure 3.3). Since then, the nitrate concentration in groundwater at this depth has been dropping. The nitrate concentration in groundwater at a depth of 15-30 metres is lower than in shallow groundwater. This is due to mixing and breakdown during downward groundwater flow. Nitrate concentrations under farming areas are higher than under nature areas because of the impact of agriculture. After 2002, the nitrate concentration under farming areas in the Sand Region fell from 12 mg/l to 7 mg/l in 2014.

There are great regional differences in the transportation of nitrate from shallow to deep groundwater. In Sand Central, the average drop from shallow to deep is from 20 mg/l to 15 mg/l. In Sand South, the concentration drops much more strongly with increasing depth, from 70 mg/l to 1 mg, and from 15 mg/l to 3 mg/l in Sand North. Nitrate probably breaks down much more readily in the subsoil in Sand South than in Sand Central.

The nitrate concentration at drinking water production sites is higher in locations with phreatic groundwater than in those with artesian groundwater. The confining layers above artesian aquifers offer protection against nitrate pollution. In phreatic aquifers, where these confining layers are absent, nitrates can penetrate to great depths. None of the production sites exceed the EU standard, but there are a number of phreatic locations with concentrations between 15 and 40 mg/l in Sand Central and in the Loess Region. There are no elevated nitrate concentrations in Sand South. This is consistent with the higher nitrate breakdown situation in Sand South.

The nitrate concentrations for drinking water production sites are taken from the REWAB database (database of records from drinking water companies). This database contains annual average data on mixed pumped groundwater per string of wells at the location (see Section 2.5) and not of individual extraction wells per string. As a result, high nitrate concentrations are averaged out, so that these data underestimate the actual fertiliser-related water quality problems at the production sites (Wuijts *et al.*, 2010). For example, an analysis by Van Loon and Fraters (2016), which looked at individual extraction wells, reveals that in the period 2000-2015, one or more raw water standards for indicators for the impact of fertilisers were exceeded in individual pump wells at 89 groundwater extraction sites. In most cases, fertiliser application plays a major role in these exceedances. In some cases they are primarily due to the drop in groundwater levels and natural causes (Van Loon and Fraters, 2016). Exceedances of the standard in individual wells is regarded as a problem because the drinking water companies have to mix various raw water flows to meet the quality standards. This increases the cost of monitoring and reduces flexibility.

5.6 References

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6 Freshwater quality

6.1 Introduction

The first part of this chapter provides an overview of the nutrient load in water bodies in the Netherlands. Nitrogen and phosphorus both affect the degree of eutrophication. This is followed by a description of the concentrations of nitrogen and phosphorus in the various fresh surface waters in the Netherlands.

The situation concerning chlorophyll-a is then described. Chlorophyll-a is another quality element that provides insight into the eutrophication status of the waters. New in this chapter is the passage on eutrophication characterisation. This is now completely in line with the system used in the Water Framework Directive (WFD).

The data presented in this chapter originate from measurements in water bodies as defined for the WFD and locations forming part of the Monitoring network for agriculture-specific surface waters (MNLSO), as also described in Chapter 2. The monitoring sites in the WFD monitoring network can be in regional or national waters. The underlying emission sources for these waters vary. National waters are mainly affected by foreign influences and outputs from regional waters, while regional waters are primarily affected by outputs from agriculture, as well as seepage, industrial discharges and discharges from urban areas.

In conformity with EU reporting guidelines (EC/DGXI, 2011), this report considers nitrate-nitrogen to be the most important variable for reflecting the effects of agriculture on surface water quality. In watercourses prone to eutrophication, nitrates disappear in varying degrees because algae absorb them in the summer months, which can result in the monitoring results presenting a distorted picture. The more eutrophicated a water body is, the lower the nitrate concentration during the summer. The winter average (October to March) is therefore more representative than the summer or annual average. The winter period is also the time when leaching and run-off processes play a key role. The maximum winter concentrations and the winter and annual averages for nitrates are presented in this chapter.

This report follows the WFD system for eutrophication characterisation and also uses data from WFD water bodies, distinguishing between lakes, rivers and coastal and transitional waters. This chapter presents the results for lakes and rivers. The situation for coastal and transitional waters is discussed in Chapter 7, along with the situation in the open sea.

6.2 Nutrient load on fresh surface waters

The greater part of the total quantity of nitrogen in the Dutch freshwater system originates from outside the country. Around 75% of the total quantity of nitrogen and 53% of the total quantity of phosphorus found in the Netherlands' fresh waters (2011-2012) originates from abroad

(PBL, 2016). The remainder in the Dutch water system originates from various other sources (Table 6.1).

Leaching and run-off are the leading domestic sources of both nitrogen (59%; Figure 6.1) and phosphorus (59%; Table 6.2). Their relative contributions in respect of phosphorus have increased over time from 15% to 60%, mainly because the contributions from other sources, such as directly from agriculture (manure in ditches, farmyard run-off, greenhouse nurseries, etc.) have decreased more steeply (Table 6.2). In the case of nitrogen, the contribution made by leaching and run-off has fluctuated between 50% and 61% since 1995.

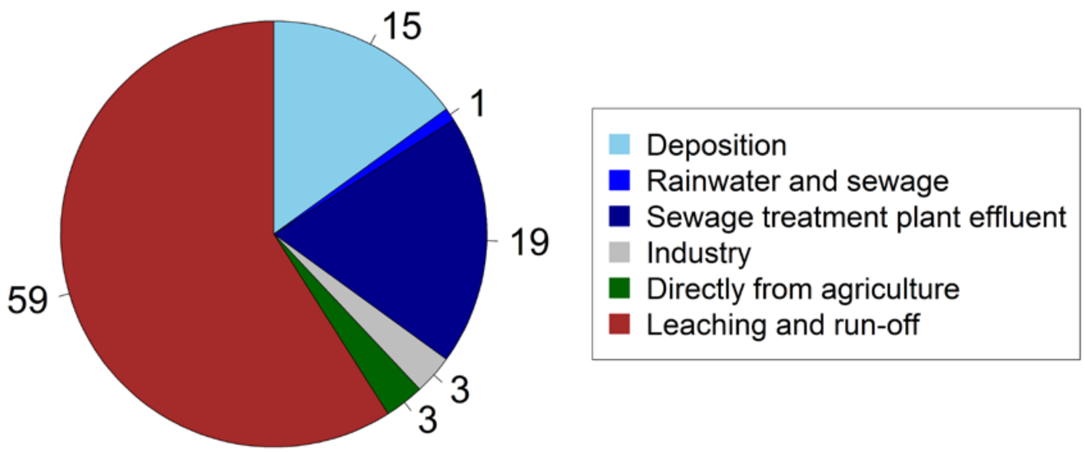

Figure 6.1: Percentages of different domestic sources of the nitrogen load on surface water in 2010-2013
Source: Emissions Registration, 1990-2013, 2015

For leaching and run-off in rural areas, the Emissions Registration does not distinguish between agricultural and natural land. A study by Van der Bolt and Schoumans (2012) shows that farmland contributes 47% of the nitrogen load in surface water and 46% of the phosphorus load.

Table 6.1: Surface water nitrogen load from domestic sources (million kg per annum)

Origin	1990	1995	2000	2005	2010	2012	2013
Atmospheric deposition[1]	24	20	17	15	13	13	13
Leaching and run-off in rural areas	59	84	88	47	54	54	42
Sewage treatment plant effluent	39	36	29	22	17	15	15
Rainwater and sewage other than from treatment plants[2]	5.0	3.4	2.3	1.7	1.2	1.2	1.2
Industry	12.7	6.5	4.6	3.9	2.4	2.5	2.4
Directly from agriculture[3]	7.7	5.7	3.7	3.2	2.7	2.7	2.6
Other	0.4	0.4	0.2	0.3	0.2	0.2	0.2
Total	148	156	145	94	90	88	76

[1] Atmospheric deposition in fresh and marine surface water up to one mile from the coastal zone. Deposition in fresh water is 11.1 million kg in 1992-1995, 7.5 million kg in 2008-2011, and 7.2 million kg in 2012-2014.

[2] Sewage other than from treatment plants relates to overflowing, rainwater gullies, discharge from private wastewater treatment systems, untreated sewage and households not connected to sewer systems

[3] Directly from agriculture relates to greenhouse nurseries, farmyard run-off and unintended fertilisation of ditches

Source: Emissions Registration, 1990-2013, 2015

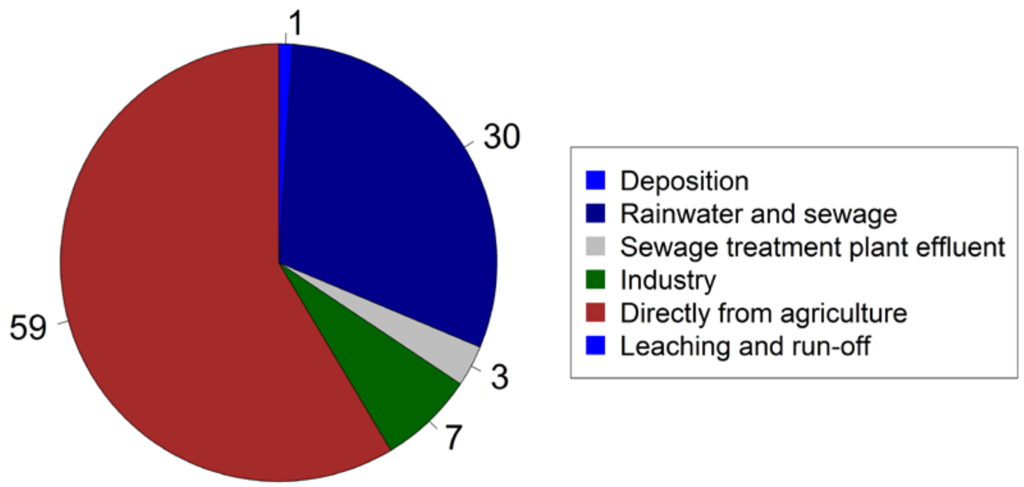

Figure 6.2 Percentages of different domestic sources of the phosphorus load on surface water in 2010-2013
Source: Emissions Registration, 1990-2013, 2015

Table 6.2: Surface water phosphorus load from domestic sources (million kg per annum)

Origin	1990	1995	2000	2005	2010	2013
Leaching and run-off in rural areas	3.4	4.3	5.1	3.4	3.8	4.6
Sewage treatment plant effluent	6.2	3.5	2.8	2.7	2.2	2.1
Rainwater and sewage other than from treatment plants[1]	0.6	0.4	0.2	0.1	0.1	0.1
Industry	11.0	3.6	1.9	0.4	0.2	0.3
Directly from agriculture[2]	0.9	0.7	0.7	0.6	0.5	0.5
Other	0.0	0.0	0.0	0.0	0.0	0.0
Total	22.1	12.5	10.8	7.2	6.9	7.5

[1] Sewage other than from treatment plants relates to overflowing, rainwater gullies, discharge from private wastewater treatment systems, untreated sewage and households not connected to sewer systems

[2] Directly from agriculture relates to greenhouse nurseries, farmyard run-off and unintended fertilisation of ditches

Source: Emissions Registration, 2015

6.3 Nitrate concentration in fresh water

6.3.1 Nitrate concentration – winter average

Nitrate concentrations, calculated as winter averages, at both WFD monitoring sites in WFD water bodies and at MNLSO monitoring sites in agriculture-specific waters have fallen since 1992 (Tables 6.3 and 6.4, Figure 6.3). Average concentrations in WFD waters have fallen from around 20 mg/l to 10-15 mg/l. The drop in nitrate concentrations is greater in regional waters than in national waters. Average nitrate concentrations in agriculture-specific waters have fallen from around 25-30 mg/l to 15-20 mg/l. The EU water quality standard of 50 mg/l (EU standard), which is used in this report as a benchmark for nitrates, was exceeded at less than 0.5% of monitoring sites in WFD waters in the latest period, 2012-2014, (Table 6.3) and at 2% of sites in agriculture-specific waters. It should be noted that this EU standard of 50 mg/l nitrate is much too high to achieve an effective eutrophication status and is not a key factor in the (ecological) water quality in the Water Framework Directive.

Table 6.3: Percentage of monitoring sites in WFD and agriculture-specific fresh waters per nitrate concentration class (as winter average) in various reporting periods[1]

Nitrate class	WFD waters			Agriculture-specific waters		
(as NO_3)	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
0-2 mg/l	9	11	14	0	5	7
2-10 mg/l	19	47	51	15	36	38
10-25 mg/l	46	32	28	36	40	37
25-40 mg/l	17	7	6	24	10	13
40-50 mg/l	3	2	1	3	5	2
>50 mg/l	6	1	0	21	4	2
Number of sites	265	623	645	33	120	138

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 6.4: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters with increasing or decreasing nitrate concentrations (as winter average) between various reporting periods[1]

Change (NO_3)	WFD waters		Agriculture-specific waters	
	'92-'95/ '08-'11	'08-'11/ '12-'14	'92-'95/ '08-'11	'08-'11/ '12-'14
Large increase (> 5 mg/l)	0	1	0	2
Small increase (1-5 mg/l)	3	8	3	10
Stable (± 1 mg/l)	14	46	7	28
Small decrease (1-5 mg/l)	25	36	17	42
Large decrease (> 5 mg/l)	57	9	73	18
Number of sites	254	579	30	114

[1] The total percentage could be higher or lower than 100 because of rounding.

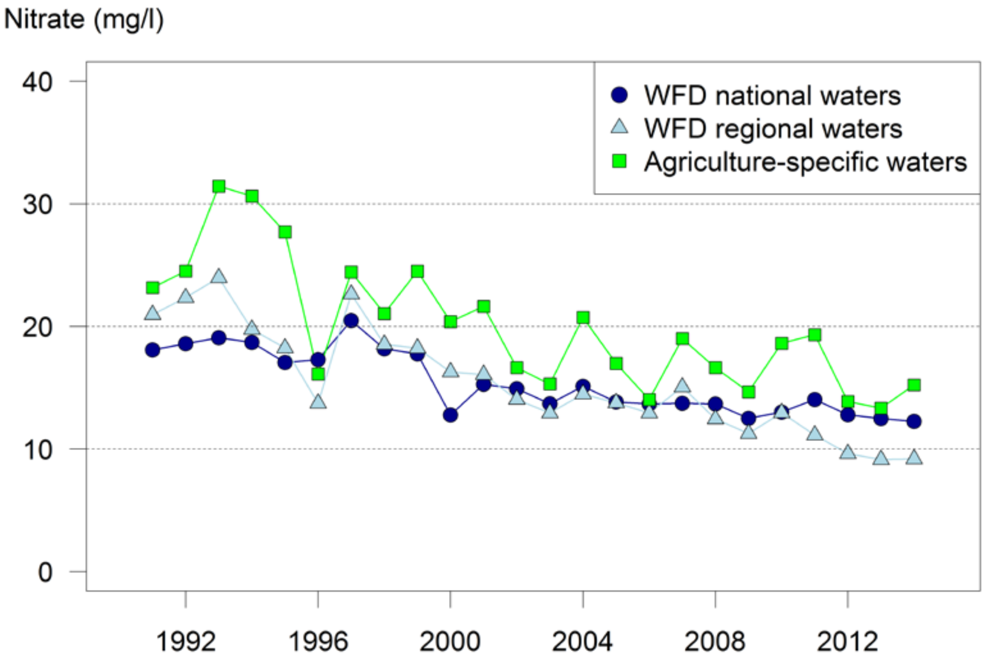

Figure 6.3: Nitrate concentration (winter average as NO_3 in mg/l) in fresh surface waters in the period 1990-2014

6.3.2 *Nitrate concentration – winter maximum*

Both the winter maximum concentrations and the average concentrations fell between 1992 and 2014. A reduction can also be seen in the maximum concentrations between the two most recent periods (Table 6.5). In addition, the percentage of waters with a reduction (61%) is greater than the percentage of waters with an increase (20%) (Table 6.6).

Table 6.5: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters per nitrate concentration class (as winter maximum) in the various reporting periods[1]

Nitrate class (NO_3 in mg/l)	WFD waters 1992-1995	WFD waters 2008-2011	WFD waters 2012-2014	Agriculture-specific waters 1992-1995	Agriculture-specific waters 2008-2011	Agriculture-specific waters 2012-2014
0-2 mg/l	5	5	5	0	0	3
2-10 mg/l	13	27	37	0	14	13
10-25 mg/l	29	39	37	15	34	39
25-40 mg/l	23	16	14	39	25	25
40-50 mg/l	9	6	4	15	11	8
>50 mg/l	21	7	4	30	16	12
Number of sites	265	623	645	33	120	138

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 6.6: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters with increasing or decreasing nitrate concentrations (as winter maximum) between various reporting periods[1]

Change (NO_3)	WFD waters '92-'95/ '08-'11	WFD waters '08-'11/ '12-'14	Agriculture-specific waters '92-'95/ '08-'11	Agriculture-specific waters '08-'11/ '12-'14
Large increase (> 5 mg/l)	5	3	7	11
Small increase (1-5 mg/l)	2	12	3	9
Stable (± 1 mg/l)	11	26	7	18
Small decrease (1-5 mg/l)	13	33	0	26
Large decrease (> 5 mg/l)	69	25	83	35
Number of sites	254	579	30	114

[1] The total percentage could be higher or lower than 100 because of rounding.

6.3.3 *Nitrate concentration – annual average*

In the latest reporting period (2012-2014), annual average nitrate concentrations above the EU standard of 50 mg/l are only found in agriculture-specific waters (1%) (Table 6.7).

Table 6.7: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters per nitrate concentration class (as annual average) in the various reporting periods[1]

Nitrate class (NO_3 in mg/l)	WFD waters 1992-1995	WFD waters 2008-2011	WFD waters 2012-2014	Agriculture-specific waters 1992-1995	Agriculture-specific waters 2008-2011	Agriculture-specific waters 2012-2014
0-2 mg/l	11	19	23	0	15	16
2-10 mg/l	30	52	54	29	46	50
10-25 mg/l	41	25	19	46	29	24
25-40 mg/l	14	3	3	10	6	6
40-50 mg/l	1	0	0	8	4	2
>50 mg/l	2	1	0	6	1	1
Number of sites	291	675	704	48	142	160

[1] The total percentage could be higher or lower than 100 because of rounding.

6.4 Eutrophication of fresh water

6.4.1 General situation

The EU standard of 50 mg/l (winter average) is not a good yardstick for providing information on ecological water quality for the Water Framework Directive and on the eutrophication of surface water. It is much too high to achieve an effective eutrophication status. More suitable items are given in Section 2.6.3. In accordance with the WFD system, various quality elements per water type were used to assess the status of WFD water bodies. Therefore, nutrients were not the only element monitored; biological quality elements in the water body such as phytoplankton and phytobenthos were also recorded.

A total of 60% of WFD water bodies were rated as eutrophic and 13% as potentially eutrophic (Table 6.8). “Eutrophic” means that eutrophication effects can be observed in the biology. The biological quality elements will then score less than “good” regardless of the nutrient score. “Potentially eutrophic” means that no eutrophication effects can be observed but that the nutrient concentrations are so high that they could bring about such effects. Most of the waters (94%) were assessed on the basis of biological characteristics; this information was not available for the rest of the waters, so they were only assessed on the basis of nutrients.

Table 6.8: Assessment of eutrophication in fresh waters in the period 2011-2013 (% of water bodies)

Classes	Percentage of water bodies
Non-eutrophic	27
Potentially eutrophic[1]	13
Eutrophic	60
Number of sites	690

[1] The biological status is good but nitrogen and phosphorus concentrations do not meet the water quality standards.

It can be inferred from the above that if a body of water is eutrophic, this does not necessarily mean that the nutrient score is less than “good”. As a result, the nutrients in almost half of all water bodies meet the relevant nutrient standards for these waters but only 27% of the waters are rated as having a good eutrophication status. Note that all tests were performed with the nationally reported targets set by the water managers. In some cases there may be different targets for eutrophication-sensitive parameters.

6.4.2 Chlorophyll-a

The concentration of chlorophyll-a has been monitored in both WFD waters and in some agriculture-specific waters since the beginning of the 1990s (Figure 6.4). The number of monitoring sites in which a summer average concentration of more than 75 µg/l was measured has also dropped (Table 6.9) from around 25% in the first reporting period to 10-15% in the latest period. The percentage of sites with a reduction between 2008 and 2014 is roughly the same as the percentage of sites with an increase (Table 6.10).

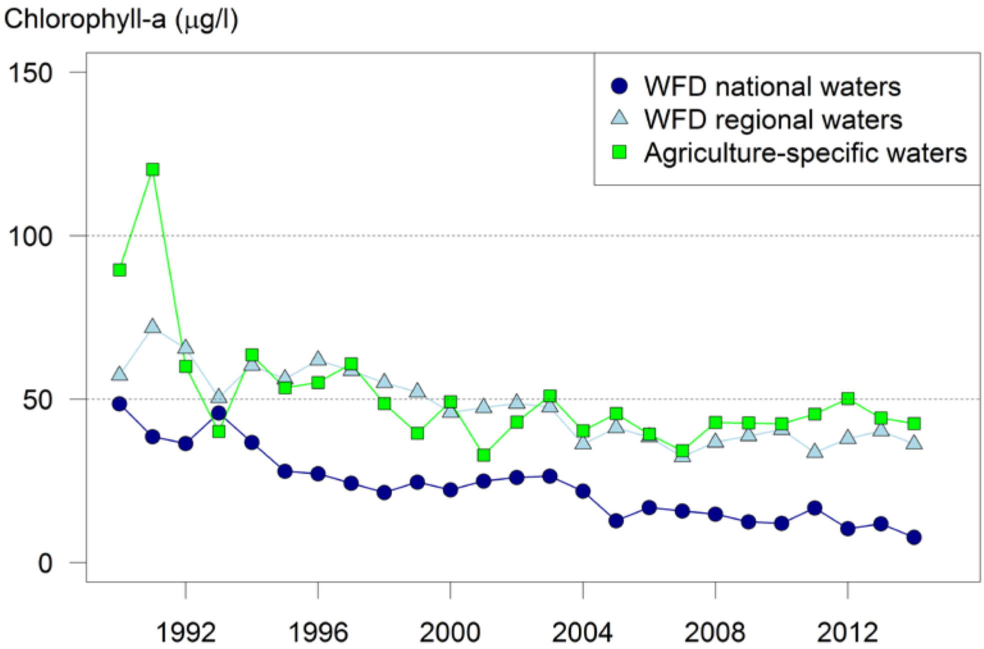

Figure 6.4: Chlorophyll-a (summer average concentration in µg/l) in fresh surface waters in the period 1990-2014

The high average concentrations in agriculture-specific waters (MNLSO) in the first two years were caused by the high concentrations (388-536 µg/l) measured in one of the 8-9 monitoring sites. That monitoring site was no longer monitored between 1992 and 2003. Since 2002 there have been at least 20 monitoring sites (see Section 2.6.2). In 2003, there was a peak measurement of 8,950 µg/l on one measurement occasion at one monitoring site. This measurement is regarded as an anomaly and is not included in the calculation.

By way of illustration, the summer average WFD standard was 10.8 µg/l for chlorophyll-a for shallow (relatively large) buffered pools (WFD type M14; Bijkerk, 2014) and 23 µg/l for poorly buffered (regional) ditches (WFD type M4; Bijkerk, 2014).

Table 6.9: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters per chlorophyll-a concentration class (as summer average) in the various reporting periods[1]

Chlorophyll class	WFD waters 1992-1995	WFD waters 2008-2011	WFD waters 2012-2014	Agriculture-specific waters 1992-1995	Agriculture-specific waters 2008-2011	Agriculture-specific waters 2012-2014
0-2.5 µg/l	0	0	1	2	0	0
2.5-8 µg/l	6	13	13	10	10	23
8.0-25 µg/l	29	39	37	31	44	32
25-75 µg/l	38	37	38	26	33	28
>75 µg/l	27	11	11	31	13	17
Number of sites	205	416	433	42	89	71

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 6.10: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters with increasing or decreasing chlorophyll-a concentrations (as summer average) between various reporting periods[1]

Change (chlorophyll)	WFD waters		Agriculture-specific waters	
	'92-' 95/ '08-'11	'08-'11/ '12-'14	'92-' 95/ '08-'11	'08-'11/ '12-'14
Large increase (> 10 µg/l)	10	16	15	21
Small increase (5-10 µg/l)	4	9	9	9
Stable (± 5 µg/l)	26	46	29	29
Small decrease (5-10 µg/l)	7	12	6	14
Large decrease (> 10 µg/l)	53	17	41	27
Number of sites	182	352	34	56

[1] The total percentage could be higher or lower than 100 because of rounding.

6.4.3 *Nitrogen and phosphorus*

Nitrogen

Summer average total nitrogen concentrations have fallen since 1992 (Figure 6.6). The number of monitoring sites in WFD waters in a high nitrogen class fell and the number of monitoring sites in a low nitrogen class rose in 2012-2014 compared with the period 1992-1995 (Table 6.11). By way of illustration, the WFD standard for total nitrogen was 1.3 mg/l (summer average) for shallow (relatively large) buffered pools (type M14). For poorly buffered (regional) ditches (type M4), the summer average standard for total nitrogen was 2.8 mg/l. The change between the two most recent reporting periods is clearly visible in WFD waters: 34% monitoring sites with a decrease compared with 17% with an increase (Table 6.12). This is slightly less obvious in agriculture-specific waters: 34% of monitoring sites showed a decrease and 28% an increase.

The volume of precipitation has a major impact on measured nitrogen concentrations in surface water. N total concentrations are generally higher in wet years than in dry ones. This is partly caused by the larger proportion of relatively nutrient-rich shallow flow paths that contribute to surface water in wet situations (Rozemeijer and Broers, 2007; Rozemeijer *et al.*, 2010). In dry situations, the opposite applies: it is the relatively high proportion of deeper, cleaner groundwater that contributes to surface water. The low average concentrations in 1990 and 1991 could possibly be explained by weather variations: these were two relatively dry years. The high N total concentration for 1998 is an example of an extremely unfavourable year for surface water quality - in other words, a very wet year (Klein and Rozemeijer, 2015).

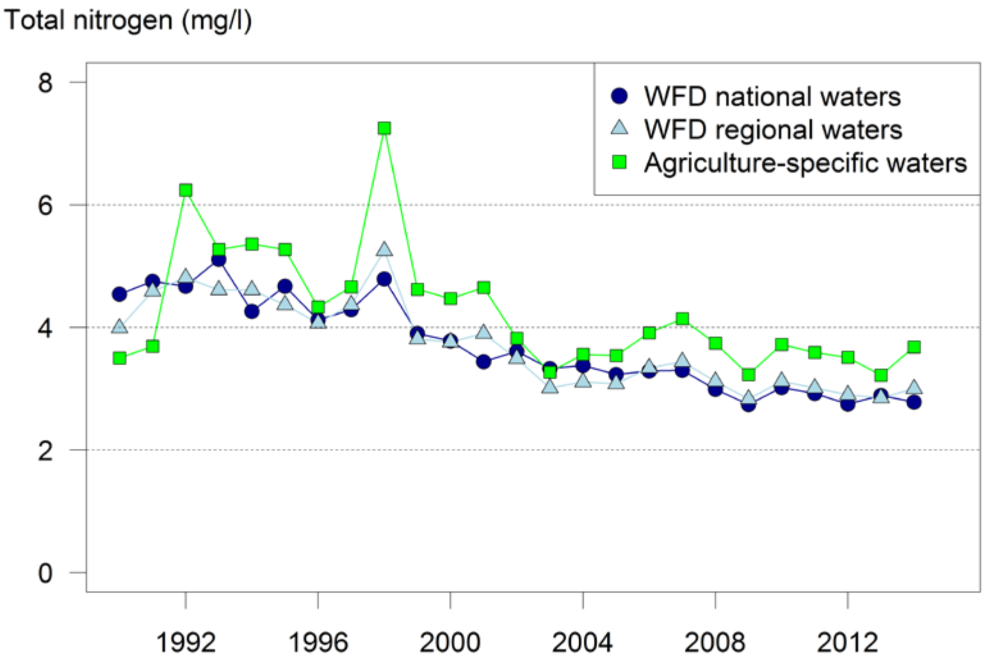

Figure 6.5: Total nitrogen concentration (summer average as N in mg/l) in fresh waters in the period 1990-2014

Table 6.11: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters per total nitrogen concentration class (as summer average) in the various reporting periods[1]

Nitrogen class (N)	WFD waters 1992-1995	WFD waters 2008-2011	WFD waters 2012-2014	Agriculture-specific waters 1992-1995	Agriculture-specific waters 2008-2011	Agriculture-specific waters 2012-2014
0-2 mg/l	11	29	33	6	20	22
2-5 mg/l	57	61	58	55	60	57
5-7 mg/l	16	7	6	17	11	13
>7 mg/l	17	3	3	22	9	7
Number of sites	402	744	764	86	164	174

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 6.12: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters with increasing or decreasing total nitrogen concentrations (as summer average) between various reporting periods[1]

Change (N)	WFD waters '92-'95/ '08-'11	WFD waters '08-'11/ '12-'14	Agriculture-specific waters '92-'95/ '08-'11	Agriculture-specific waters '08-'11/ '12-'14
Large increase (> 0.5 mg/l)	5	10	10	19
Small increase (0.25-0.50 mg/l)	1	7	1	9
Stable (± 0.25 mg/l)	12	50	6	39
Small decrease (0.25-0.50 mg/l)	5	15	7	13
Large decrease (> 0.5 mg/l)	78	18	76	20
Number of sites	399	726	84	163

[1] The total percentage could be higher or lower than 100 because of rounding.

Phosphorus
The summer average total phosphorus concentration in WFD waters has been declining steadily since the early 1990s (Figure 6.6). In agriculture-specific waters the concentration increased up to the end of the 1990s and then started to drop again (Van Duijnhoven *et al.*, 2015).

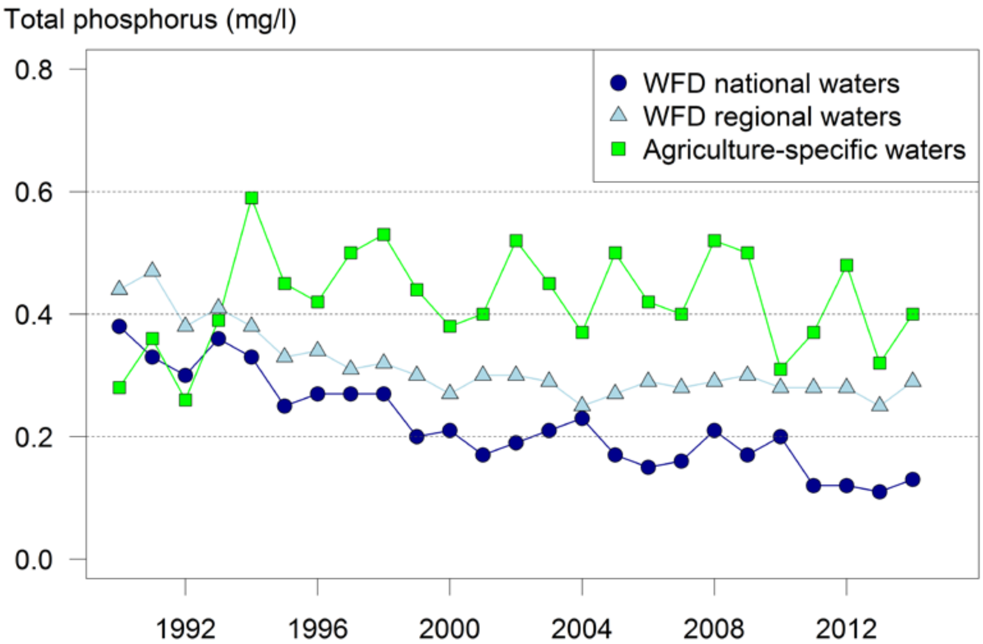

Figure 6.6: Total phosphorus concentration (summer average as P in mg/l) in fresh waters in the period 1990-2014

The percentage of monitoring sites with a total phosphorus concentration higher than 0.2 mg/l in WFD waters fell from 61% in 1992-1995 to 42% in 2008-2011 and then to 36% in 2012-2014 (Table 6.13). In agriculture-specific waters there was also a decline between 1992 and 2008 (from 53% to 46%), but none thereafter. A comparison of the two most recent reporting periods reveals that total phosphorus concentrations in WFD and agriculture-specific waters have stabilised with little evidence of concentrations increasing or decreasing. By way of illustration, the WFD standard for shallow (relatively large) buffered pools (type M14) for total phosphorus is 0.09 mg/l (summer average). The summer average standard for poorly buffered regional ditches (type M4) for total phosphorus is 0.15 mg/l.

Table 6.13: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters per total phosphorus concentration class (as summer average) in the various reporting periods[1]

	WFD waters			Agriculture-specific waters		
Phosphorus class (P)	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
<0.05 mg/l	3	5	8	7	2	4
0.05-0.10 mg/l	11	21	25	22	30	22
0.10-0.20 mg/l	25	32	30	18	21	28
0.20-0.50 mg/l	39	26	22	20	15	16
>0.50 mg/l	22	16	14	33	31	30
Number of sites	408	746	767	88	164	174

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 6.15: Percentage of monitoring sites in WFD and agriculture-specific fresh surface waters with increasing or decreasing total phosphorus concentrations (as summer average P) between the various reporting periods[1]

	WFD waters		Agriculture-specific waters	
Change (P)	‘92-‘95/ ’08-‘11	‘08-‘11/ ‘12-‘14	‘92-‘95/ ’08-‘11	‘08-‘11/ ‘12-‘14
Large increase (> 0.10 mg/l)	0	0	2	4
Small increase (0.05-0.10 mg/l)	2	2	2	2
Stable (± 0.05 mg/l)	83	94	77	83
Small decrease (0.05-0.10 mg/l)	9	2	13	7
Large decrease (> 0.10 mg/l)	6	1	6	4
Number of sites	406	738	86	163

[1] The total percentage could be higher or lower than 100 because of rounding.

6.5 Trends in agricultural practice and quality of fresh surface water

The reduction in the nitrogen surplus in agriculture since 1987 may have contributed to a reduction in the nitrate concentrations in fresh waters. Average nitrate concentrations at 82% of all WFD sites and 90% of sites in agriculture-specific waters fell between the periods 1992-1995 and 2008-2011, whereas concentrations rose at just 3% of sites. Between 2008-2011 and 2012-2014 the number of reductions – 45% for WFD waters and 60% for agriculture-specific waters – was higher than the number of sites where concentrations rose (about 10%).

Despite these improvements, 60% of fresh WFD waters were eutrophic in the period 2011-2013. Just over a quarter (27%) of waters were non-eutrophic, and a small proportion (13%) were potentially eutrophic because their biological status was good but the nutrient concentrations did not comply with the WFD water quality standards.

An analysis of the trend for nitrates (winter average), as described in Section 2.6.3, shows a downward trend in the aggregated trend lines for national, regional and agriculture-specific waters (Figures 6.7-6.9). The 25th and 75th percentile trend lines for nitrates (winter average) also fell over the whole period. More than 90% of monitoring sites in national waters and just over half in regional WFD waters and agriculture-specific waters were suitable for a trend analysis (measurement series of at least 10 years).

Nitrate (mg/l)

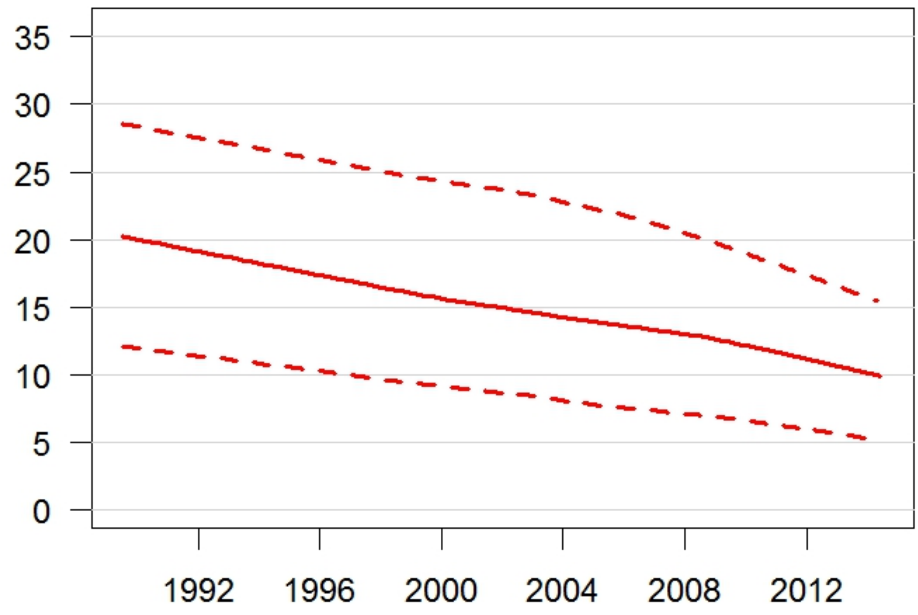

Figure 6.7: Calculated trend in nitrate concentration (winter average as NO_3 in mg/l) for agriculture-specific waters; median (continuous line) and 25th and 75th percentiles (dotted lines)

Nitrate (mg/l)

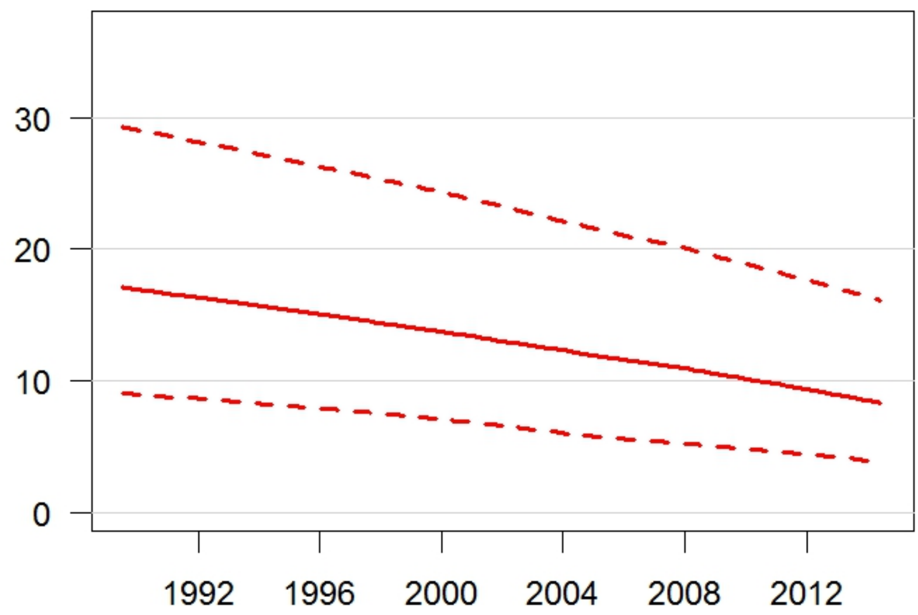

Figure 6.8: Calculated trend in nitrate concentration (winter average as NO_3 in mg/l) for regional WFD waters; median (continuous line) and 25th and 75th percentiles (dotted lines)

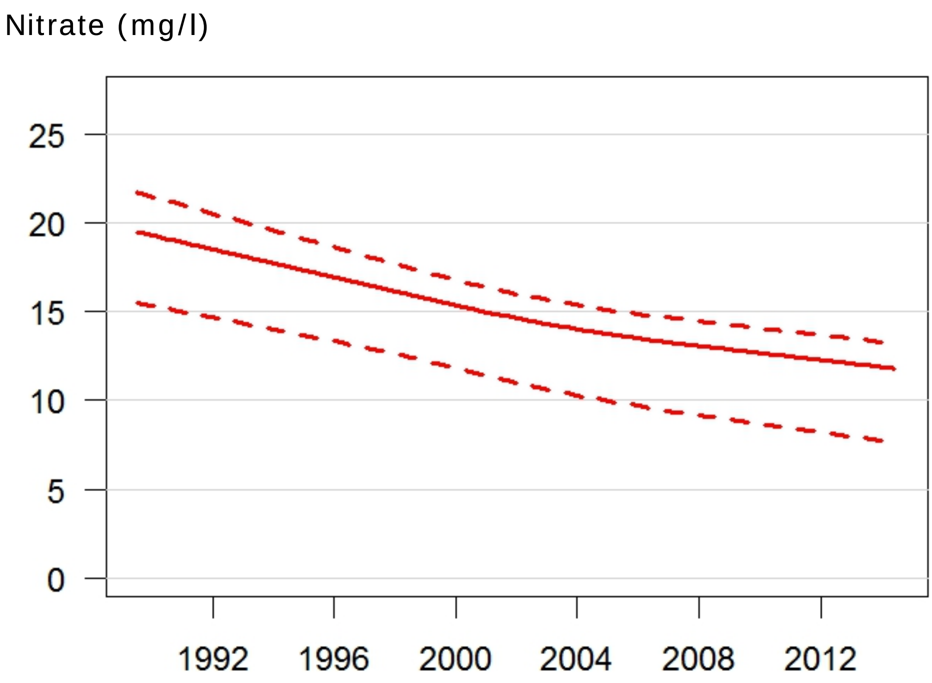

Figure 6.9: Calculated trend in nitrate concentration (winter average as NO_3 in mg/l) for national WFD waters; median (continuous line) and 25th and 75th percentiles (dotted lines)

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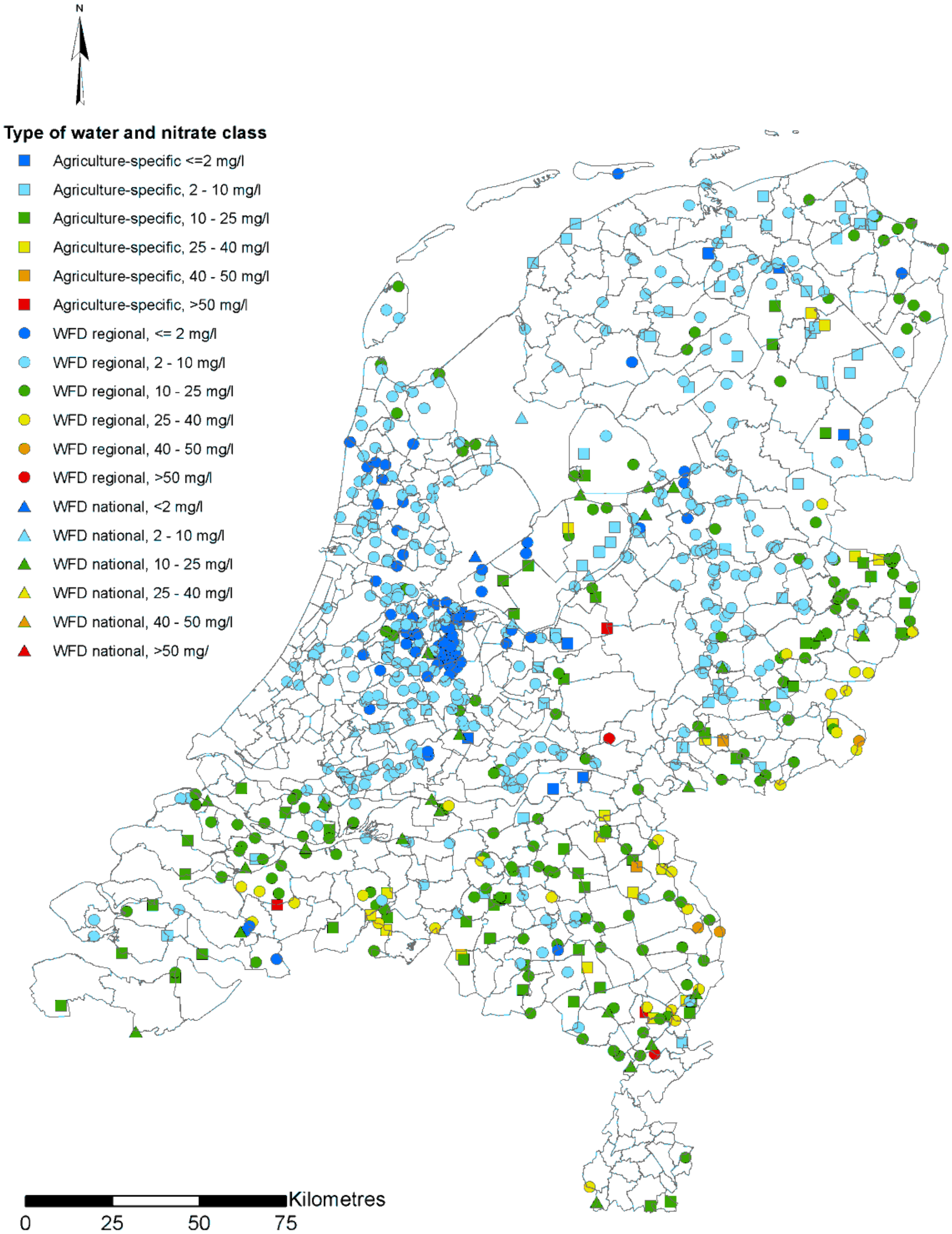
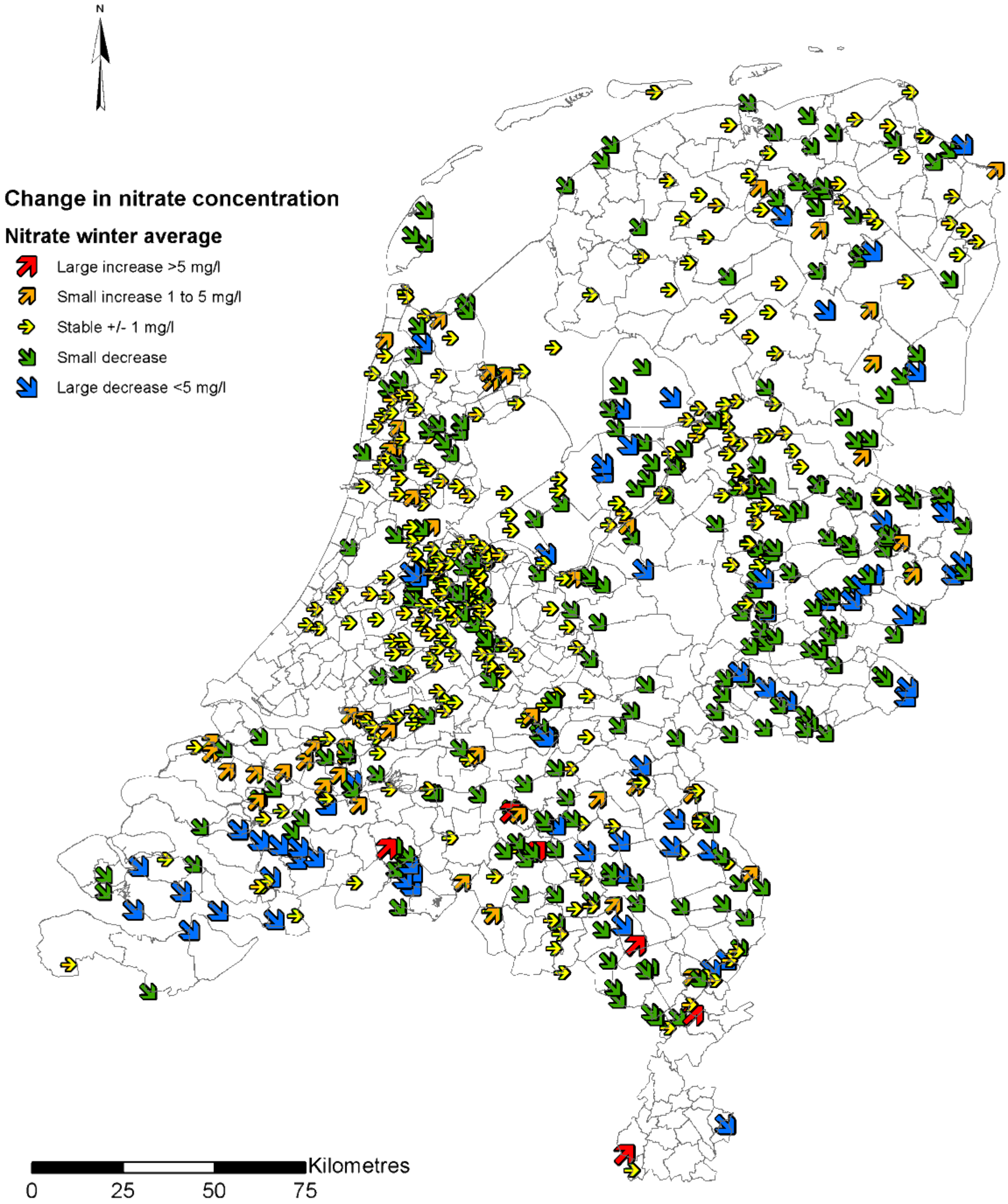
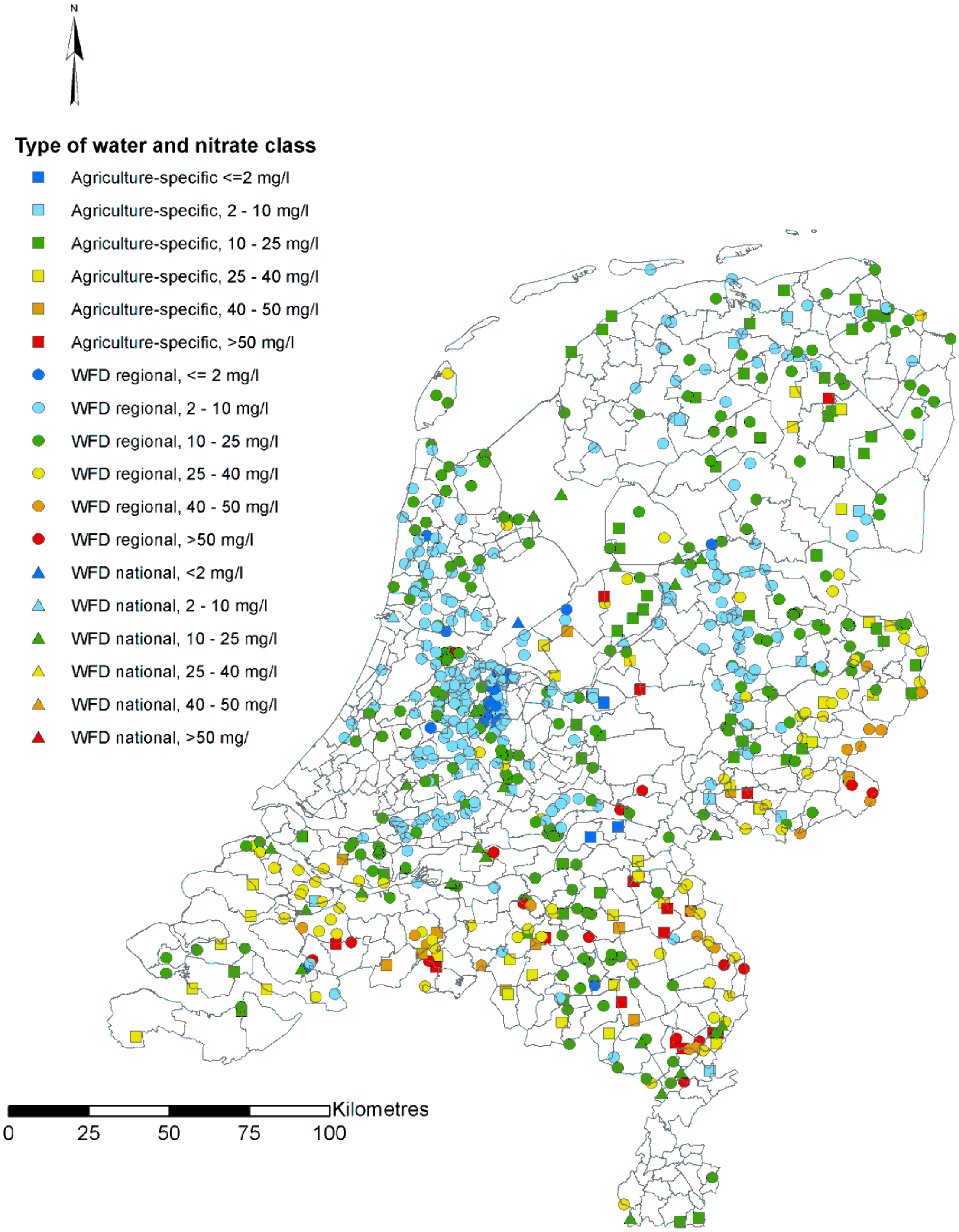


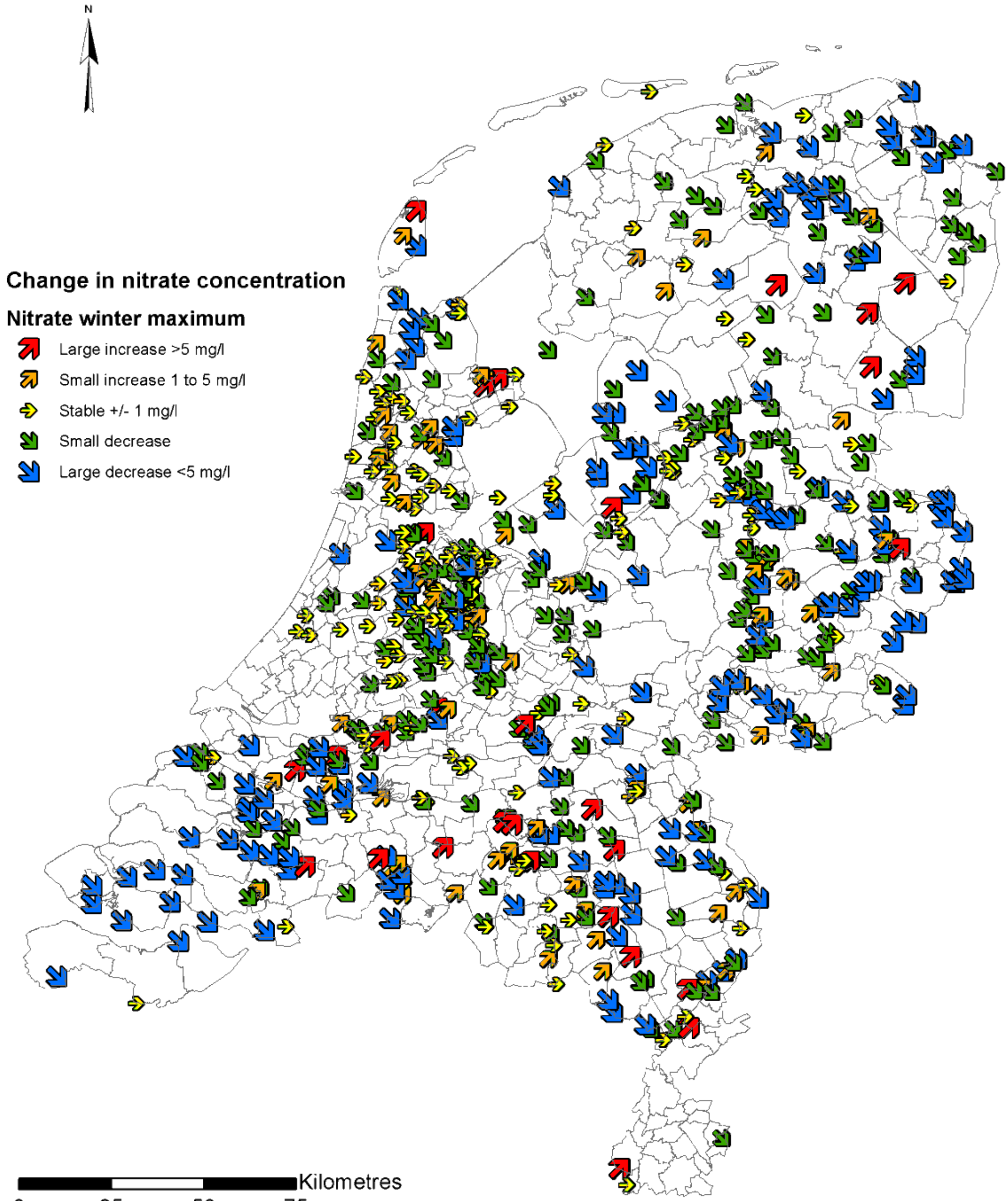
Map 6.1: Winter average nitrate concentration in Dutch fresh waters by monitoring site in the period 2012-2014



Map 6.2: Change in winter average nitrate concentration in Dutch fresh waters by monitoring site between 2008-2011 and 2012-2014; the change shown here is the difference between averages for 2008-2011 and 2012-2014



Map 6.3: Winter maximum nitrate concentration in Dutch fresh waters by monitoring site in the period 2012-2014



Map 6.4: Change in winter maximum nitrate concentration in Dutch fresh waters by monitoring site between 2008-2011 and 2012-2014; the change shown here is the difference between averages for 2008-2011 and 2012-2014

7 Marine and coastal water quality

7.1 Introduction

This chapter discusses the results of the monitoring of nitrogen and phosphorus concentrations in marine surface waters.

Just as in the previous chapter on fresh water, Chapter 7 provides an overview of nitrogen emissions in marine surface waters. A distinction is made between the two types of marine waters defined in the Water Framework Directive: transitional waters and coastal waters. All other marine waters are defined as open sea. These locations do not form part of the waters defined in the Water Framework Directive.

The data presented in this section are based on average or maximum winter concentrations (December to February), since the least biological activity occurs in this period. As a result, the nitrate concentrations measured in winter are a better indicator of changes in the water quality status than nitrate emissions measured in summer.

7.2 Nutrient load on marine and coastal waters

From 2012 to 2014, the nutrient load in the North Sea and the Waddenzee via the Netherlands was around 230 million kg nitrogen and 8 million kg phosphorus per annum (see Table 7.1). Direct discharges generally contribute little to the total load: 2% for nitrogen and 6% for phosphorus. By far the greatest part comes from river water.

Table 7.1: Total nitrogen and phosphorus load in the North Sea and Waddenzee from and via the Netherlands and via atmospheric depositions (in kg million per annum) for the period 1992-2014[1]

	Nitrogen (N)			Phosphorus (P)		
	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
Discharge via rivers[2]	591	237	231	38.0	9.5	7.9
Direct discharges[3]	11	4	4	3.6	0.5	0.5
Total load via water from and via the Netherlands	602	241	235	41.6	10.0	8.4
Atmospheric deposition[3]	19 (59)	14 (43)	13 (42)	ND[4]	ND	ND

[1] The average outputs for each period (1992-1995, 2008-2011 and 2012-2014) are given.
[2] Calculated from the RWS-DONAR database
[3] Data from Emission Registration; atmospheric deposition in 12 mile zone, with deposits on the Dutch continental shelf in brackets
[4] ND = No Data

The nutrient load via rivers fell further between 2008 and 2014: by 2.6% for nitrogen and by more than 16% for phosphorus. The nitrogen and phosphorus load via rivers from and via the Netherlands in 2012-2014 was 39% and 21% of that in 1992-1995 respectively.

The contribution to the total load in the North Sea (Table 7.2) from the Netherlands has declined. The figure for nitrogen was 34% in 1992-1995 and is estimated at 19% for 2012-2014. The contribution for phosphorus was 51% in 1992-1995 and is also estimated at 19% for 2012-2014.

Table 7.2: Output loads for nitrogen and phosphorus in the North Sea (in million kg per annum) for the period 1992-2013[1]

	Nitrogen (N)			Phosphorus (P)		
	1992-1995	2008-2011	2012-2013	1992-1995	2008-2011	2012-2013
Output via rivers and directly[2]	1373	970	1081	82	42	43
Atmospheric deposition[2]	568	441	409	ND[3]	ND	ND

[1] The average outputs from each period (1992-1995, 2008-2011 and 2012-2013) are given for the OSPAR region II (North Sea, Skagerrak, Kattegat, Channel zone).

[2] Estimate for 2012-2013 NL OSPAR doc. no. HASEC 16/07/01 add. 2

[3] ND = No Data

7.3 Nitrate concentration in marine and coastal waters

Nitrate concentrations in transitional waters have been falling since the early 1990s (Figure 7.1). Concentrations in coastal waters and the open sea are stable (Table 7.3) and lower than in transitional waters (Figure 7.1). Concentrations remain unchanged at below 10 mg/l (Table 7.4).

Table 7.3: Percentage of monitoring sites in marine waters per nitrate concentration class (as winter average) in the various reporting periods[1]

Nitrate class (NO_3 in mg/l)	Transitional waters			Coastal waters			Open sea		
	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
0-10 mg/l	36	47	60	100	100	100	100	100	100
10-25 mg/l	64	53	40						
25-40 mg/l									
40-50 mg/l									
>50 mg/l									
Number of sites	14	15	15	10	12	12	13	14	12

[1] The total percentage could be higher or lower than 100 because of rounding.

The maximum concentrations present the same picture as the average concentrations: a reduction in transitional waters and lower and stable concentrations in the open sea (Figure 7.2). Nitrate concentrations in coastal waters at 8-10% of sites were more than 10 mg/l up to 2011 (Table 7.5). Concentrations in the latest period were below 10 mg/l at all sites, indicating that there has been a reduction (Table 7.6).

Table 7.4: Percentage of monitoring sites in marine waters with increasing or decreasing nitrate concentrations (as winter average) between various reporting periods1

Change	Transitional waters		Coastal waters	
	'92-'95/ '08-'11	'08-'11/ '12-'14	'92-'95/ '08-'11	'08-'11/ '12-'14
Large increase (> 5 mg/l)				
Small increase (1-5 mg/l)				
Stable (± 1 mg/l)	14	47	50	100
Small decrease (1-5 mg/l)	71	53	50	
Large decrease (> 5 mg/l)	14			
Number of sites	14	15	10	12

[1] The total percentage could be higher or lower than 100 because of rounding.

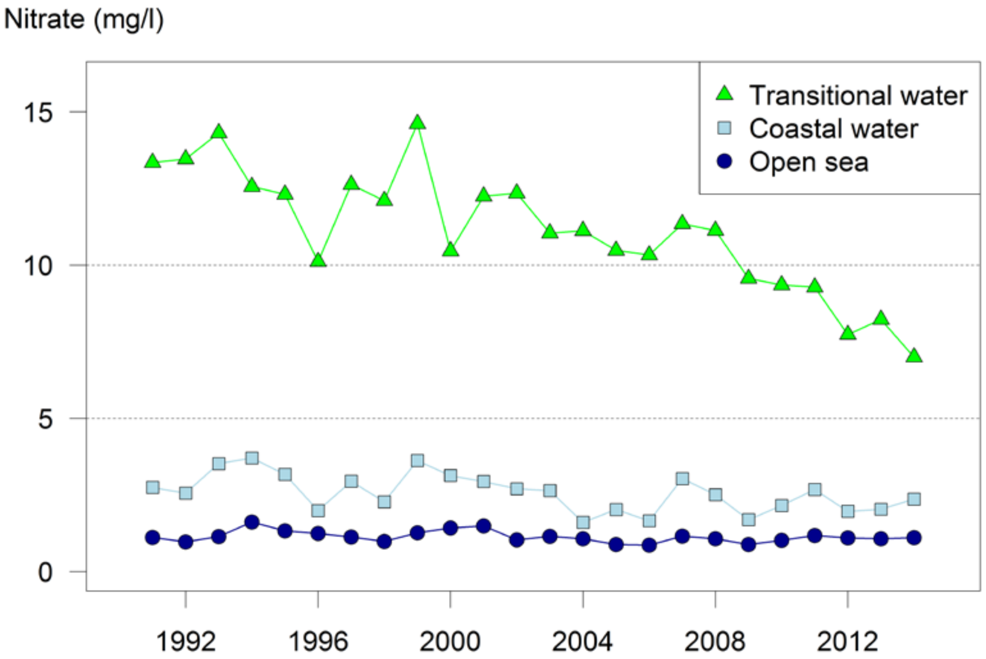


Figure 7.1: Winter average nitrate concentration (mg/l) in open sea and Dutch transitional and coastal waters in the period 1991-2014

Table 7.5: Percentage of monitoring sites in marine waters per nitrate concentration class (as winter maximum) in the various reporting periods[1]

Concentration	Transitional waters			Coastal waters			Open sea		
	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
0-10 mg/l	14	40	47	90	92	100	100	100	100
10-25 mg/l	64	60	53		8				
25-40 mg/l	21								
40-50 mg/l									
>50 mg/l									
Number of sites	14	15	15	10	12	12	13	14	12

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 7.6: Percentage of monitoring sites in marine waters with increasing or decreasing nitrate concentrations (as winter maximum) between the various reporting periods[1]

Change	Transitional waters '92-'95/ '08-'11	Transitional waters '08-'11/ '12-'14	Coastal waters '92-'95/ '08-'11	Coastal waters '08-'11/ '12-'14	Open sea '92-'95/ '08-'11	Open sea '08-'11/ '12-'14
Large increase (> 5 mg/l)						
Small increase (1-5 mg/l)		7	10	17	10	17
Stable (± 1 mg/l)	21	47	30	58	30	58
Small decrease (1-5 mg/l)	14	47	60	17	60	17
Large decrease (> 5 mg/l)	64			8		8
Number of sites	14	15	10	12	10	12

[1] The total percentage could be higher or lower than 100 because of rounding.

A high maximum was measured in the transitional waters in 2000 (Figure 7.2), whereas the average concentration in that year was lower than in the years either side (Figure 7.1). This is due to outliers impacting more heavily on the maximum than on the average. The time of sampling is key. For example, there may be a high concentration at the time of sampling (although in reality peaks are often missed). The maxima in transitional waters were caused by the same monitoring site in 22 of the 24 years.

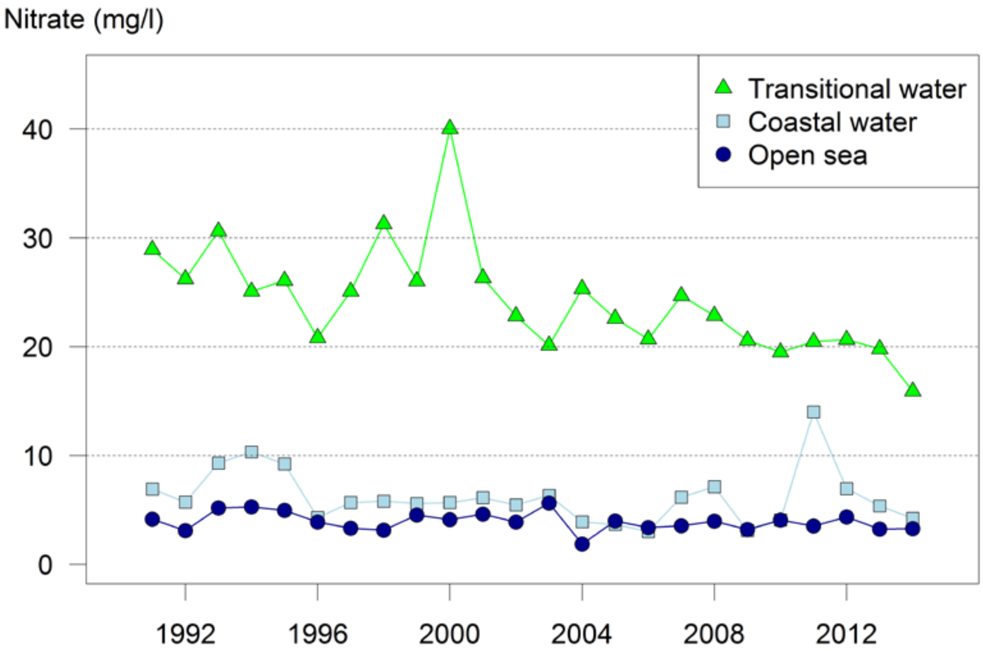


Figure 7.2: Winter maximum nitrate concentration (as NO_3 in mg/l) in open sea and Dutch transitional and coastal waters in the period 1991-2014

7.4 Eutrophication of marine and coastal waters

7.4.1 General situation

Six percent of WFD waters are rated as "non-eutrophic", 81% as "potentially eutrophic" and 13% as "eutrophic" in the latest reporting period (Table 7.7). "Potentially eutrophic" means that the biological status is good but the nutrient concentrations do not meet the WFD water quality standards. It is not possible to provide a trend because this indicator is new. However, trends are given for a number of parameters that play a role in the eutrophication status, such as the concentration of inorganic nitrogen (DIN) and the chlorophyll-a concentration (Figures 7.3 and 7.4).

Table 7.7: Assessment of eutrophication in marine and coastal waters in the period 2011-2013 (% of water bodies per class)

Classes	Percentage of water bodies
Non-eutrophic	6
Potentially eutrophic[1]	81
Eutrophic	13
Number of sites	16

[1] The biological status is good, but the nutrient concentrations do not meet the WFD water quality standards.

To determine the eutrophication of fresh waters, including coastal and transitional waters, the status of the biological quality element “algae” (combination of *Phaeocystis* bloom and chlorophyll-a) and nutrients was looked at. This is in accordance with the Water Framework Directive method. It is striking that the biological quality element of phytoplankton is rated good almost everywhere (except in the Waddenzee), but that the potential for eutrophy is still present in almost all coastal waters because DIN winter concentrations in coastal and transitional waters are rated “inadequate” or “poor” in the Water Framework Directive assessment.

7.4.2 *Inorganic nitrogen*

The winter concentrations of inorganic nitrogen (DIN) corrected for salt content (Figure 7.3) show the same trend as the nitrate concentrations (Figures 7.1 and 7.2). By way of illustration, the standard for inorganic nitrogen (DIN) with standardised salinity (30 psu) for the winter average (expressed as N) is 0.46 mg/l in coastal waters.

The downward and upward outliers in the trend for transitional waters (1996 and 1999 respectively) could possibly be explained by variations in the weather (see explanation below Figure 6.5 in the previous chapter). The year 1996 was a very dry year with relatively low concentrations. The peak in the concentration in transitional waters was in 1999 and not in 1998, as is the case with fresh waters. This is due to the way winter is defined (winter 1999 is the winter following the summer of 1998). The time lag between upstream and downstream also plays a role.

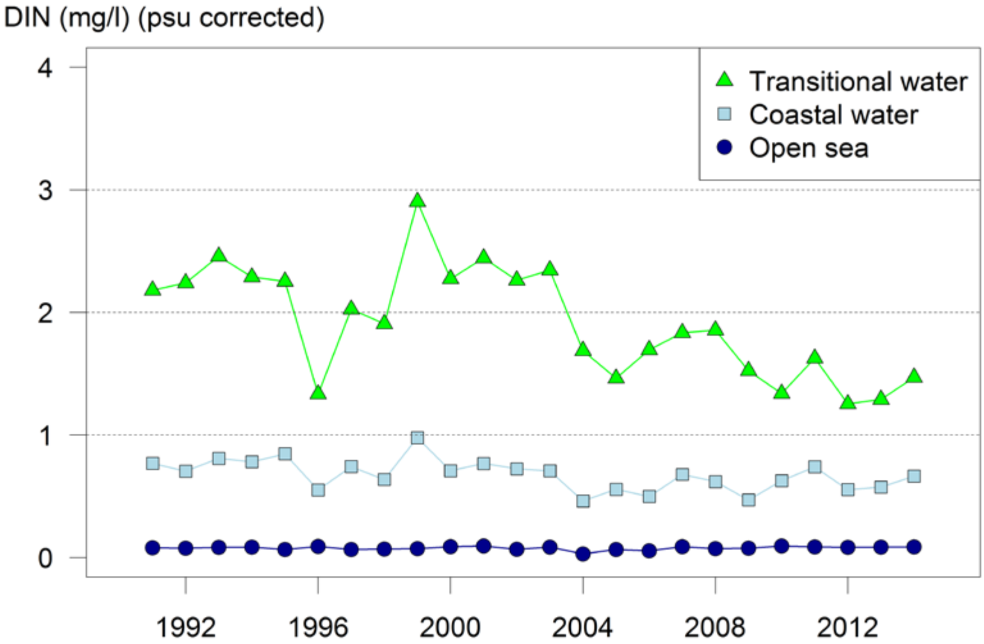


Figure 7.3: Average winter dissolved inorganic nitrogen concentrations (DIN, as N in mg/l), standardised to a salinity of 30 psu, in Dutch transitional waters, coastal waters and open sea in the period 1991-2014

7.4.3 Chlorophyll-a

The summer average chlorophyll-a concentrations in all types of marine waters fell between 1992 and 2014 (Figure 7.4). Between 2008 and 2014, concentrations at all monitoring sites were stable (Table 7.9). In the latest reporting period, concentrations were below 25 µg/l at over 90% of monitoring sites, and more than 90% of monitoring sites in open sea had a concentration lower than 8 µg/l (Table 7.8). By way of illustration, the standard for chlorophyll-a for coastal waters is 14 µg/l. This applies to the 90th percentile value in the winter months.

Table 7.8: Percentage of monitoring sites in marine waters per chlorophyll-a concentration class (as summer average) in the various reporting periods[1]

	Transitional waters			Coastal waters			Open sea		
Concentration	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014	1992-1995	2008-2011	2012-2014
0-2.5 µg/l							38	53	57
2.5-8.0 µg/l	17	54	77	20	42	67	25	33	36
8.0-25 µg/l	83	38	15	80	50	25	38	13	7
25-75 µg/l		8	8		8	8			
>75 µg/l									
Number of sites	12	13	13	10	12	12	16	15	14

[1] The total percentage could be higher or lower than 100 because of rounding.

Table 7.9: Percentage of monitoring sites in marine waters with increasing or decreasing chlorophyll-a concentrations (as summer average) between the various reporting periods[1]

Change	Transitional waters '92-'95/ '08-'11	Transitional waters '08-'11/ '12-'14	Coastal waters '92-'95/ '08-'11	Coastal waters '08-'11/ '12-'14	Open sea '92-'95/ '08-'11	Open sea '08-'11/ '12-'14
Large increase (>5 µg/l)	8					
Small increase (1-5 µg/l)						
Stable (± 1 µg/l)	42	100	60	100	73	100
Small decrease (1-5 µg/l)	50		40		27	
Large decrease (>5 µg/l)						
Number of sites	12	13	10	12	15	13

[1] The total percentage could be higher or lower than 100 because of rounding.

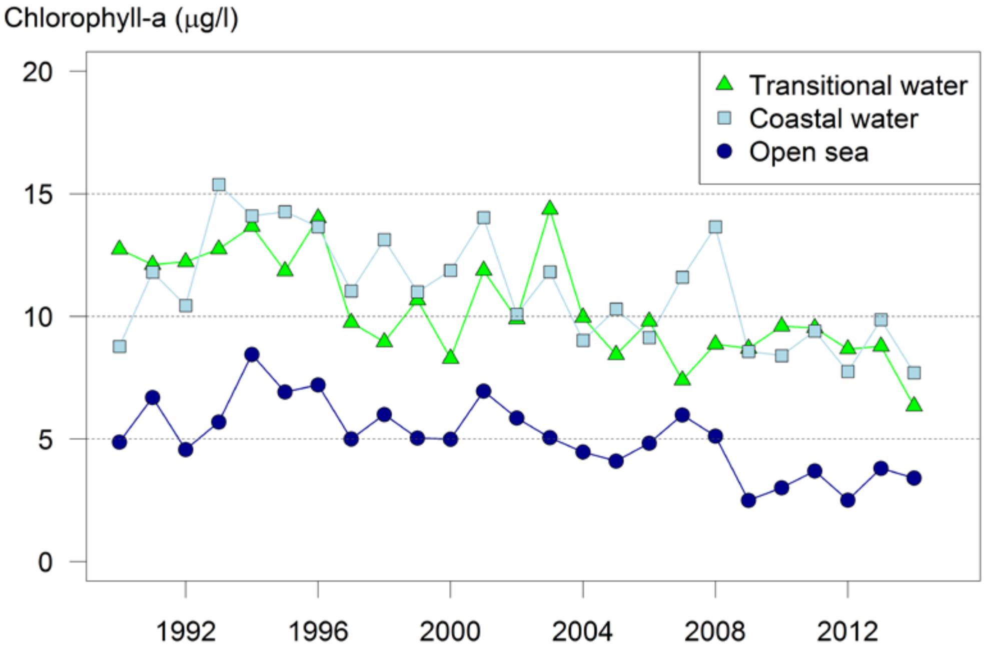


Figure 7.4: Summer average chlorophyll-a concentration (µg/l) in open sea and Dutch coastal and transitional waters in the period 1990-2014

7.5 Trends in agricultural practices and quality of marine surface water

The reduction in the nitrogen surplus in agriculture since 1987 has probably also contributed to a reduction in nitrate concentrations in marine waters. At 85% of monitoring sites in transitional waters and 50% of those in coastal waters, the nitrate concentration fell between the periods 1992-1995 and 2008-2011 and there were no increases. Between 2008-2011 and 2012-2014 there was a reduction at 53% of monitoring sites in transitional waters and no change in coastal waters. The analysis of the trend for nitrates (winter average) described in Section 2.6.3 shows a downward trend both in transitional waters (Figure 7.5) and in the open sea (Figure 7.6). The downward trend at sites in transitional waters is steeper from 2000 onwards.

Despite these improvements in nitrate concentrations, the dissolved nitrogen concentrations (nitrate and ammonium) are also too high in almost all marine waters. Eutrophication effects are visible in the biology of 13% of waters, but the biology is good in 81% of waters despite dissolved nitrogen concentrations being too high. This probably means that there are other factors causing the algal biomass not to indicate eutrophic conditions, such as light limitation, grazing by plankton or other nutrients apart from nitrogen.

Nitrate (mg/l)

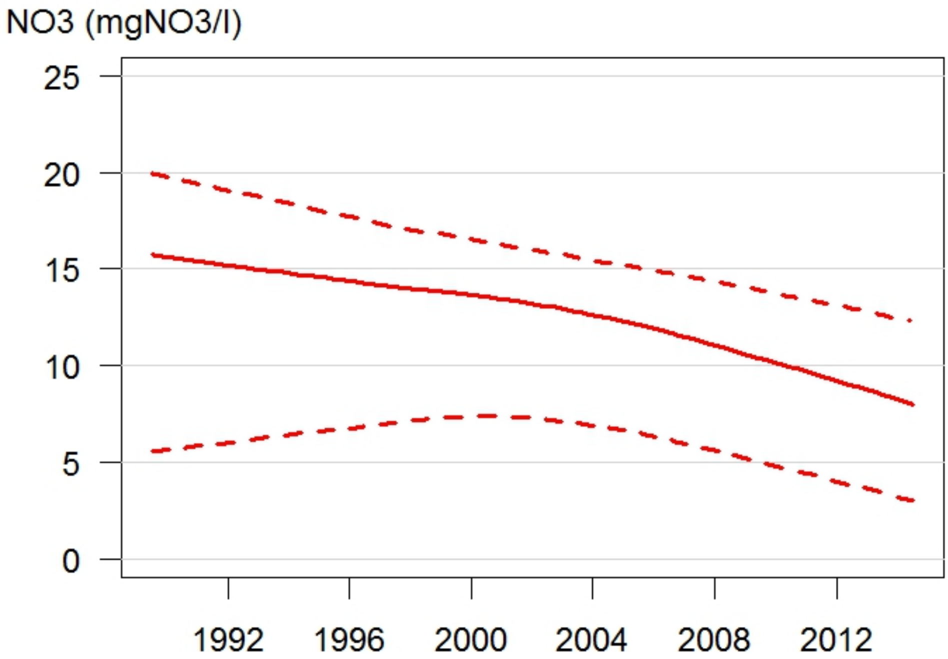


Figure 7.5: Calculated trend for nitrate concentrations (winter average expressed as NO_3 in mg/l) for WFD transitional waters; median (unbroken line) and 25th and 75th percentile (dotted lines)

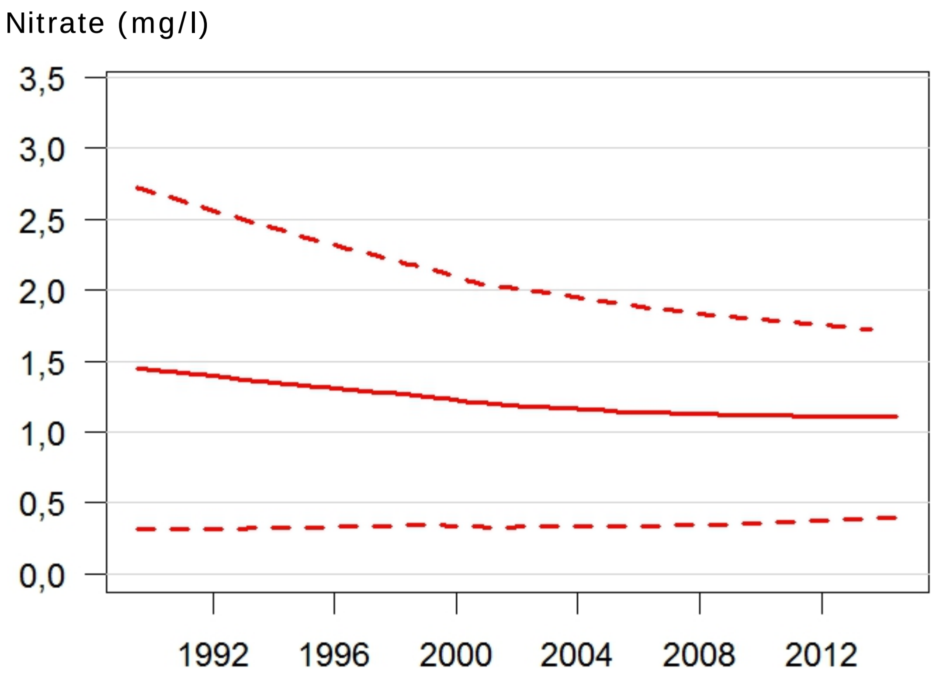


Figure 7.6: Calculated trend for nitrate concentrations (winter average expressed as NO_3 in mg/l) for open sea sites; median (unbroken line) and 25th and 75th percentile (dotted lines)

7.6 References

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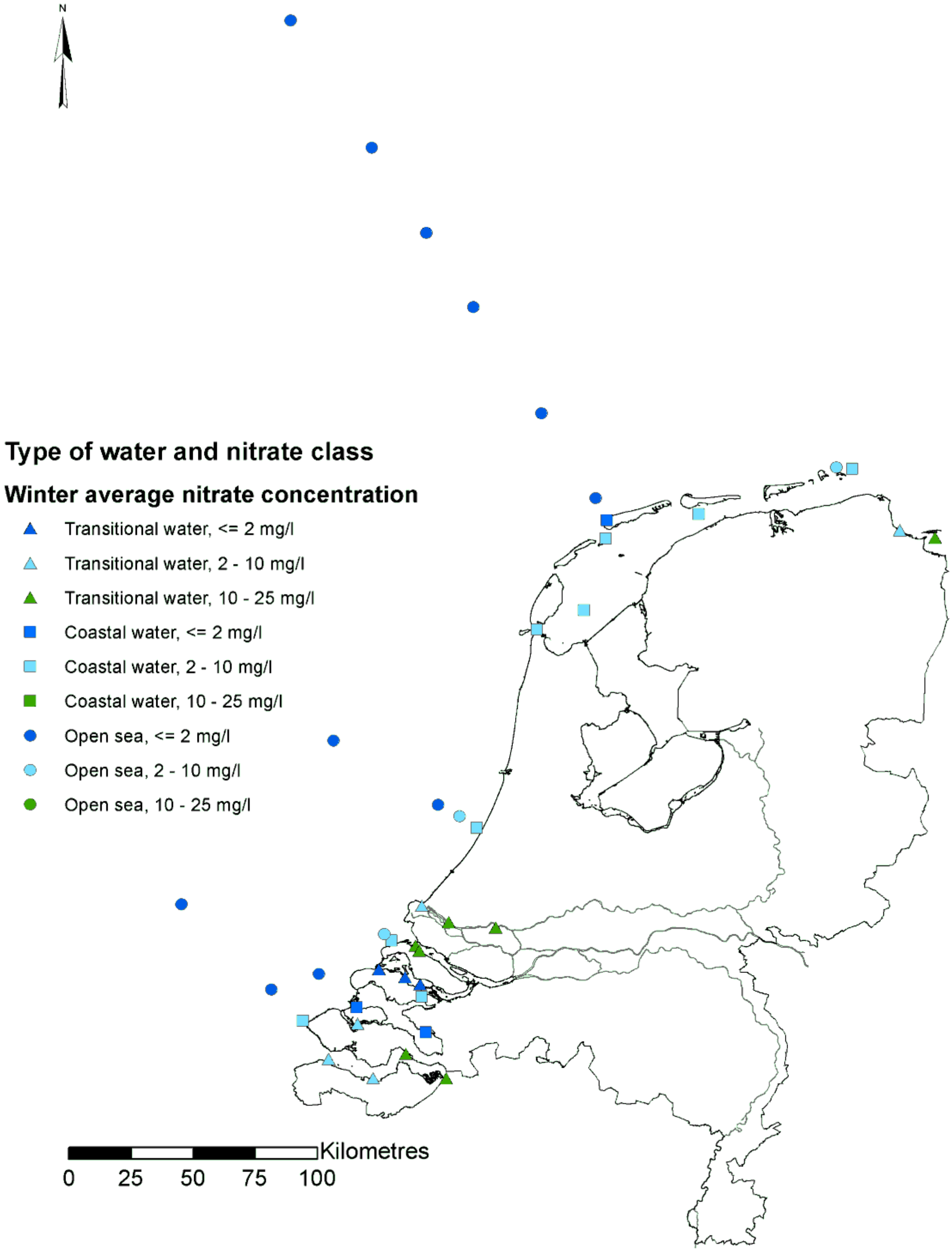
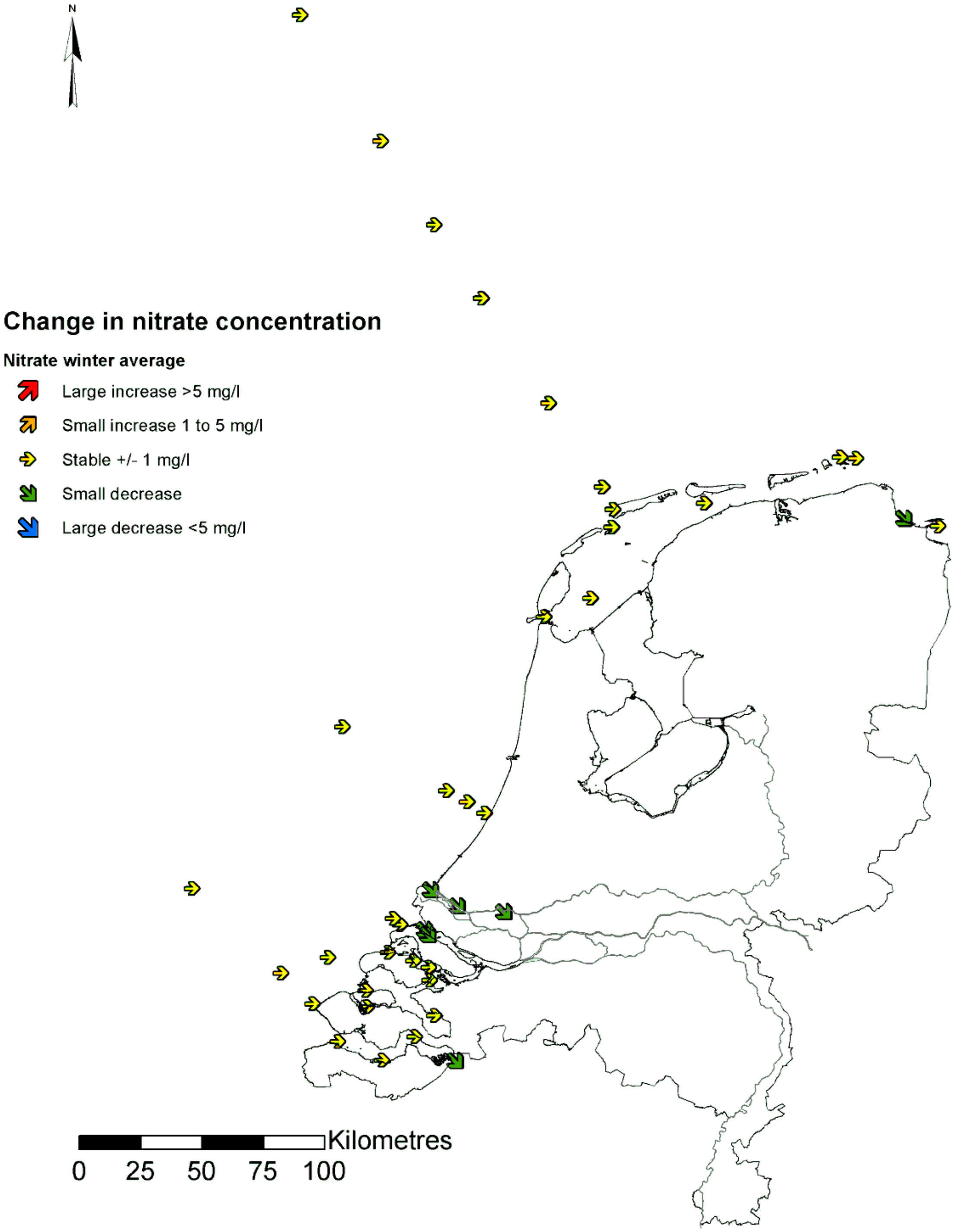
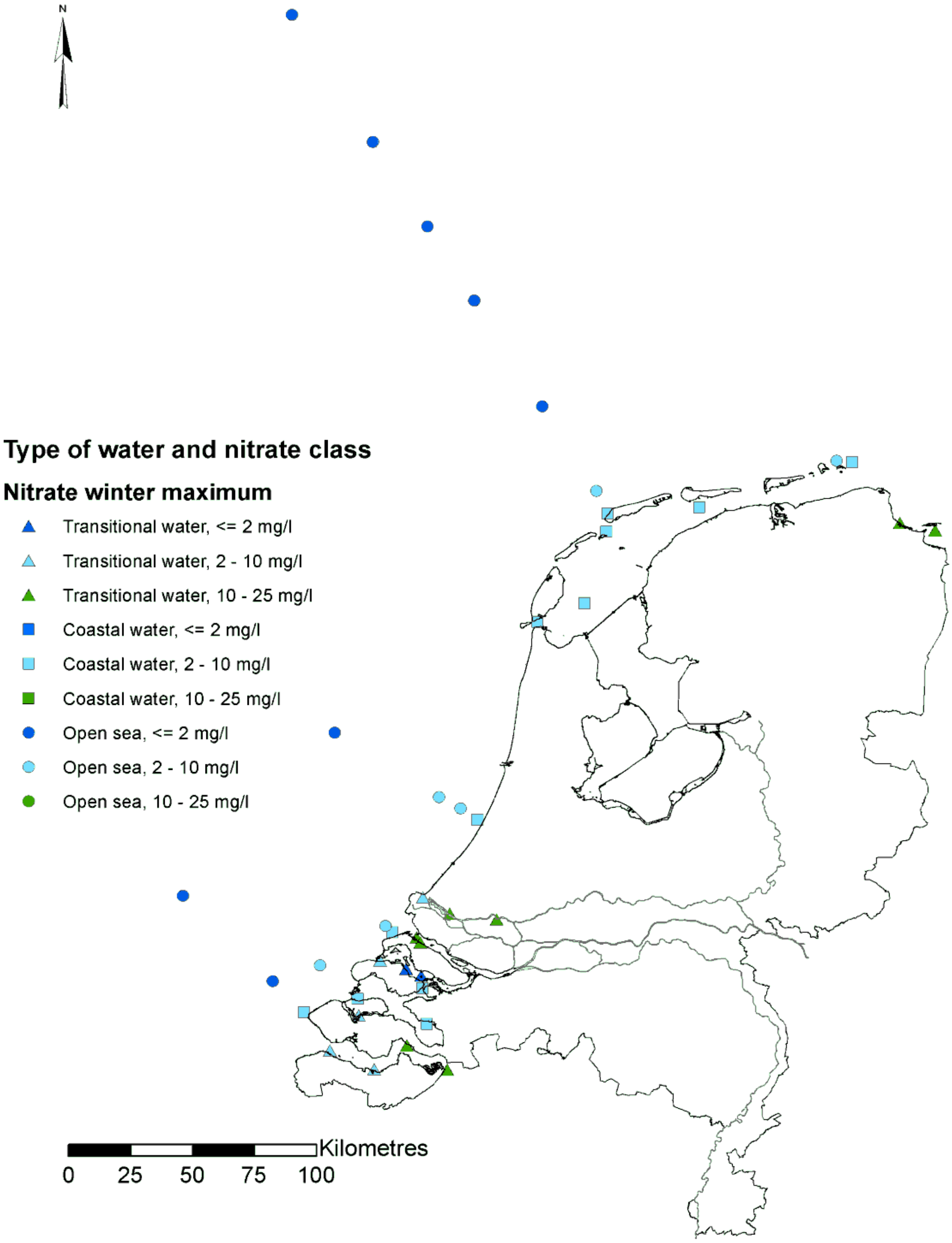


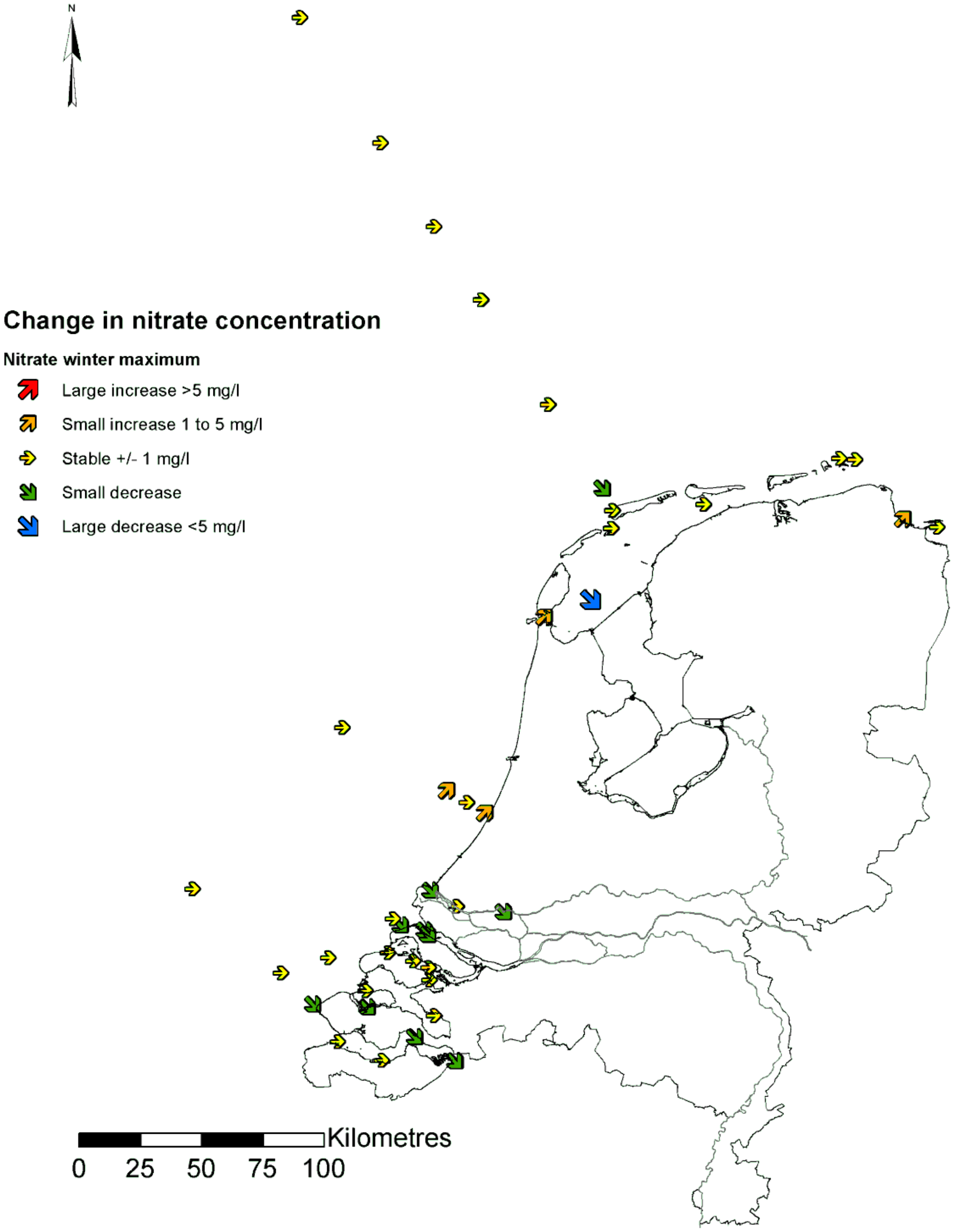
Map 7.1: Winter average nitrate concentration in Dutch coastal and transitional waters and open sea per monitoring site in the period 2012-2014



Map 7.2: Change in winter average nitrate concentration in Dutch coastal and transitional waters and open sea between 2008-2011 and 2012-2014 by monitoring site; the change shown here is the difference between averages for 2008-2011 and 2012-2014



Map 7.3: Winter maximum nitrate concentration in Dutch coastal and transitional waters and open sea by monitoring site in the period 2012-2014



Map 7.4: Change in winter maximum nitrate concentration in Dutch coastal and transitional waters and open sea between 2008-2011 and 2012-2014 by monitoring site; the change shown here is the difference between averages for 2008-2011 and 2012-2014

8 Future developments in water quality

8.1 Assessment of forecasting possibilities

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

Travel times of water that leaches from root zones and was studied under the LMM programmes are estimated to be less than five years (Meinardi and Schotten, 1999; Meinardi *et al.*, 1998a, 1998b). It is therefore assumed that the effects of the Fifth Action Programme (2014-2017) on the quality of the upper groundwater on farms will become apparent between 2018 and 2023.

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

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

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

The effects of measures on nitrate concentrations in fresh agriculture-specific surface waters will be discernible fairly quickly compared with their impact on nitrate concentrations in groundwater at a depth of over 5 metres. Change in quality will probably be comparable to the effects on the upper groundwater of farms. Improvement in the quality of surface water in the Clay and Peat Regions will be comparable to that in the water that leaches from root zones on farms, with the same improvement response as produced by the Fifth Action Programme (2014-2017). The contribution of young groundwater (1-5 years old) to surface water in the Sand Region varies from less than 10% to more than 70%. It is therefore assumed that the effects of measures from the Fifth Action Programme on nitrate concentrations in fresh surface water will only become apparent in the first five years following full implementation of the Action Programme. Because of mixing, it will probably be hard to distinguish the effects of the measures on nitrate concentrations from the effects of natural conditions on them. Examples of the latter are factors such as differences in precipitation.

Forecasting the future development of eutrophication due to agriculture is even more difficult than for nitrate concentrations, the main reasons being:

- The differences in surface waters with regard to their sensitivity to eutrophication
- Phosphorus concentrations and other factors such as hydromorphology, which also play an important part in the eutrophication process
- Contributions from other sources of nutrient input, such as urban wastewater and cross-border rivers
- The extreme difficulty with predicting the response times of aquatic ecosystems to a substantial reduction in nutrient inputs and concentrations

8.2 Future developments in water quality

For an ex-ante evaluation of the draft River Basin Management Plans for the Water Framework Directive, model calculations were carried out to establish the effects of the Fifth Action Programme on nitrate concentrations in the upper groundwater and nitrogen and phosphorus leaching and run-off into surface water in the longer term (Groenendijk *et al.*, 2015).

Due to time lag, the nitrate concentration in groundwater in the Sand Region is likely to fall further over the next few years (Groenendijk *et al.*, 2015). The model calculations also show that there will be no further reduction in sandy soils in Sand Central and Sand North after 2017, but that the nitrate concentration in the sandy soils in Sand South will continue to fall slightly after 2017, partly due to a reduction in the nitrogen surplus (Groenendijk *et al.*, 2015).

Nitrate concentrations will mainly improve in Sand South (see Figure 8.1), although this improvement will be insufficient to meet the standard there. The calculated nitrate concentration will fall from 71 mg/l in 2013 to 62 mg/l in 2027 in Sand South, from 36 mg/l to 34 mg/l in Sand Central and from 40 mg/l to 37 mg/l in Sand North (Groenendijk *et al.*, 2015).

The total nitrogen load in Dutch surface waters will not fall as a result of the fertiliser policy because the reduction in the sand areas is cancelled out by an increase in some of the clay areas (Figure 8.2; Groenendijk *et al.*, 2015). However, the phosphorus load in Dutch surface waters will drop slightly (-0.1 kg P per ha per year) (Groenendijk *et al.*, 2015).

The results shown here do not fully take account of autonomous developments from 2013 onwards. New calculations will be performed in connection with the evaluation of the Fertilisers Act 2016; these developments have been taken into account. These will only be available in the second half of 2016 and could therefore not be included in this report.

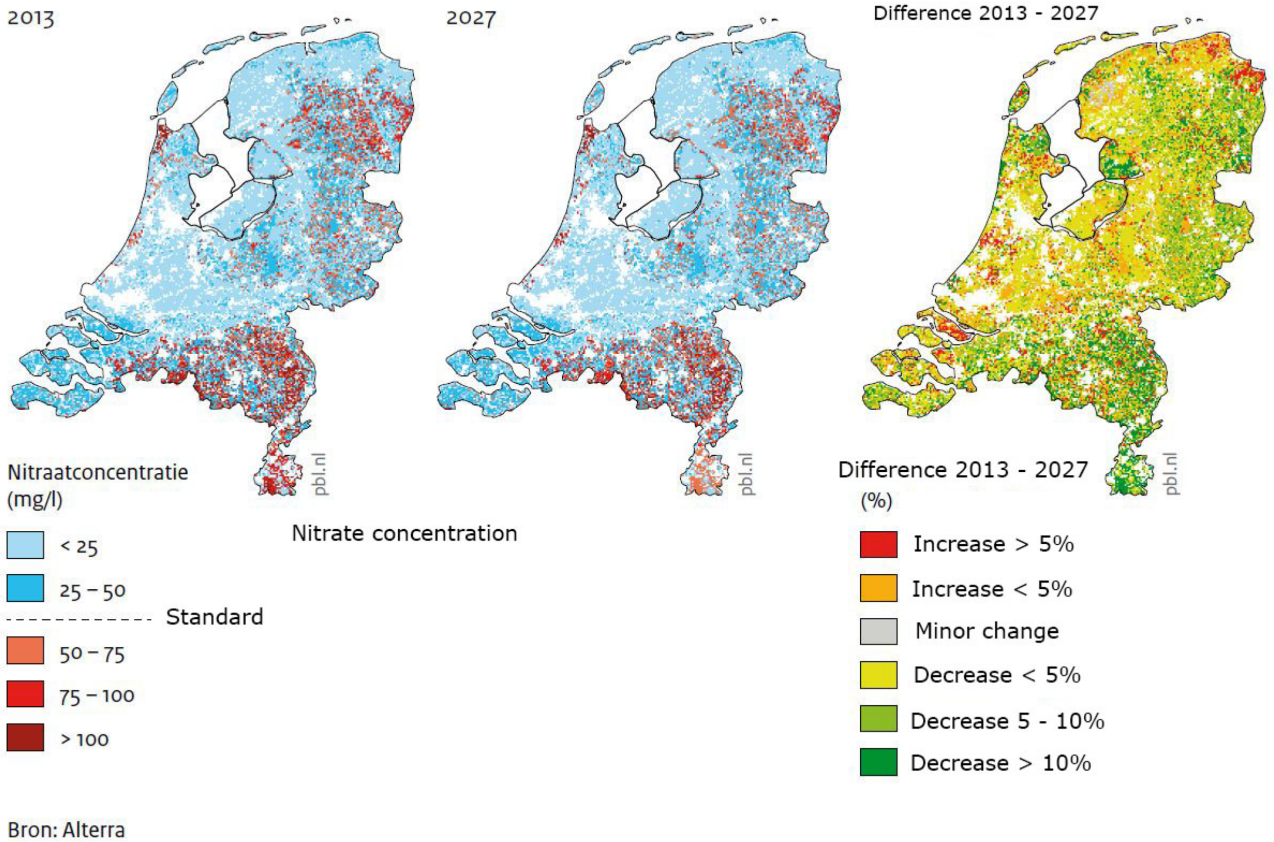


Figure 8.1: Nitrate in upper groundwater with the Fifth Action Programme (2014-2017) with a stable livestock population, 2013–2027
Source: Van Gaalen et al. (2016)

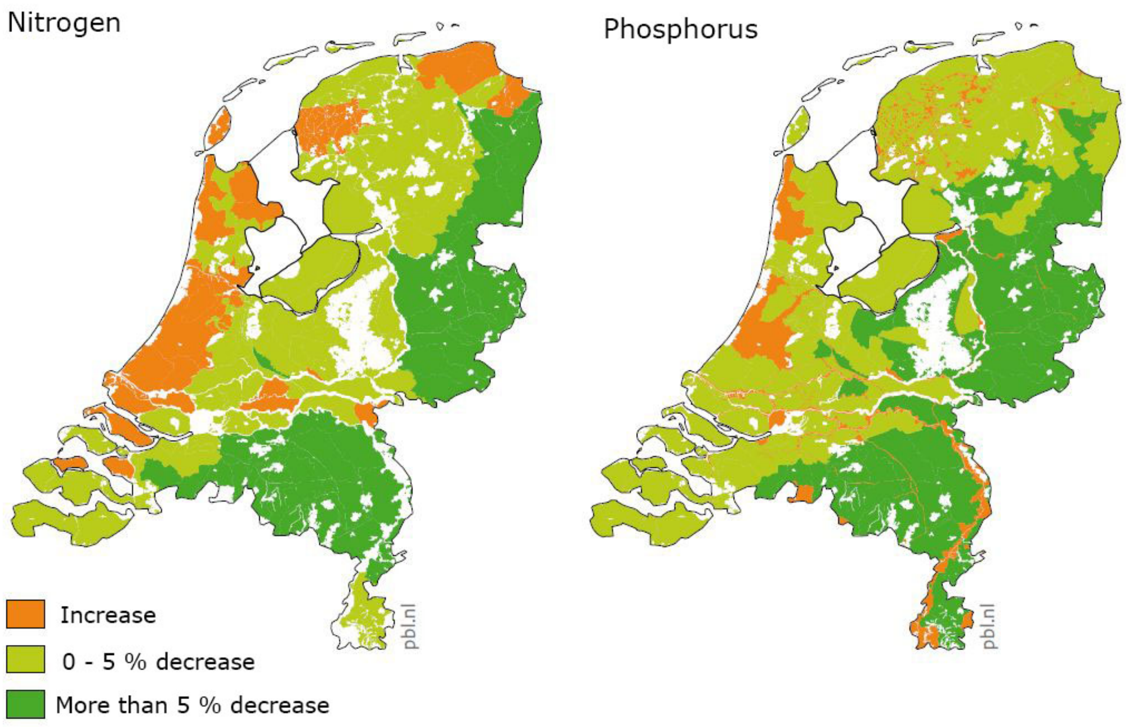


Figure 8.2: Change in the nitrogen load (left) and phosphorus load (right) in surface water with the Fifth Action Programme (2014-2017) with a stable livestock population, 2013–2027
Source: Van Gaalen *et al.* (2016)

8.3 References

Groenendijk, P., Renaud, L., Luesink, H., Blokland, P.W., De Koeijer, T. (2015); Gevolgen van mestnormen volgens het 5de Actieprogramma voor nitraat en N- en P-belasting van het oppervlaktewater. Wageningen, Alterra, report 2647

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With thanks to

Project Support
Wilbert van Zeventer (Ministry of Infrastructure and the Environment)
Marijke Koning (Ministry of Economic Affairs)

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Translation
DBF Communicatie

B. Fraters et al.

RIVM Report 2016-0019

Published by

National Institute for Public Health and the Environment
P.O. Box 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.nl/en

August 2016

008954

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